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NEUROATHESETICS AND GROWING INTEREST IN "POSITIVE AFFECT" IN PSYCHIATRY: NEW EVIDENCE AND PROSPECTS FOR THE THEORY OF INFORMATIONAL NEEDS

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SUMMARY

What are the necessary and sufficient conditions to experience pleasure in interpersonal communication and dealing with art, science, and philosophy – this is what the theory of informational needs (TIN) suggested eleven years ago is about. At the same time, at the beginning of this century, several lines of research have emerged. Neuroaesthetics has been established; the discovery of the mirror neuron system and theories about its function have appeared; a growing interest in positive affect and pleasure has developed in psychiatry and medicine. The purpose of the present paper is to reconsider the TIN (Branković 2001) in the context of the advance in neuroscience during the last decade and to show how much conceptual clarity is gained when the recent empirical and theoretical findings are viewed from the standpoint of the TIN. A computational model of the aesthetic response based on the TIN's two-factor model of hedonic value of stimuli is delineated.

Key words: *neuroaesthetics – mirror neuron system – positive affect – aesthetic experience – peak experience – motivation – emotion – attachment – computational model – theory of informational needs*

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INTRODUCTION

What are the necessary and sufficient conditions to experience pleasure in interpersonal communication and dealing with art, science, and philosophy? That is what the theory of informational needs (TIN) suggested eleven years ago was about (Branković 2001). The three kinds of the peak experience (sexual, emotional, and exploratory), an analogous, cyclic nature of the sexual, the attachment, and the exploratory motivation, and a two-factor model of hedonic value of stimuli (tickling intrinsic motivation) have been suggested in the TIN.

The analogy among the three informational needs (sexual, emotional, and exploratory) consists in the experience of excitement which accompanies satisfying of any of the three needs. But experiences of sexual excitement, emotional excitement (pleasure-in-intimacy), and exploratory excitement are different feelings (Lichtenberg 1989). They sometimes reach the level of the respective kind of the peak experience – sexual orgasm, "emotional" orgasm ("emotional" peak experience), and "exploratory" orgasm ("exploratory" peak experience). The cycles of the informational needs include in an analogous fashion four phases (see Table 1): the desire phase, the excitement phase, the peak experience (orgasm) phase, and the resolution phase (Branković 2001). There are two ways of satisfying informational needs. One way is through a direct communication with another person, and the other is self-satisfying. There are two ways of self-satisfying. One is creative and the other is self-satisfying through consumption.

For both ways of satisfying informational needs I described two characteristics (determinants, conditions) of stimulation which are necessary for emerging and rising of sexual/emotional/exploratory excitement. These are (1) similarity with the sexual taste, familiarity with the perceived emotions, and similarity with the exploratory interest, and (2) unexpectedness, i.e. receiving information in the theory of information meaning of the word (the less expected sexual/emotional stimulus or data, the greater rise of sexual/emotional/exploratory excitement).

Creative inspiration according to the TIN occurs when one meets the second (excitement) phase of the cycle of sexual, emotional, or exploratory need. From the cyclic and homeostatic nature of the informational needs it is understandable why and how long inspiration irresistibly forces one to create – in order to satisfy informational need, i.e. until reaching the peak of excitement (the peak experience).

During the last eleven years development in neuroscience brought to empirical and theoretical results which are highly relevant for the TIN. Neuroaesthetics as a brand new research field has been established. The last decade brought out the discovery of the mirror neuron system and theorizing about its function. At the same time a growing interest in positive affect and pleasure has appeared in psychiatry and medicine in general.

The application of neuroimaging methods offers a powerful means to study brain functions related to emotion processing, empathy, and aesthetic experience, "but the resulting knowledge is more likely to be

beneficial when combined with conceptual analyses that decompose the complex psychological construct of empathy (and aesthetic experience) into component structures, representations, processes, and computations" (Decety 2011b). The purpose of the present paper is to reconsider the theory of informational needs (Branković 2001) in the context of the advance in neuroscience during the last decade and to show how much conceptual clarity is gained when the recent empirical and theoretical findings are viewed from the standpoint of the TIN.

NEUROAESTHETICS AND THE THEORY OF INFORMATIONAL NEEDS

Although the term was coined thirteen years ago (Zeki 1999), neuroaesthetics is still an emerging field of research dealing with the neural processes that underlie aesthetic behavior (Nadal & Pearce 2011, Skov & Vartanian 2009). But aesthetic experiences are not bounded only to interactions with artworks. "According to our definition of neuroaesthetics, aesthetic phenomena are common rather than unique, and are obviously evoked when we create paintings and watch movies, but also when we embrace a loved one" (Skov & Vartanian 2009: 4). This view is akin to the common explanation of the necessity for another person and creative behavior proposed in the TIN (Branković 2001). That is why the empirical findings of neuroaesthetics are relevant for the theory of intrinsic motivation such as the TIN.

