Available online at www.sciencedirect.com

ScienceDirect

Physics of Life Reviews 13 (2015) 47–49

PHYSICS of LIFE reviews

www.elsevier.com/locate/plrev

Comment

Can modular psychological concepts like affect and emotion be assigned to a distinct subset of regional neural circuits? Comment on "The quartet theory of human emotions: An integrative and neurofunctional model" by S. Koelsch et al.

Thorsten Fehr [a,b,*], Manfred Herrmann [a,b]

[a] *Center for Cognitive Sciences, Department of Neuropsychology and Behavioural Neurobiology, University of Bremen, Germany*
[b] *Center for Advanced Imaging, University of Bremen, Germany*

Received 17 April 2015; accepted 17 April 2015

Available online 20 April 2015

Communicated by L. Perlovsky

The proposed *Quartet Theory of Human Emotions* by Koelsch and co-workers [11] adumbrates evidence from various scientific sources to integrate and assign the psychological concepts of 'affect' and 'emotion' to four brain circuits or to four neuronal core systems for affect-processing in the brain. The authors differentiate between affect and emotion and assign several facultative, or to say modular, psychological domains and principles of information processing, such as learning and memory, antecedents of affective activity, emotion satiation, cognitive complexity, subjective quality feelings, degree of conscious appraisal, to different affect systems. Furthermore, they relate orbito-frontal brain structures to moral affects as uniquely human, and the hippocampus to attachment-related affects. An additional feature of the theory describes 'emotional effector-systems' for motor-related processes (e.g., emotion-related actions), physiological arousal, attention and memory that are assumed to be cross-linked with the four proposed affect systems. Thus, higher principles of emotional information processing, but also modular affect-related issues, such as moral and attachment related affects, are thought to be handled by these four different physiological subsystems that are on the other side assumed to be highly interwoven at both physiological and functional levels. The authors also state that the proposed sub-systems have many features in common, such as the selection and modulation of biological processes related to behaviour, perception, attention and memory. The latter aspect challenges an ongoing discussion about the mind–body problem: To which degree do the proposed sub-systems 'sufficiently' cover the processing of complex modular or facultative emotional/affective and/or cognitive phenomena? There are current models and scientific positions that almost completely reject the idea that modular psychological phenomena are handled by a distinct selection of regional brain systems or neural modules, but rather suggest highly complex and cross-linked neural networks individually shaped by livelong learning and experience [e.g., 6,7,10,13]. This holds in particular true for complex emotional phenomena such as aggression or empathy in social interaction [8,13]. It thus remains questionable, whether – beyond primary sensory and motor-processing – a small number of modular

DOI of original article: http://dx.doi.org/10.1016/j.plrev.2015.03.001.
* Corresponding author.
E-mail address: fehr@uni-bremen.de (T. Fehr).

http://dx.doi.org/10.1016/j.plrev.2015.04.027

sub-systems sufficiently cover the organisation of specific phenomenological and social features of perception and behaviour [7,10].

Hypotheses about regional brain, or to say modular, processing of specific emotional aspects were predominantly derived from lesion studies that are always compromised by the fact that there is no way to differentiate between necessity and sufficiency of the damaged brain regions related to the lost mental abilities [e.g., 4,6]. Furthermore, most neuroimaging studies address just a part of the picture by using region of interest analyses that bears the problem of reverse inference. This means that mental content processing (e.g., complex affective, emotional, or cognitive information) cannot be inferred from the inspection of Cartesian distributions of brain activation patterns [7,17]. Additionally, from a methodological point of view, most approaches in functional neuroimaging take care to avoid false positive results, however, at the expense of accepting considerable negative impact on validity by Type II errors [12]. This procedure might lead to an underestimation of functionally relevant neural correlates of complex cognitive and emotional processes, and furthermore, this leads to a potential underestimation of the relevance of functionally sufficient *individual* fractions of neural resources involved [7,18].

