Measuring Affect for the Study and Enhancement of Co-Present Creative Collaboration

Morgan, E; Gunes, H; Bryan-Kinns, N; Affective Computing and Intelligent Interaction (ACII'13)

Measuring Affect for the Study and Enhancement of Co-Present Creative Collaboration

Evan Morgan
School of Electronic Engineering
and Computer Science
Queen Mary University
London, UK
Email: evan.morgan@eecs.qmul.ac.uk

Hatice Gunes
School of Electronic Engineering
and Computer Science
Queen Mary University
London, UK
Email: hatice@eecs.qmul.ac.uk

Nick Bryan-Kinns
School of Electronic Engineering
and Computer Science
Queen Mary University
London, UK
Email: nick.bryan-kinns@eecs.qmul.ac.uk

***Abstract*—Affective computing research has tended to focus on the recognition of emotional states in individuals, with the intention of enhancing human-computer interaction. In this paper we advocate the need for a shift of attention towards emotional communication *between people*. To contextualise our views we discuss the ways in which rapid technological advances have impacted society and human psychology over the last decade. By outlining our doctoral research topic, we then highlight how affective computing based research could help us understand and enhance co-present human-human interactions. We are especially interested in studying situations where the interaction is directed towards collaborative creativity, as there is little existing work in this area and we see great potential for real-world applications to stem from our research.**

I. Introduction

In 1997, when Rosalind Piccard outlined her manifesto for Affective Computing [1], the technological landscape was a far cry from the one that confronts us today. Mobile phones were little more than mobile phones, social networking took place predominantly in the presence of others, and the only creatures tweeting were birds. The huge changes afoot were, to an impressive extent, foreseen by Mark Weiser in his definitions of Ubiquitous Computing - a term he had coined early in the 90's [2]. Weiser envisaged that computers would become omnipresent, but comparably invisible components in our everyday lives and physical environment. He hypothesised that this change would be driven by the expansion of the Internet, and a human desire "not to be held hostage" by technology [3]. The emergence of Affective Computing appeared to encapsulate the kind of technological advances that Weiser had in mind. By being able to interact with humans on an emotional level, affective computers could adopt a wider role in our lives whilst simultaneously appearing less computer-like.

Something that Weiser also understood was that the influence of technology on people is not a one-way process. Rather, it is a feedback loop, where new technologies lead to changes in lifestyles, which lead to changes in needs, and consequently investment in new technologies [4]. In the two decades since Weiser made his predictions, technological advances have emerged at such a pace that there has been little opportunity to reflect on the simultaneous changes occurring in the people exposed to these technologies. There is, however, an increasing amount of evidence to suggest that these changes are significant, affecting the way we interact [5]–[8], and the way we think [9]. Furthermore, it appears that these changes are not merely an extension of the affordances provided by new technology, they are also derivative of the very fabric on which much of this technology is built - digital data and structured logic. This is most starkly demonstrated in the modern methods that many of us use to represent and express ourselves - the binary 'like' button on Facebook, the length-restricted 'packets' of text sent via Twitter, our geo-located positions on Google Maps. Examples also exist beyond the internet: in 2012 the 'New Aesthetic' was popularised as a term referring specifically to the growing emergence of artwork and other physical objects that are directly influenced by the Internet and digital technology [10]. New consumer products like the Nike Fuelband are designed for a growing market of people who use technology to measure and quantify aspects of their daily lives in order to enhance their wellbeing [11].

In short, where we set out to create technology that was human-centred, it appears that to some extent humans are becoming technology-centred. Perhaps this is of little surprise, as for many people interactions with technology are now more commonplace than interactions with people. However it begs the question - if this trend in human-computer interaction continues, do we risk undermining some of the evolutionarily complex elements of human-human interaction? We believe that this is a poignant question for the affective computing community. By endowing computers with emotional capabilities, one has the power to either erode or exemplify a core human trait. In order to encourage the latter, we intend to undertake research that puts human-human interaction ahead of human-computer interaction. By first investigating the subtleties in the communication of affect between people, we will be better placed to re-consider the role that computers might play in enhancing affective interactions.