On the other hand, due to a great theoretical and methodological diversity, "it (neuroaesthetics) is clearly in need of a coherent framework" (Skov & Vartanian 2009: 5). Therefore, the relation between neuroaesthetics and the TIN could be bidirectional. I suggest that the TIN appears as a suitable comprehensive theoretical frame for neuroaesthetics dealing with the intrinsic motivational aspects of aesthetic behavior. With this aspect of the relation between neuroaesthetics and the TIN I continue in "Alternative theorizing on the aesthetic experience".

The empirical and theoretical results of neuroaesthetics which I find relevant for the TIN are summarized in the Table 1.

In agreement with the TIN, there is increasing experimental evidence that perceived emotions in a music piece and felt emotional response to the music differ (Gabrielsson 2002, Salimpoor, Benovoy, Longo, Cooperstock & Zatorre 2009, Marin & Bhattacharya 2009). The distinction between "emotions in the music" and "induced subjective state of the listener" is pointed out also by Konečni (2005, 2008) and recently by Mar (2011) who differentiated "emotional recognition (perception)" from "evocation of an empathic feeling (response)" as two steps in the process.

Also, there is growing evidence about the key role of emotional arousal in the process of aesthetic responding and pleasure (Menon & Levitin 2005, Juslin & Västfjäll, 2008, Salimpoor, Benovoy, Longo, Cooperstock & Zatorre 2009, Schäfer & Sedlmeier 2011) as suggested in the TIN. Functional neuroimaging studies of aesthetic responding revealed involvement of brain regions mediating reward and autonomic processing such as ventral tegmental area, nucleus accumbens, hypothalamus, hippocampus, amygdala, insula, and orbitofrontal cortex (Blood & Zatorre, 2001, Brown, Martinez & Parsons 2004, Menon & Levitin 2005, Koelsch, Fritz, von Cramon, Müller & Friederici 2006, Di Dio, Macaluso & Rizzolatti 2007, Di Dio & Gallese 2009, Lacey, Hagtvedt, Patrick, Anderson, Stilla, Deshpanade et al. 2011, Pereira, Teixeira, Figueiredo, Xavier, Castro & Brattico 2011). Brain damage studies pointed to the necessity of amygdala for emotional processing of music (Gosselin, Peretz, Johnsen & Adolphs 2007).

Neurochemical evidence for the intrinsic motivational effect of music is the recent finding that intense pleasure in response to music can lead to dopamine release in the striatal system (Salimpoor, Benovoy, Larcher, Dagher & Zatorre 2011).

The conceptualization of intrinsic motivation suggested eleven years ago I named "the theory of informational needs" in order to stress a necessary condition – unexpectedness of stimuli, which renders them effective in satisfying the sexual, emotional, and exploratory need. In the meantime, many neuroscience studies have demonstrated "that novelty is a critical stimulus dimension for amygdala engagement" and processing "in the affective brain" (Weierich, Wright, Negreira, Dickerson & Barrett 2010, see also Daselaar, Fleck & Cabeza 2006, Steinbeis, Koelsch & Sloboda 2006, Koelsch, Kilches, Steinbeis & Schelinski 2008, Pearce, Ruiz, Kapasi, Wiggins & Bhattacharya 2010, Pereira, Teixeira, Figueiredo, Xavier, Castro & Brattico 2011). It is not any more the question whether unexpectedness of stimuli is necessary for elicitation of aesthetic response but by what artistic devices is it achieved and what schemata in cognitive processing (computation) are therein involved (Ockelford 2006, Pearce & Wiggins 2006, Bae & Young 2009, Maguire, Maguire & Keane 2011).

CHILLS AS AN INDICATOR OF THE PEAK EXPERIENCE

Relying on Maslow's (1962) description of the peak experience and Lichtenberg's (1989) theory of motivetion I suggested a differentiated view to the peak experience which included its three kinds related to the three separated motivational systems: sexual, attachment, and exploratory (Branković 2001). In the meantime, the concepts of the emotional (attachment) and exploratory excitement and peak experiences have become operationalized and widely accepted (see Table 1).