The proposed functional neuro-anatomical separation between the four affect-systems appears well concluded from the respective literature, but it is not always convincing. The line of argumentation might also give rise to the assumption that the proposed affect- and effector-subsystems are integrated parts of just *one* functional and physiological network, wherein each of the sub-systems processes basically the same phenomena at different complexity levels [compare 13]. At this place, we would like to draw attention to some particular aspects to the discussion:

(1) Why do Koelsch and co-workers [11] especially point to the language system as one of the most important instances of reconfiguration of emotional content? Without doubt, the language system belongs to the most important and complex coding instance of information processing in humans. However, other information processing modalities, such as spatial, visual, auditory, olfactory, motor, and all memory-related domains might also equally contribute to emotional content reconfiguration via transcoding from one to the other system. The most prominent candidates demonstrating such transcoding of complex emotional contents between modalities are individuals with synaesthesia [19]. Furthermore, Koelsch et al. [11] mention that they are the first who emphasize the role of language in a theory of human emotion processing. For example, Lindquist and Barrett [13] in their constructionist model of emotion also proposed language as an important instance for the conceptualisation of knowledge about emotions recruited during appraisal of emotionally relevant contents. Furthermore, prosody as an important feature of emotion communication is a well established concept in neuropsychology, and – from a pragmatic point of view – clinical psychologists and psychotherapists regularly use verbal self-instruction strategies to regulate or modify emotion processing in their clients. Thus, the concept of "language embodied emotion" appears to be a rather established.

(2) Ecological validity of both animal and human studies on the neural organisation of emotion processing is mostly limited by several factors, such as a lack of *realistic emotion-inducing stimulation* [6,8,21,23], *missing* or *inappropriate control conditions* for the differentiation between *emotion*, *arousal* and/or *task complexity-effects* [6,8], or sample characteristics (e.g., emotion processing in patients with particular brain lesions that might be assigned to both specific lesion location or coping with behavioural disorders or even by the interaction of both). The detailed analysis of individual differences appears to be a crucial aspect that is mostly neglected, although there is evidence that there is more individuality than overlap in the processing of complex emotional content [18]. Inter-individual differences in complex emotional processing are not necessarily noise that needs to be averaged out [15,24]. This valuable source of information should in particular be considered by complementary, methodological approaches to enhance the validity of brain physiological data analyses [7,15,24]. Furthermore, virtual or realistic presentation of emotion-related content, and virtual or realistic, more or less individually relevant and potentially as harming appraised content [8,18] appear to have a tremendous effect on the appraisal of emotional content, and – as a consequence – on the involved neural resources: The identical realistic scenario can induce fear and flight tendencies in one individual and anger and approach tendencies in another with comparable demographic background. There is strong evidence that individual learning history appears to strongly modulate both *appraisal of* and *responses to* realistic and/or virtual context, implying individually elaborated perception-action-cycle networks [6,8] that can in principle involve all parts of the neural system [2,3,10] according to individual emotional and cognitive strategies applied [7].

(3) Koelsch and co-workers [11] discuss emotion-percept only related to the somato-sensory domain and neglect hetero-modal postcentral cortices in occipito-parieto-temporal brain regions, e.g. the Emotional Body Language System proposed by de Gelder [5], which might be a prominent candidate for an important higher *perceptual* memory instance potentially networking with higher motor-related areas involved in emotionally driven actions [8]. Orbito-

frontal brain regions might serve as an important executive, but just inhibitory instance, which helps to assure contextual commensurability. Basic principles of the latter function obviously are individually learned [20] according to social and cultural norms also assumed for higher emotional entities such as guilt, shame, regret and other emotional domains putatively important for adequate moral judgement abilities as noted by Koelsch et al. [11].

In sum, the *Quartet Theory of Human Emotions* by Koelsch and co-workers [11] provides an intriguing number of ideas seminally integrated into a new concept. This idea particularly considers higher principles of emotion processing, hosted in different affect and emotional effector systems that are highly cross-linked and operate together at different complexity levels. However, we additionally need, beside contemporary theoretical innovations [3,6,9,13,14], new and advanced analytical approaches to better catch spatio-temporal and individual characteristics of neural emotion-processing [1,7,16,18,22], and new experimental designs more validly inducing emotional brain responses [e.g., 8,21] appear to be necessary for a comprehensive testing of the here proposed theory of human emotion and to further explore the complexity of interactions and processing principles of the proposed sub-systems.