Our research will be concerned with a particular type of interaction - one which is emotionally rich, and which showcases perhaps the most unique and celebrated of human qualities - the capacity to create. In particular, we will investigate collaborative creativity in the context of musical performance, where two or more individuals are co-presently engaged in the activity of creating music. Creativity in itself is a little understood human trait, and we believe that our research will also contribute towards a better understanding of the influence that affect and social signals have on creative actions.

II. Research Motivation & Aims

Following on from the issues discussed above, our core motivation is a desire to see that advances in affective computing contribute towards the understanding and enrichment of our emotional experiences with other people. In order to further our understanding in this field, we believe it is necessary to undertake empirical studies that employ quantitative methods to investigate affect in the context of *live* human-human interaction situations. These studies can be enriched by asking more extensive and detailed research questions with the help of tools and methods that are the result of existing affective computing research. The new challenges will arise from the fact that the stimulus-response pathway is no longer unidirectional. Instead, a more complex situation exists whereby one person's emotional response becomes the other person's emotional stimulus, and vice versa.

Given the expanse of interaction situations that occur in everyday human life, we decided that our PhD study will focus on a particular type of situation. Our criteria for selecting this situation were: creativity, emotional richness, co-presence (shared space), and the potential for technological intervention. We chose live, creative musical collaboration because is satisfies all of these criteria. Furthermore, we believe that emotion-sensing technologies hold great potential in enhancing our experience of the performing arts in general, where emotional expression is exaggerated and the value of physical presence is highly regarded. An additional advantage to our chosen situation is that qualitative and quantitative measures of engagement and creativity can be obtained through analysis of actions during music making experiences [12], [13]. Investigating the relationship between measures of creative collaboration and real-time emotional data would be something that very few, if any, previous studies have attempted.

In light of the above, the main aims of our research are as follows:

- *Investigate how best to continuously measure affect in dyadic/triadic interactions:* We will adopt, and then modify various techniques from the field of affective computing, which could include physiological, cognitive and behavioural measures. Following a pilot study, we will select a specific set of tools and methods based on their ability to discriminate relevant aspects of affective communication.
- *Design and create a collaborative interface for musical performance:* The interface will be used for collecting experimental data and observations. It will be specifically designed in order to maximise action awareness between participants, and to encourage non-verbal affective communication. Affect sensing should be incorporated into the design in such a way as to minimise the visibility and felt presence of the sensors. Part of the intention in designing this interface will be to direct our research towards real-world applications and technological innovation.
- *Analyse experimental data:* Using statistical and machine learning techniques, we will investigate correlations between features of affective interaction, user experience and creative output. These findings should contribute towards our understanding of emotions and their role in creative collaborations. They should also suggest specific recommendations for the design of new musical interfaces.

III. Background & Related Work

A. Affect Recognition

Embodied human emotion is commonly separated into three components; cognitive (thoughts and feelings), behavioural (expressions and actions) and physiological (biochemical and electrical changes in the body). The automatic recognition of human emotions through analysis of these components is an area of research that has gathered momentum since the turn of the century. For example, the analysis of behavioural features such as facial expressions and posture can successfully discriminate posed emotional states [14]. In the study of anxiety, physiological parameters such as salivary cortisol [15], heart rate [16], and galvanic skin response (GSR) [17] have been shown to vary with levels of stress. Functional MRI and EEG are able to identify felt emotions by analysing the brain's response to affective stimuli such as images [18] and music [19].

Much of the work in this area has been carried out in the field of Affective Computing, which encompasses the development of technologies that are able to recognise, react to, and/or express emotions. The work in this field has mainly focused on categorising the discrete emotional responses of individuals who are presented with pre-recorded, static or virtual stimuli, usually in a laboratory setting [14]. Following the success of this work, researchers are now starting to look towards systems that are able to recognise affect in more true-to-life, spontaneous settings [22]. For example, researchers at MIT Media Lab have developed software that can use a webcam to continuously monitor the facially-expressed emotion of people viewing online videos [20]. In another application, the musical score and sequence of scenes in a film were dictated by the emotional responses of the audience, as inferred from physiological measurements [21]. These examples highlight the importance of considering context and task when designing for the measurement of affect in the wild [22] (e.g. a webcam is well suited for measuring affect at a computer, but in a dark cinema its performance may degrade).