Maslow (1962) introduced and started the study of the peak experience a half century ago. But revival of the research interest in this subject happened during the last several years mostly due to the operationalization

Table 1. The key concepts of the theory of informational needs (TIN) and recent theoretical and empirical findings

Concepts of the Theory of Informational Needs (Branković 2001)		Theoretical Results	Empirical Findings
Cyclic Character of Emotional and Exploratory Need (analogous to sexual need)	1. Desire Phase		
	2. Emotional and Exploratory Excitement	"The feelings that are rather vaguely described as 'being touched' or 'being moved'… examples are the tears during sentimental moves… flash of warmth… moist eyes, chills, thrills" (Scherer & Zentner 2001, Konečni 2005, 2008)	Dopamine release in nc. accumbens during pleasant excitement elicited by music (Salimpoor et al. 2011). Intensive pleasure induced by music correlates with activity in brain regions involved in reward, emotion, and arousal (Blood & Zatorre 2001)
	3. Emotional and Exploratory Orgasm (Peak Experience)	The term "skin orgasm" for the chill phenomenon (Panksepp 1995). "Aesthetic awe" (Konečni 2005, 2008)	Pleasure associated with scientific insight (such as an unexpected solution to a problem) is accompanied by a visceral thrill (Hudson 2011).
	4. Resolution Phase (refractoriness to emotional/ exploratory excitement)	"Emotional draining" (Konečni et al. 2007)	Refractoriness to emotional (musical) stimuli ("emotional saturation") due to high incidence of the experienced emotional peaks during the first presented musical piece (Lowis 2010). "Emotional draining": "Listening to it (the U.S. anthem) and responding with chills, they became temporarily emotionally drained, so that Rachmaninoff had a feeble impact… there may be attentional, processing, and physiological limits to how many chills people can experience in a given time period." (Konečni et al. 2007)
Creative Self-Satisfying (humans engage in imaging and thinking in order to get excited; a record of that is an artwork)		"Remembering feelings produces an amount of arousal; it is a form of self-stimulation that is rewarding. Humans seek such arousal and therefore engage in the act of remembering (van Weelden 1997)	Chills as an indicator of the peak pleasant excitement were elicited by mere mental self-stimulation – by recalling emotional events or other thoughts without any external stimulation (Grewe, Katzur, Kopiez & Altenmüller 2010).
Self-satisfying through consumption		The Aesthetic Trinity Theory (Konečni 2005, 2008) "Commotion model" of the listening to musical performance (Scherer & Zentner 2001)	Music-induced chills (Rickard 2004, Craig 2005, Grewe et al. 2007, Konečni et al. 2007, Salimpoor et al. 2011). Literature-induced chills (Konečni et al. 2007).
Difference between Perceived and Felt Emotion (Pleasant Excitement) in Attachment Motivation		"Emotions in the music" and "induced subjective state of the listener" (Konečni 2005, 2008) "Emotional recognition (perception)" and "empathic feeling (response)" (Mar 2011)	Perceived emotions and felt emotions differ. (Gabrielsson 2002, Salimpoor, Benovoy, Longo, Cooperstock & Zatorre 2009, Marin & Bhattacharya 2009)
Aesthetic Taste (familiarity with the perceived emotions)		Leder et al. (2004) use the notion without defining it.	Former experiences remain active components in our reactions to music. (Grewe et al. 2007a)
Informational Character of Emotional Need (Attachment Motivation)		Chills elicited by music are related to the surprise accompanying an event (Huron 2006). "What's beautiful is not necessarily interesting. A beautiful thing is interesting only as long as it is new (Schmidhuber 2009c)	"Novelty, sudden and unexpected change in music" elicits chills. (Grewe et al. 2007a, 2007b, Guhn et al. 2007) "Novelty is a critical stimulus dimension for amygdala engagement" and the processing "in the affective brain" (Weierich et al. 2010, see also Daselaar et al. 2006, Steinbeis, Koelsch & Sloboda 2006, Koelsch et al. 2008, Pearce et al. 2010, Pereira et al. 2011)
Application of the TIN		Salutogenesis (Esch & Stefano 2004, 2005)	Assessment of the brain monoaminergic signaling through mathematical modeling of the SCR to emotional textual stimuli (Branković 2012)

through the phenomenon of chills, thrills or frisson – the shiver that usually starts at the back of the neck, with piloerection, and spreads down the back and arms, sometimes reaching other parts of the body (Grewe, Kopiez & Altenmüller 2009, Konečni, Wanic & Brown 2007, Rickard 2004), and which can be also objectively measured (Benedek & Kaernbach 2011). The intrinsic motivational role of chills and peak emotional responses to music (Blood & Zatorre 2001, Benedek & Kaernbach 2011) has been recently confirmed by the finding of anatomically distinct dopamine release in the nucleus accumbens and the caudate (Salimpoor, Benovoy, Larcher, Dagher & Zatorre 2011).