References

[1] Achtziger A, Fehr T, Oettingen G, Gollwitzer P, Rockstroh B. Strategies of intention formation are reflected in continuous MEG activity. Soc Neurosci 2008;4:11–27.
[2] Basar E. The theory of the whole-brain-work. Int J Psychophysiol 2006;60:133–8.
[3] Basar E, Güntekin B. A breakthrough in neuroscience needs a "Nebulous Cartesian System" oscillations, quantum dynamics and chaos in the brain and vegetative system. Int J Psychophysiol 2007;64:108–22.
[4] Brower MC, Price BH. Neuropsychiatry of frontal lobe dysfunction in violent and criminal behaviour: a critical review. J Neurol Neurosurg Psychiatry 2001;71:720–6.
[5] De Gelder B. Towards the neurobiology of emotional body language. Nat Rev Neurosci 2006;7:242–9.
[6] Fehr T. Neuronale Korrelate der Aggression beim Menschen – virtuelle Medien und reale Lebensumgebung. In: Kaminski W, Lorber M, editors. Gamebased learning. 2012. München: kopaed.
[7] Fehr T. A hybrid model for the neural representation of complex mental processing in the human brain. Cogn Neurodyn 2013;7:89–103.
[8] Fehr T, Achtziger A, Roth G, Strüber D. Neural correlates of the empathic perceptual processing of realistic social interaction scenarios displayed from a first-order perspective. Brain Res 2014(1583):141–58.
[9] Ferguson CJ, Dyck D. Paradigm change in aggression research: the time has come to retire the general aggression model. Aggression Violent Behav 2012;17:220–8.
[10] Fuster JM. Cortex and memory: emergence of a new paradigm. J Cogn Neurosci 2009;21:2047–72.
[11] Koelsch S, Jacobs AM, Menninghaus W, Liebal K, Klann-Delius G, von Scheve C, et al. The quartet theory of human emotions: an integrative and neurofunctional model. Phys Life Rev 2015;13:1–27 [in this issue].
[12] Liebermann MD, Type I CWA. Type II error concerns in fMRI research: re-balancing the scale. Soc Cogn Affect Neurosci 2009;4:423–8.
[13] Lindquist KA, Barrett LF. A functional architecture of the human brain: emerging insights from the science of emotion. Trends Cogn Sci 2012;16:533–40.
[14] Mausfeld R. On some unwarranted tacit assumptions in cognitive neuroscience. Front Psychol 2012. http://dx.doi.org/10.3389/psyg.2012.00067.
[15] McGonigle DJ. Test-retest reliability in fMRI: or how I learned to stop worrying and love the variability. NeuroImage 2012;62:116–20.
[16] Miedl SF, Fehr T, Herrmann M, Meyer G. Risk assessment and reward processing in problem gambling investigated by event-related potentials and fMRI-constrained source analysis. BMC Psychiatry 2014;14:229. http://dx.doi.org/10.1186/s12888-014-0229-4.
[17] Poldrack RA. Can cognitive processes be inferred from neuroimaging data? Trends Cogn Sci 2006;10:59–63.
[18] Regenbogen C, Herrmann M, Fehr T. The neural processing of voluntary completed, real and virtual violent and non-violent computer game scenarios displaying pre-defined actions in gamers and non-gamers. Soc Neurosci 2010;5:221–40.
[19] Safran A, Sanda N. Color synesthesia. Insight into perception, emotion, and consciousness. Curr Opin Neurol 2015;28:36–44.
[20] Tremblay RE, Nagin DS. The developmental origins of physical aggression in humans. In: Tremblay RE, Hartup Archer JWW, editors. Developmental origins of aggression. New York, USA: Guilford Press; 2005.
[21] Trautmann S, Fehr T, Herrmann M. Emotions in motion: dynamic compared to static facial expressions of disgust and happiness reveal more widespread emotion-specific activations investigated by fMRI. Brain Res 2009;1284:100–15.
[22] Trautmann-Lengsfeld SA, Domínguez-Borràs J, Escera C, Herrmann M, Fehr T. The perception of dynamic and static facial expressions of happiness and disgust investigated by ERPs and fMRI constrained source analysis. PLoS ONE 2013:8. http://dx.doi.org/10.1371/journal.pone.0066997.
[23] Yang S, Mulvey EP. Violence risk: re-defining variables from the first-person perspective. Aggression Violent Behav 2012;17:198–207.
[24] Zilles K, Amunts K. Individual variability is not noise. Trends Cogn Sci 2013;17:153–5.