An area of research that has not yet received much attention is the application of affect recognition in situations where the interaction is occurring *between* people. This, in itself, is not an entirely new idea. In her early work, Picard discussed the potential for affective computing to increase the "affective bandwidth" of person-to-person communication [23, p. 57]. However, her choice of language was computer-centric, with the word *bandwidth* implying that emotional communication could be improved by simply transmitting more information. The reality is that we still do not possess a good understanding of what effective emotional communication actually entails.

B. Affect and Creative Collaboration

The influences of affect on creativity and collaboration are relatively unexplored areas of research, which tend to reside within the realms of social psychology and cognitive science. To gain insight into these areas it is helpful to look towards more general theories that encompass the study of affect and interaction. The theory of *emotional contagion* refers to the processes by which the emotional representations of a person or group influence the emotions of another person or group. Evidence for emotional contagion has been reported in studies of dyadic as well as group interactions [24]. In the latter it has been reported that emotional contagion also affects group processes such as task performance and cooperation. An interrelated theory is that of *behavioural mimicry* - a process whereby actions or emotions represented by one person subconsciously cause congruent behaviour in another person. There is a growing body of evidence for behavioural mimicry at both behavioural and cognitive levels (see [25] for a review). In particular, it has been shown that positive mood increases mimicry behaviour and that mimicry stimulates convergent thinking [26]. The potential for further studies relating affective and social states to mimicry behaviour is highlighted by the recent publication of a multimodal database for mimicry analysis [27]. The database comprises audio-visual recordings of mimicry-prone dyadic interactions, which are annotated with various behavioural observations.

The aforementioned findings indicate that the theories of emotional contagion and behavioural mimicry have the potential to assist in advancing our understanding of how emotion and non-verbal behaviour influences creative collaboration. Following the same abstracted approach, it is also helpful to put interaction to one side and look specifically towards research on emotion and creativity. Existing studies have predominantly explored the long-term influence of mood on creative output, often in a workplace setting. Such studies have generally reported that positive mood causes increased creativity [28]. Interestingly, it has also been suggested that changes in mood may be more conducive to creative thinking than static mood states [29]. A more robust theory for the relationship between emotion and creativity is provided by the "dual pathway" model [30] (see Fig. 1). This model suggests that emotions with high arousal (e.g. anger, elation) lead to greater originality and creative fluency (the number of ideas, insights and solutions generated) when compared to low arousal emotions (e.g. sadness, serenity). For positive emotions with high arousal, the increased creativity is attributed to increased cognitive flexibility. For negative emotions with high arousal, the increased creativity is attributed to increased persistence. Cognitive flexibility and persistence therefore represent the two proposed pathways to increased creativity. A notable feature of these studies is that they tend to focus on correlations between discrete emotional states and overall creativity. There is an absence of research that addresses continuous affective interactions and their measurement and assessment, as well as their real-time influences on creative tasks.

A final theory which is worthy of attention is the theory of *distributed cognition* [31]. This is a framework for looking at social interaction, which emphasises that cognitive processes are not confined to the individual and can in fact be represented by distributed psychological, physical and temporal constructs. For example, during the joint editing of a manuscript, the reviewer and author's written comments over time represent the distributed cognitive processes which lead to the final version of the manuscript. It is reasonable to suggest that this framework could also be applied to the study of affective collaborative interactions. Indeed, the term "distributed emotion" has already been coined and investigated [32], but further research is required to validate its potential for enhancing affective, creative and collaborative interactions.