The proposition that informational needs could be self-satisfied through creating (imaging, thinking) in order to get excited and to reach the peak of pleasant excitement (Branković 2001) has been recently experimentally confirmed. Pleasant chills were elicited by mere mental self-stimulation – by recalling emotional events or other thoughts without any external stimulation (Grewe, Katzur, Kopiez & Altenmüller 2010).

The hypothesis of refractoriness of the final, the resolution phase of the cycles of emotional and exploratory need (Branković 2001) has been also experimentally confirmed through the study of chills. Lowis (2010) detected refractoriness to musical stimuli ("emotional saturation") after high incidence of the experienced emotional peaks during the previously presented musical piece. The phenomenon ("emotional draining") was also observed by Konečni, Wanic & Brown (2007): "Listening to it (the U.S. anthem) and responding with chills, they (participants) became temporarily emotionally drained, so that Rachmaninoff had a feeble impact… there may be attentional, processing, and physiological limits to how many chills people can experience in a given time period."

Chills research led to conclusions which are in accordance with the two-factor model of the hedonic value of stimulus (Branković 2001; see also Introduction). There are no universal musical (i.e. emotional) stimuli capable of triggering pleasant excitement in all people. Rather, chills occur depending on individual memories, emotional experience, and associations (Grewe, Nagel, Kopiez & Altenmüller 2005). "We can be moved and motivated by music, but our 'free will' and former experiences remain active components in our reactions" (Grewe, Nagel, Kopiez & Altenmüller 2007a). "Music can be understood as an emotional communication system… It's not music, but the feelings of the people we hear playing that are important to us (Grewe, Nagel, Kopiez & Altenmüller 2007b). It is in accordance with our thesis that familiarity with perceived emotions is necessary for experiencing pleasant excitement while satisfying emotional need (Branković 2001).

On the other hand, sudden and unexpected change in a music piece appeared to be the common agent which elicits the listener's excitement and chills (Grewe, Nagel, Kopiez & Altenmüller 2007a, 2007b, Guhn, Hamm & Zentner 2007, Huron 2006). Furthermore, both intra – music repetition (Grewe, Nagel, Kopiez & Altenmüller 2007a) and re-exposition to the same musical pieces through several days have a "habituation" effect on chill-response. These findings support the proposition of unexpectedness of stimuli as a necessary condition for eliciting emotional excitement and point to the informational character of the attachment motivation (Branković 2001).

NEUROBIOLOGY OF THE EMPATHIC RESPONSE, AESTHETIC EXPERIENCE, AND THE THEORY OF INFORMATIONAL NEEDS: A PUTATIVE COMPUTATIONAL MODEL

The process of emotional response to receiving information about someone else's emotional situation and response has two distinct steps. The first step is recognition, perception of another being's emotions and the other step is the own evoked emotional response (Lichtenberg 1989, Branković 2001, Konečni 2005, 2008, Mar 2011).

(i) During the last decade an advance has been made in respect of the understanding of the neural mechanism underpinning the first step, i.e. recognition of the emotional situation and response of others. The mirror neuron system (MNS) has been proposed as a cortical brain mechanism which enables an individual to intuitively understand others' actions and emotions. The mirror neural mechanisms allow us to directly understand the meaning of the actions and emotions of others by internally simulating them, without any conceptual reasoning (Gallese, Keysers & Rizzolatti 2004). The mechanism has been implied in the explanation of eliciting the aesthetic response to visual artworks (Freedberg & Gallese 2007) and music (Molnar-Szakacs & Overy 2006).

(ii) Contrary to the still prevailing assumption in the current literature inherited from Aristotle, Lipps (1903) and Tolstoy (1905) that empathic and aesthetic response consist in induction of emotions which correspond to the emotions of another person (Gallese, Keysers & Rizzolatti 2004, Freedberg & Gallese 2007, Molnar-Szakacs & Overy 2006, Decety & Lamm 2006, Decety 2011a), a different view which introduces a distinction between the perceived emotions and the elicited emotional response emerged in the last two decades (Lichtenberg 1989, Branković 2001, Konečni 2005, 2008). There is empirical evidence that perceived and felt emotions differ (Gabrielsson 2002). Ignorance of this distinction is the source of confusion introduced by many investigators (Konečni 2005). Lichtenberg (1989) introduced the syntagm pleasure-in-intimacy to denote the excitement experienced while receiving information about someone else's emotional state. To denote the

peak of this excitement accompanied with visible physiological reactions I have applied the term "emotional" orgasm (Branković 2001; cf. the term "skin orgasm" for the chill phenomenon in Panksepp 1995). Konečni (2005, 2008) has referred to the music-induced emotional excitement accompanied with thrills (chills) as the states of "being moved", "being touched", and "aesthetic awe".