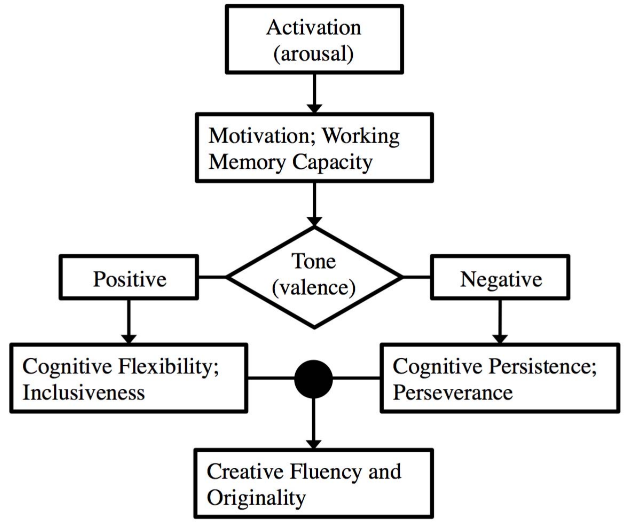

Fig. 1. Schematic of the dual pathway to creativity model (reproduced from [30])

IV. Hypotheses & Methodology

Our core hypothesis is that emotional communication between interacting individuals comprises subtle and codependent dynamic properties which are neither fully understood nor modelled. Furthermore, we propose that modern technology is sufficiently advanced to facilitate the study of these properties through quantitative measurement. In the specific context of collaborative music performance, we also hypothesise that the nature of the affective communication and social signals displayed will have an observable effect upon the creative outcomes of the interaction.

We will attempt to investigate our hypotheses using methods that centre on experimental studies of dyadic or triadic interactions. We will initiate this work by carrying out a pilot study, described below.

A. Pilot Study

The intention of the pilot study will be to inform and guide the research on creative and collaborative music making, and the subsequent development of a collaborative music interface. This interface will act as a musical instrument, enabling multiple people to compose live music together. It will also have the ability to sense affective features of their interaction, which will be used in real-time to guide and enhance the collaborative experience.

Our pilot study will invite pairs of experienced percussionists to participate in a set of collocated performances, during which various measurements will be recorded and variables modified. We have chosen to exclusively use percussionists in this study for the following reasons:

- *Collection of performance data:* Features of a drum-based performance, such as timing, can be recorded accurately using electronic sensors. This would be more difficult to achieve with wind instruments, for example.
- *Information conveyed in the visual channel:* Playing the drums generally involves pronounced physical movement. By maximising the visually available performance information we hope to increase the affective stimuli available to both musicians.
- *Influence of melody:* The drum performances will not contain significant melodic content. This simplifies the experimental setup, since it would be difficult to quantify melodic aspects of the performance, such as major/minor keys, which would clearly influence affective responses.

The percussionists will each have a single drum, which they will play with one hand only, thus restricting the complexity of the performances. There will be two performance conditions, one where the participants are separated by an opaque screen, and the other where they are in full visibility of each other. For each condition the participants will give two performances: in the first they will each play an identical pre-written rhythm that is simple enough to be played from memory; in the second they will improvise together freely. Following the performances, the participants will be asked to watch video recordings of their improvised pieces whilst providing feedback in the form of a survey. The survey will ask the participants to rate segments of each performance based upon subjective reports of experience and musical creativity.

Previous studies on co-present music performance have focused on the outwardly observable features of communicative processes such as the organisation of space and musical contributions [33], [34]. By highlighting features of collaborative interaction these studies help reveal the role which technology might have in enhancing and mediating music making activities in both co-present and non-co-present situations. Our pilot study will follow on from this work but will also investigate features that may not be visible to the naked eye, such as subcutaneous and subconscious psychophysiological variables. Table I provides a list of the variables we aim to incorporate in our study.

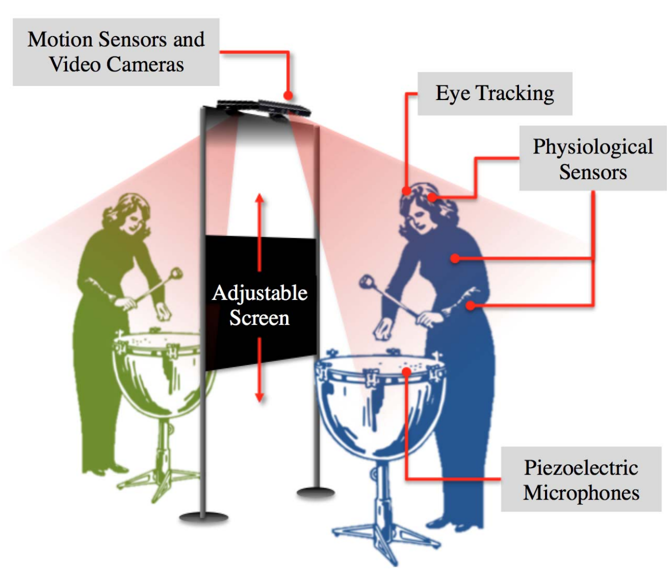

Fig. 2. Illustration of the proposed setup for the pilot study involving pairs of percussionists.

TABLE I. List of Variables & Equipment to be Used for the Pilot Study

Independent Variables	Dependent Variables: Type	Dependent Variables: Capture Equipment
Collaborator visibility • *Full* • *None*	Physiological • *Heart Rate* • *GSR* • *EEG*	• *Shimmer wireless ECG and GSR sensors*[a] • *Emotiv EEG headset*[b]
Musical task • *Improvisation* • *Identical set-piece*	Behavioural • *Body motion* • *Gaze* • *Facial expressions*	• *Asus Xtion*[c] • *Pupil eye tracker*[d] • *Video capture*
	Task outcomes • *Timing* • *Velocity/amplitude* • *Structure*	• *Piezoelectric contact microphones attached to drums*

[a]http://www.shimmer-research.com
[b]http://www.emotiv.com
[c]http://www.asus.com/Multimedia/Xtion_PRO_LIVE
[d]https://code.google.com/p/pupil

The main aims of the pilot study are as follows:

- *Test equipment:* We will use a combination of physiological monitoring equipment in order to measure heart rate, GSR, and EEG. We will also use depth sensitive cameras in order to record motion capture data. The pilot study will enable us to assess the practicalities of using such equipment on musicians.
- *Identify variables:* By recording a large range of variables whilst modifying multiple independent variables we will be able to get an idea of which variables, and data sources offer the greatest potential for further investigation.
- *Obtain preliminary findings:* In the course of analysing data from the study, we hope to report findings, which not only lead onto further work but which are also publishable in their own right.

Where possible, the study will be controlled - this will be done by ensuring that conditions between experiments change as little as possible, and by collecting baseline data with musicians performing alone. An outline of the experimental setup for the pilot study is shown in Fig. 2.

B. Evaluation

Our research will gather a large amount of quantitative data. The most significant portion of this will relate to affective measures. We will analyse these measures by starting at the level of the individual, and subsequently extending our analysis to incorporate relationships *between* individuals, both in dyadic and triadic collaborations. Additionally, action related data will enable us to look at the timing and the nature of participant

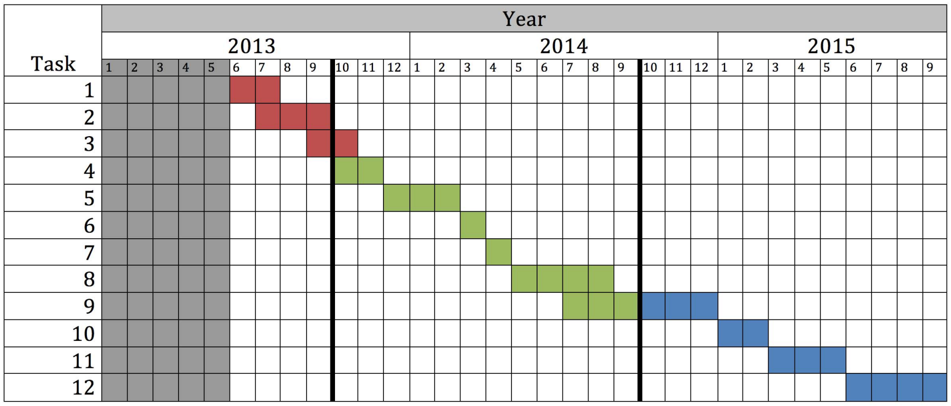

Fig. 3. Gantt chart outlining the timings of the proposed future research.

interaction with the music interface. Lastly, observations, self-report measures and audio recordings will provide information relating to engagement and creativity. Correlations between all of these data sets will also be investigated.