Our experimental dealing with the aesthetic response and mathematical modeling of the skin conductance response (SCR) to pleasant emotional stimuli yielded to a putative underpinning neural mechanism (Branković 2008, 2011, 2012). According to our model the initial step in the process is generation of the initial neural event, i.e. the input neural signal for the SCR system. It takes place in the interaction amygdala–hippocampus: The "Outcome of the specific patterning of the match-mismatch process in the hippocampus/amygdala complex determines the precise constellation of signals to be either routed onward to the hypothalamus or aborted, and shapes the affective response or lack thereof to any stimulus event" (Hadley 1989, Laine, Spitler, Mosher & Gothard 2009). In the amygdala-hippocampus interplay the role of the hippocampus is to detect the novelty and unexpectedness of the stimulus (Kumaran & Maguire 2007a, 2007b, 2008, Vinogradova 1975). On the other hand, "attachment of significance (emotional meaning) to a stimulus is critically dependent on the amygdala" (Mishkin & Aggleton 1981). In the TIN we assumed that only unexpected emotional stimuli are capable to elicit pleasant emotional excitement, i.e. pleasure-in-intimacy (Branković 2001).

One of the major outputs of the amygdala is the projection to the hypothalamic behaviour system. This projection plays a critical role in expression of the autonomic response to stimulus (LeDoux 1992). A majority of the amygdala cell groups project directly to hypothalamus but there is also an influence through the ventral hippocampus which in turn projects to the medial hypothalamus directly and by way of the lateral septal nucleus (Petrovich, Canteras & Swanson 2001). The septal region was the first identified "reward centre" (Olds & Milner 1954). It seems that septal nuclei are deeply involved in discriminating the reward contingency of environmental stimuli (Matsuyama, Uwano, Hori, Ono & Nishijo 2011). It has been suggested "that an important function of septal neurons is to coordinate adaptive behavioral responses to enable animals to increase interaction with reinforcing stimuli" (Sheehan, Chambers & Russell 2004). Apart from the relay position between the hippocampus and hypothalamus "an integrative and executive function (of the lateral septum) in the control of mood and motivation" (ibid., p. 98) could stem from the pacemaker and frequency modulation effect on the hippocampal theta-rhythm (Vinogradova 1995, Vertes & Kocsis 1997, Kirk 1998, Denham & Borisyuk 2000, Wang 2002, Nerad & McNaughton 2006). Changing the frequency of hippocampal theta neural oscillations the septum modulates the interaction between the amygdala and the hippocampus since "only coherently oscillating neuronal groups can interact effectively, because their communication windows for input and for output are open at the same times" (Fries 2005, see also Lubenov & Siapas 2009, Wang 2010). Also, the medial septum directly controls theta amplitude and translates the level of ascending brainstem activity into the corresponding frequency of hippocampal theta (Jackson & Bland 2006). In this way, the process of generation of the neural response to an emotional stimulus through the amygdala-hippocampus interplay is highly dependent on the frequency modulation effect of the septum and brainstem. That could account for the evidence that the septum plays a critical role in the regulation of motivation, that the lateral septum is implicated in a variety of psychiatric conditions as well as the findings that it is a neural substrate for the behavioural effects of antidepressants and antipsychotics (Sheehan, Chambers & Russell 2004).

It is tempting to hypothesize that some features of the neural input to the SCR system convey the novelty (or unexpectedness) aspect of the stimulus and some other significance (or emotional meaning) of the stimulus (cf. Barry 2006). It has been already suggested that different features of stimuli are represented through different dimensions of the neural pulse code in one neural system (Masuda & Aihara 2007). The neural code of the amigdalo-hippocampal circuit probably converts some subjective features (estimations) of stimuli ("stimulus attributes arrived at by computational process", and not physical attributes of stimuli (Eggermont 1998)) into emotional response. Dealing with a mathematical method of identification of the hidden neural input for the SCR response I have recently suggested a putative scenario of neural computations during the SCR process to pleasant emotional stimuli, i.e. a putative computational model of the aesthetic response (Branković 2012). The model predicts that the found metrics of the hidden-input for the SCR fits well the neural code metrics of the amigdalo-hippocampal circuit periodic sinchronizations. For example, the strength (amplitude, height) of the "hidden" neural input for the emotional SCR could relate to postsynaptic integration of the early high frequency (24-45 Hz) component of synchronous periodic amigdalo-hippocampal activity (Kano, Inaba & Avoli 2005). Duration of the pulses in the identified input for the SCR could relate to the burst duration neural code (Kepecs & Lisman 2004). Further work should be done to explore the statistics and semantics of the code of the "hidden-input" for the SCR and to examine a correlation of the "hidden-input" metrics (Branković 2011, 2012) with the determinants of the hedonic value of aesthetic stimuli such as those defined in the TIN – unexpectedness and familiarity with the perceived emotions (Branković 2001).