V. Current & Future Work

This doctoral research project began in October 2012, however it was preceded by a five month industrial placement project. The project involved the design and subsequent analysis of a high profile interactive public installation, which incorporated both physiological and motion sensors [35]. A large amount of data was collected during the installation, the experience of organising and analysing this data provided valuable insights into the methods and challenges that may accompany our future work. Over the last year we have also been involved with the development of two audio-visual installations, both of which use physiological measurements as inputs. One of these - Cor Cordis - was exhibited as an installation at the 2012 conference on New Interfaces for Musical Expression (NIME). The installation used wireless sensors to simultaneously measure the breathing movements and heart beats of up to four people and subsequently map them to a light sculpture and audio soundscape. This practical work has developed our skills in designing and building interactive music interfaces. It has also forced us to critique existing works. Our doctoral research will build upon these works.

A rough outline for future work is provided in the Gantt chart in Fig. 3, and comprises the following tasks:

1) Carry out a pilot study with percussionists
2) Analyse data from the pilot study
3) Write a paper on the pilot study
4) Background research and design of a collaborative music interface
5) Build a collaborative music interface with affect and non-verbal behaviour sensing
6) Test the interface in a short pilot study
7) Modify/redesign if required
8) Carry out public/private studies with the interface
9) Analyse the acquired data
10) Write a paper on the main study
11) Investigate and implement design suggestions for affective and communicative interaction
12) Write up PhD thesis

With regard to the studies involving our collaborative music interface, we are particularly keen on gathering data from non-laboratory settings. We found in our previous works [35] that this approach of taking research into ‘the wild’ provides some valuable advantages, especially when evaluating technology that is designed to have real-world applications. The Victoria & Albert Museum in London holds frequent showcase events for postgraduate students to exhibit their research. This could be a great opportunity for us to access the kind of high-profile setting where we hope to collect a large amount of our data.

VI. Conclusion

The research presented in this paper aims to investigate collaborative creativity in the context of musical performance, where two or more individuals are co-presently engaged in the activity of creating music. Our work aims to contribute towards a better understanding of the influence that affect and social signals have on creative actions, specifically during music performances. By outlining the motivations and intentions behind our doctoral research, we hope to stimulate discussion and constructive criticism surrounding the topics that we have addressed. Such dialogue is an important part of the research process, especially during these formative stages. We believe that the work we are undertaking will explore territories that are relatively untouched by the existing affective computing research. Therefore, our hope is that our research findings will bring valuable insight and contributions to the field, and inspire future work.

References

[1] R. W. Picard, *Affective computing*. Cambridge, MA, USA: MIT Press, Oct. 1997. [Online]. Available: http://dl.acm.org/citation.cfm?id=265013

[2] M. Weiser, “The Computer for the 31st Century,” *Scientific American*, vol. 265, no. 3, pp. 94–104, Sep. 1991.

[3] ——, “Hot topics-ubiquitous computing,” *Computer*, vol. 26, no. 10, pp. 71–72, 1993. [Online]. Available: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=237456

[4] ——, "How computers will be used differently in the next twenty years," in *Proceedings of the 1999 IEEE Symposium on Security and Privacy (Cat. No.99CB36344)*, Xerox PARC. IEEE Comput. Soc, 1999, pp. 234–235. [Online]. Available: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=766917

[5] M. Drouin and C. Davis, "R u txting? Is the Use of Text Speak Hurting Your Literacy?" *Journal of Literacy Research*, vol. 41, no. 1, pp. 46–67, Jan. 2009. [Online]. Available: http://jlr.sagepub.com/content/41/1/46.abstract

[6] S. Turkle, *Alone Together: Why We Expect More from Technology and Less from Each Other*. Basic Books, 2012. [Online]. Available: http://www.amazon.com/Alone-Together-Expect-Technology-Other/dp/0465031463

[7] M. B. Wooldridge and J. Shapka, "Playing with technology: Mothertoddler interaction scores lower during play with electronic toys," *Journal of Applied Developmental Psychology*, vol. 33, no. 5, pp. 211–218, Sep. 2012. [Online]. Available: http://dx.doi.org/10.1016/j.appdev.2012.05.005 http://linkinghub.elsevier.com/retrieve/pii/S0193397312000445

[8] Y. Amichai-Hamburger and Z. Hayat, "The impact of the Internet on the social lives of users: A representative sample from 13 countries," *Computers in Human Behavior*, vol. 27, no. 1, pp. 585–589, Jan. 2011. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S0747563210003067

[9] G. W. Small, T. D. Moody, P. Siddarth, and S. Y. Bookheimer, "Your brain on Google: patterns of cerebral activation during internet searching." *The American journal of geriatric psychiatry : official journal of the American Association for Geriatric Psychiatry*, vol. 17, no. 2, pp. 116–26, Feb. 2009. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/19155745

[10] J. Bridle, "The New Aesthetic - About," 2012. [Online]. Available: http://new-aesthetic.tumblr.com/about

[11] R. Calvo and D. Peters, "Promoting psychological wellbeing: loftier goals for new technologies"," *IEEE Technology and Society (to appear)*.

[12] N. Bryan-Kinns, P. G. T. Healey, and J. Leach, "Exploring mutual engagement in creative collaborations," in *Proceedings of the 6th ACM SIGCHI conference on Creativity & cognition - C&C '07*. New York, New York, USA: ACM Press, Jun. 2007, p. 223. [Online]. Available: http://dl.acm.org/citation.cfm?id=1254960.1254991

[13] A. Tanaka, N. Tokui, and A. Momeni, "Facilitating collective musical creativity," in *Proceedings of the 13th annual ACM international conference on Multimedia - MULTIMEDIA '05*. New York, New York, USA: ACM Press, Nov. 2005, p. 191. [Online]. Available: http://dl.acm.org/citation.cfm?id=1101149.1101177

[14] Z. Zeng, M. Pantic, G. I. Roisman, and T. S. Huang, "A survey of affect recognition methods: audio, visual, and spontaneous expressions." *IEEE transactions on pattern analysis and machine intelligence*, vol. 31, no. 1, pp. 39–58, Jan. 2009. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/19029545

[15] N. Takai, M. Yamaguchi, T. Aragaki, K. Eto, K. Uchihashi, and Y. Nishikawa, "Effect of psychological stress on the salivary cortisol and amylase levels in healthy young adults." *Archives of oral biology*, vol. 49, no. 12, pp. 963–8, Dec. 2004. [Online]. Available: http://dx.doi.org/10.1016/j.archoralbio.2004.06.007

[16] B. M. Appelhans and L. J. Luecken, "Heart rate variability as an index of regulated emotional responding." *Review of General Psychology*, vol. 10, no. 3, pp. 229–240, 2006. [Online]. Available: http://doi.apa.org/getdoi.cfm?doi=10.1037/1089-2680.10.3.229

[17] T. Wu, Y. Luo, L. S. Broster, R. Gu, and Y.-j. Luo, "The impact of anxiety on social decision-making: Behavioral and electrodermal findings," *Social Neuroscience*, vol. 8, no. 1, pp. 11–21, Jan. 2013. [Online]. Available: http://dx.doi.org/10.1080/17470919.2012.694372

[18] F. Schneider, W. Grodd, U. Weiss, U. Klose, K. R. Mayer, T. Nägele, and R. C. Gur, "Functional MRI reveals left amygdala activation during emotion," *Psychiatry Research: Neuroimaging*, vol. 76, no. 2-3, pp. 75–82, Dec. 1997. [Online]. Available: http://dx.doi.org/10.1016/S0925-4927(97)00063-2

[19] L. A. Schmidt and L. J. Trainor, "Frontal brain electrical activity (EEG) distinguishes valence and intensity of musical emotions," *Cognition & Emotion*, vol. 15, no. 4, pp. 487–500, Jul. 2001. [Online]. Available: http://dx.doi.org/10.1080/02699930126048

[20] H. Gunes and B. Schuller, "Categorical and Dimensional Affect Analysis in Continuous Input: Current Trends and Future Directions," *Image and Vision Computing*, vol. 31, no. 2, pp. 120–136, Jul. 2013. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S0262885612001084

[21] D. McDuff, R. el Kaliouby, and R. Picard, "Crowdsourced data collection of facial responses," in *Proceedings of the 13th international conference on multimodal interfaces - ICMI '11*. New York, New York, USA: ACM Press, Nov. 2011, p. 11. [Online]. Available: http://dl.acm.org/citation.cfm?id=2070481.2070486

[22] J. Price, "CultureLab," *New Scientist Online*, 2011. [Online]. Available: http://www.newscientist.com/blogs/culturelab/2011/03/plug-in-for-emotional-response-cinema.html

[23] R. W. Picard, *Affective Computing*. The MIT Press, 2000.