ALTERNATIVE THEORIZING ON THE AESTHETIC EXPERIENCE

The flourishing of neuroaesthetics during the past decade has been accompanied by several theoretical syntheses aimed at providing a conceptual framework for the emerging field of research. Here I consider four theoretical proposals regarding the nature of the aesthetic experience and compare them with my own view on the subject exposed in the TIN (Branković 2001).

My comparison of the proposed conceptualizations is influenced by the point of view of the TIN which is not necessarily a shortcoming. It helped in the choice of the criteria for the models' comparison (Table 2) and suggested the following pattern for the analysis of the models. The pattern consists in a signal processing view on the suggested explanations of the aesthetic experience separating: (1) the input (aesthetic stimulus) side from (2) the output (aesthetic experience) side and (3) the process linking these two, i.e. a computational model of the aesthetic response. The results of the comparison through this pattern of analysis are presented in the Table 2.

Reber, Schwartz & Winkielman (2004) proposed "an integrative framework for the study of aesthetic pleasure" which can be assigned as a 'processing fluency model' of aesthetic pleasure: "The more fluently perceivers can process an object, the more positive their aesthetic response" (ibid, p. 364). The processing fluency encompasses both perceptual (the ease of identifying the physical identity of the stimulus) and conceptual fluency (the ease of mental operations concerned with stimulus meaning). The features of stimuli (in the interactionist object (stimulus) – subject (perceiver) perspective) which facilitate fluent stimulus processing according to these authors are: (1) the amount of information ("stimuli with less information are not only more pleasing, but also easier to process"); (2) figural goodness; (2) symmetry; (3) contrast and clarity; (4) stimulus repetition; and (5) prototypicality.

Reber and colleagues do not consider the phenomenon of the peak experience (as an output and indicator of aesthetic experience) and do not make a distinction between aesthetic and exploratory experience: "Although human reason conceptually separates beauty and truth, the very same experience of processing fluency may serve as a nonanalytic basis for both judgments" (ibid, p. 377).

A similar conceptualization has been exposed in a "comprehensive theory that explains what psychologically constitutes aesthetic experiences" (Leder, Belke, Oeberst & Augustin 2004). Dealing with the problem "why people are attracted by art" the authors concluded that: "the challenge of art is mainly driven by a need for understanding (ibid., p. 489)… "Exposure to art provides the perceiver with a challenging situation to classify, understand and cognitively master the artwork successfully. It is this entire process that we call an aesthetic experience. … Successful mastery of an artwork is the source of intrinsic motivation to search future exposure (and the challenge) of art in the future." (ibid., p. 493)… and "that the aesthetic experience can be understood as a challenging perceptual problem-solving process" (ibid., p. 499).

Leder & colleagues (2004) offered a list of stimulus characteristics responsible for eliciting of the aesthetic experience in a traditional manner, similarly to that of Reber, Schwartz & Winkielman (2004) which includes: complexity, contrast, symmetry, order, familiarity, prototypicality, and style.

Regarding the affective component (output) of the aesthetic experience Leder & colleagues proposed that "Ongoing success in cognitive mastering results in positive changes of the 'affective state', leading to a state of pleasure or satisfaction. … Thus we believe that the perceiver somehow evaluates his affective state and uses this information to stop the processing once a satisfactory state is achieved. In certain cases, the emotional state attending aesthetic experiences can even extend to what Csikszentmihalyi (1999) termed experience of flow, a strong, positive emotional state which bears strong, intrinsic motivational potential." (ibid., pp.501-502). It is questionable whether the experience of flow (Csikszentmihalyi 1999) reaches the highest level of emotional excitement which is indispensable from the peak experience.

Schmidhuber's (2009a, 2009b, 2009c, 2010) "formal theory of creativity, fun, and intrinsic motivation" could be regarded as an attempt to improve and formalize some previous views in aesthetics and developmental psychology. Although Schmidhuber (2010) assigns the Berlyne's (1950, 1960) work on curiosity and novelty and Piaget's (1955) concepts of assimilation and accommodation as related to his theory, I find his view much more similar to Hunt's (1965) conceptualization of intrinsic motivation.