[24] S. Barsade, "The ripple effect: Emotional contagion and its influence on group behavior," *Administrative Science Quarterly*, no. December, pp. 644–675, 2002. [Online]. Available: http://www.jstor.org/stable/10.2307/3094912

[25] T. L. Chartrand and J. L. Lakin, "The Antecedents and Consequences of Human Behavioral Mimicry." *Annual review of psychology*, no. September 2012, Sep. 2012. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/23020640

[26] H. Aarts, T. L. Chartrand, R. Custers, U. Danner, G. Dik, V. E. Jefferis, and C. M. Cheng, "Social Stereotypes and Automatic Goal Pursuit," *Social Cognition*, vol. 23, no. 6, pp. 465–490, Dec. 2005. [Online]. Available: http://guilfordjournals.com/doi/abs/10.1521/soco.2005.23.6.465

[27] X. Sun, J. Lichtenauer, M. Valstar, and A. Nijholt, *Affective Computing and Intelligent Interaction*, ser. Lecture Notes in Computer Science, S. DMello, A. Graesser, B. Schuller, and J.-C. Martin, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011, vol. 6974. [Online]. Available: http://www.springerlink.com/index/10.1007/978-3-642-24600-5

[28] T. Amabile and S. Barsade, "Affect and Creativity at Work," *Administrative Science* ..., 2005. [Online]. Available: http://asq.sagepub.com/content/50/3/367.short

[29] K. R. Jamison, "Touched with Fire: Manic-Depressive Illness and the Artistic Temperament," Dec. 2001. [Online]. Available: http://litmed.med.nyu.edu/Annotation?action=view&annid=11923

[30] C. K. W. De Dreu, M. Baas, and B. a. Nijstad, "Hedonic tone and activation level in the mood-creativity link: toward a dual pathway to creativity model." *Journal of personality and social psychology*, vol. 94, no. 5, pp. 739–56, May 2008. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/18444736

[31] J. Hollan, E. Hutchins, and D. Kirsh, "Distributed cognition: toward a new foundation for human-computer interaction research," *ACM Transactions on Computer-Human Interaction*, vol. 7, no. 2, pp. 174–196, Jun. 2000. [Online]. Available: http://portal.acm.org/citation.cfm?doid=353485.353487

[32] C. Glazer, "Looking Closely at Emotional Expression in an Online Course: A Case Study of Distributed Emotion," Ph.D. dissertation, University of Texas, 2003. [Online]. Available: http://www.scholarlypursuits.com/diss.pdf

[33] P. G. T. Healey, J. Leach, and N. Bryan-kinns, "Inter-Play : Understanding Group Music Improvisation as a Form of Everyday Interaction," *Proceedings of Less is More Simple Computing in an Age of Complexity*, 2005.

[34] S. Nabavian and N. Bryan-Kinns, "Analysing group creativity: A distributed cognitive study of joint music composition," *Proc. of Cognitive Science*, pp. 1856–1861, 2006. [Online]. Available: http://www.eecs.qmul.ac.uk/ nickbk/papers/Analysing Group Creativity A Distributed Cognitive Study of Joint Music Composition.pdf

[35] E. L. Morgan, H. Gunes, and D. Harris, "Gesturing at Architecture: Experiences and Issues with New Forms of Interaction," in *Proc. of CHI'13 Workshop on Experiencing Interactivity in Public Spaces (EIPS)*, Paris, France, 2013, pp. 117–121. [Online]. Available: http://www.cs.tut.fi/ihte/EIPS_workshop_CHI13/papers.shtml