Hunt assumed "emergence of an interest in what is novel and new in an otherwise recognitively familiar situation" (ibid., 259). Optimal level of "incongruity between the input and what is already in the storage" determines hedonic value of stimuli and directs behavior (ibid., 219). Schmidhuber with a similar wording points to Hunt's "optimal level of incongruity" in his explanation of intrinsic motivation for dealing with art, music, and science: "The observer (creator) of the data is interested in melodies (but also art and scientific discoveries) that are unfamiliar enough to contain somewhat unexpected…, but familiar enough to allow for quickly recognizing the presence of a new learnable regularity… The interesting or aesthetically rewarding musical and other subsequences are precisely those with previously unknown yet learnable types of regularities… The boring patterns are those that are either already perfectly known… or whose structure seems too hard to understand" (Schmidhuber 2010). We

have already shown how this "optimal level" one-factor model of hedonic value of stimuli can be realized as a two-factor model where " the upper limit of the optimal range of incongruity" (Hunt 1965) or the Schmidhuber's condition "unfamiliar enough to contain somewhat unexpected" is regarded as a single factor "unexpectedness" in the TIN (Branković 2001). The other factor or dimension of the hedonic value of stimuli in the TIN corresponds to "the lower limit of the optimal level of incongruity" (Hunt 1965) and the Schmidhuber's condition "familiar enough". It is familiarity with the perceived emotions in the artwork.

Schmidhuber further mathematically defines the hedonic value of stimuli: "Interestingness or Novelty or Surprise or Aesthetic Reward or Aesthetic Value" is a time-dependent variable, the first derivative of another time-dependent variable which he called "subjective beauty". Schmidhuber considers subjective beauty as the learning process, the progress in revealing the regularity (beauty) in the stimulus pattern. The learning processes exhibit a progression from small beginnings that accelerates and approaches maxima over time and therefore are mostly represented by sigmoid curves. It is obvious why Schmidhuber insists on the calculus definition of the aesthetic (reward) value of stimuli as the first derivative (the steepness) of the learning (sigmoid) function. The first derivative of the sigmoid function is an inverted-U curve. This enables Schmidhuber to explain the well documented inverted-U dependence of liking from repetition of the stimulus (Berlyne 1971, Sluckin, Hargreaves & Colman 1983, Schellenberg 2008).

Here we point out that Schmidhuber's choice of mathematical representation of "aesthetic value (interestingness)" of stimuli is biased by his insisting on the one-factor, "compressibility model" of aesthetic (reward) value. In fact, inverted-U curve can be computationally obtained also as a result of a multiplication of two time-varying factors such as: (1) an exponential decaying of unexpectedness of the stimulus pattern over time and (2) a sigmoid rise of recognized familiarity of emotional stimuli (cf. Branković 2001). Actualy, Schmidhuber also implicitly encompasses two factors: "What's (objectively) beautiful is not necessarily interesting. An (objectively) beautiful thing is interesting only as long as it is new (Schmidhuber 2009c: 23). But Schmidhuber does not consider this (objective, static) beauty as a factor (stimulus aspect) in his theorizing; he is focused on the "subjective beauty" as a learning process.

Schmidhuber does not consider the phenomenon of the peak experience (as an output and indicator of aesthetic experience). He also does not make a distinction between aesthetic and exploratory experience.

Table 2. Comparison of the suggested conceptual frameworks for neuroaesthetics and the aesthetic experience

Criteria for the Comparison	Theory of Informational Needs (Branković 2001, 2012)	"Processing Fluency" (Reber at al. 2004)	"Cognitive Mastering" (Leder et al. 2004)	"Compression Progress Drive" (Schmidhuber 2009a,b, 2010)	Aesthetic Trinity Theory (Konečni 2005, 2008)
„All form of art encompassed?" (Skov & Vartanian 2009) (explanatory power, model's scope)	Yes	Yes	Yes	Yes	Yes
„Aesthetic experience explanation relies on basic neural processes such as perception, memory, and emotion?" (Skov & Vartanian 2009)	Yes	Yes	Yes	Yes	Yes
Hedonic value of aesthetic stimuli defined? (input metrics)	Yes	Yes	Yes	Yes	No
The peak experience (chills) predicted? (output metrics)	Yes	No	?	Yes (by Hudson, 2011)	Yes
Computational model linking aesthetic response with stimulus suggested?	Yes	Implicitly	Yes	Yes	No
Inverted-U curve linking pleasantness to repetition explained?	Yes	Yes	Yes	Yes	No
Distinction between aesthetic and exploratory experience predicted? (model's selectivity, specificity)	Yes	No	No	No	Yes

Contrary to the aforesaid explanations of the aesthetic experience where the peak experience is either not or only implicitly considered as the most genuine and profound affective component of the aesthetic experience stands the aesthetic trinity theory (ATT) of Vladimir Konečni (2005, 2008). Konečni depicted three different levels of emotional response to art and music, i.e. three levels of aesthetic response. The mildest aesthetic response according to Konečni (2005) consists in the chills or thrills phenomenon. Two higher levels of aesthetic response Konečni denoted as the state of "being moved or touched" and "aesthetic awe". "To be moved, sometimes with a lump in the throat, tears or thrills, appears to be the most interesting, memorable, and profound music-related subjective state. Being moved is rare and even rarer still is the listening environment that can help music be sublime and elevate the response to aesthetic awe" (Konečni 2008: 127).

Konečni regards aesthetic awe as the ultimate humanistic moment. Aesthetic awe is always accompanied by the responses of being touched and chills, but the latter two can also occur in awe's absence. Thrills are the most common and the weakest aesthetic response, and it can occur without the others. Looking at this gradation of the excitement accompanying the aesthetic response from the perspective of the TIN (Branković 2001, see also Introduction) these three levels of aesthetic response could be seen as relating to different phases of the emotional need cycle. Thrills and the state of being moved would refer to the second phase, i.e. the phase of pleasant emotional (pleasure-in-intimacy) excitement, and aesthetic awe would refer to the third phase, i.e. the phase of the peak of this excitement ("emotional orgasm").

What is still missing in Konečni's (2005, 2008) theory is conceptualization of the input metrics, i.e. a model of the hedonic value of aesthetic stimuli. Yet, Konečni has introduced a view and concept which seems promising for further research of emotional communication through music. It is the notion of "behavioral morphology of basic emotional states": "There is an impressive array of musical means by which to express, allude to, and depict nonmusical, emotion-laden events and processes – which is facilitated by music's temporal nature and the fact that composers, performers, and listeners are all intimately familiar with the behavioral morphology of basic emotional states" (Konečni 2008).

GROWING INTEREST IN "POSITIVE AFFECT" IN PSYCHIATRY AND MEDICINE

Decreased motivation, loss of pleasure (anhedonia), and loss of interest are core and highly common depressive symptoms. Yet, they are not appropriately represented in the majority of standard depression rating scales which are heavily weighted towards symptoms of general distress and negative affect (depressed mood, sadness, anxiety, and guilt) (Nutt, Demyttenaere, Janka, Aarre, Bourin, Canonico et al. 2007). These facts recently inspired Nutt and colleagues to point to "the other face of depression" – a syndrome of reduced positive affect which has a distinct neurochemical profile and predicts therapeutic efficacy of antidepressants with noradrenergic and dopaminergic activity in individual treatment (ibid).

On the other hand, although "the neuroscience of pleasure is still in its infancy" (Kringelbach & Berridge 2009), "modern science begins to understand pleasure as a potential component of salutogenesis" (Esch & Stefano 2004). It has been proposed that positive sensations and mind states like joy, interest, satisfaction, contentment, lust, and love have stress-reducing and health-promoting potential. They could be a factor which is available for each individual and which could serve health processes and protect from disease (Esch & Stefano 2004, 2005, Fredrickson 2004). Also, a transformative role of the aesthetic experience causing a long-term change in the involved brain circuits (through experience-dependent plasticity) has been recently proposed (Preminger 2012).

Growing interest in positive affect in psychiatry and medicine during the last decade parallels the emergence and development of neuroaesthetics, the studies of the MNS and chills (thrills). I assume that further study of positive affect in psychiatry and medicine will benefit from findings of neuroaesthetics, the MNS, and chills. To accomplish this integration a conceptual framework of the TIN could be useful.

For instance, dealing with the pleasant emotional excitement during literary reading I have identified a regulatory scheme of a sympathetic component (measured as skin conductance response, SCR) of the aesthetic experience (Branković 2011). The control system parameters of the SCR elicited by emotional textual (literary) stimuli showed changed in individuals acutely in a depressive episode in comparison with healthy persons (Branković 2008, 2012). Also, treatment with antidepressants was accompanied with normalization of the system parameters in the early phase (after seven days) of the treatment (Branković 2012). In this way, the concept of pleasant emotional excitement (pleasure-in-intimacy) of the TIN has been shown to be helpful in enabling the task to develop a method for clinically applicable assessment of the brain neurochemistry and prediction of the therapeutic response to a specific antidepressant (Branković 2012).

CONCLUSION

About at the same time, at the beginning of this century, several lines of research have emerged or intensified: neuroaesthetics, the discovery of the mirror neuron system, the research on chills (thrills) as an indicator of the peak emotional excitement, and theorizing on the aesthetic experience. Also, a growing interest in positive affect in psychiatry and medicine has

appeared during the last decade. An integration of these research programs into a comprehensive picture seems feasible through the conceptual framework of the TIN (Branković 2001).

Further research based on this paradigm could lead to clinical applications of the concepts of the TIN (such as the pleasant emotional excitement) and it may contribute to translation of some concepts of modern neuroscience into everyday clinical work. (cf. Branković 2012).

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