Intersections of Mathematical, Cognitive, and Aesthetic Theories of Mind

Abstract

New mathematical and cognitive theories of the mind are connected to psychological theories of aesthetics. I briefly summarize recent revolutionary advancements toward understanding the mind due to new methods of neuroimaging studies of the brain and new mathematical theories modeling the brain-mind. These new theories describe abilities for concepts, emotions, instincts, imagination, adaptation and learning. I consider the operation of these mechanisms in the mind hierarchy. I concentrate on the emotions of satisfaction or dissatisfaction related to understanding or misunderstanding of the surrounding world. These emotions are usually below the threshold of conscious registration at lower levels (of object perception). I discuss why, and in what sense, these emotions are aesthetic, I relate them to appraisal emotions, and I argue that at higher levels of abstract cognition these emotions are related to the perception of art. The contents of cognitive representations at the top of the mind hierarchy are analyzed, and aesthetic appraisal emotions at these highest levels are related to emotions of the beautiful. I emphasize that aesthetic emotions, so important in art, are not specific to art, but to cognition at the highest levels of the mind hierarchy.

In his review of "Aesthetics and Psychobiology" by Berlyne (1971), Gardner (1974) wrote that the psychology of aesthetics is a subject of great interest, to which eminent psychologists devoted much thought. Still, he pointed out, progress in this area was "dismal." This lack of progress is due to "the dizzying complexity of the domain," and "persistent pursuit of… fruitless lines of inquiry." He identified two of these fruitless directions: what motivate people to produce art, and tests measuring creativity. Recent directions in psychology of aesthetics were reviewed in Locher, Martindale, and Dorfman (2006), and in Silvia (2005). Silvia suggested appraisal as a more fundamental aspect of aesthetic emotions than older ideas based on arousal and prototype preference. A proposal in this paper is consistent with this emphasis on appraisal and further develops this idea.

Mathematical and Cognitive Mechanisms of the Mind

Our understanding the mind is far from complete. Even definitions of basic notions are the subjects of multiple debates in various disciplines. These discussions and disagreements were reviewed in (Perlovsky 2006a) and in references therein. This reference selected certain definitions and mechanisms which unified the views of many authors across several disciplines and formulated them to be consistent (or at least not inconsistent) with hundreds of publications, and with widely held intuitions about the mind. A mathematical framework underlies this new, consistent, formulation. Some predictions of this mathematical theory were experimentally proven in neuroimaging experiments (Bar et al., 2006). As discussed later in this paper, the consistency between cognitive and mathematical theories turns out to be fundamentally important. Here I would like to emphasize that striving for consistency helps to select particular interpretations among diverse and often inconsistent views on complex matters addresses here. Aims and page limitations of this paper do not permit discussing qualifications and detailed arguments. Instead, here I summarize the main results with a view of relating them to psychological literature in the following sections. I keep the summary brief, obviously risking oversimplifications, and I would refer critical readers to the original publications.

Before summarizing the mechanisms of the mind formulated in the above reference, I remind readers that attempts to mathematically formulate cognitive mechanisms began as far back as the 1950s, with the appearance of computers. Early developers of artificial intelligence naïvely believed that soon computers would by far exceed human intelligence. This did not happen; computers still cannot perform most cognitive tasks that are easy for animals and children. These developmental and mathematical reasons for failures were summarized in (Perlovsky 2006a) and ultimately reduced to the role of logic. It turns out that logic is not the fundamental mechanism of the mind, but is an approximate result of illogical mind-brain mechanisms. Most (actually all) previously used mathematical techniques relied on logic, even those that at first seemed free from logic.[1]

This ubiquity of logic is related to a fundamental property of mind-brain operations: vague-fuzzy mechanisms in the mind usually are not accessible to

[1] Neural networks, statistical pattern recognition, and other "self-learning" algorithms used logic in the process of training: training examples had to be presented as logical statements (such as "this is a chair"). Fuzzy logic used logic to set degrees of fuzziness. Etc.

consciousness, only logical or approximately logical results of cognitive processes are available to consciousness. For example, visual perception takes about 1/6 to 1/5th of a second, which involves thousands of neuronal operations, but consciously we are not aware of this and it seems that we see objects "immediately" (Grossberg, 1988; Bar et al., 2006). Because of this, conclusions about mind mechanisms which are obtained by logical thinking are not reliable, even if they might seem logically perfect. For a better understanding of the cognitive process we must turn to mathematical models, as well as psychological and neural experiments. The mathematical theory is needed to connect a wealth of experimental data into a coherent understanding of the mind mechanism. Of course, after these mechanisms are understood they can be logically described without a need for mathematics.

Fundamental mechanisms of the mind mechanisms identified in (Perlovsky, 2006a) with the help of mathematical modeling and neural experiments include instincts, emotions, concepts, and behavior. Concepts are most directly available to consciousness, and for this reason I consider them first. The mechanism of concepts operates like internal models[2] of the objects and situations in the world; this analogy is quite literal, e.g., during visual perception of an object, a concept-model in our memory projects an image onto the visual cortex, which is matched there to an image, projected from retina. If a match occurs, the concept (object or situation…) is recognized. Details of this mechanism are essential for this paper and they are considered later.

Concepts serve for satisfaction of the basic instincts, which have emerged as survival mechanisms long before concepts. Many psychologists keep the notion of instinct in low regard, because historically, instincts were mixed up with instinctual behavior and other less useful ideas. This paper uses the word "instincts" to describe simple, concrete, inborn, non-adaptive mechanisms of internal sensors; our body has dozens of these instinctual sensors, measuring blood pressure for example, or a sugar level in blood; when a sugar level in blood goes below a certain level an instinct "tells us" to eat. Such separation of instinct as "internal sensor" from "instinctual behavior" helped developing a mathematical description of cognition and explaining many cognitive functions, as described later.

How do we know about instinctual needs? We do not hear instinctual pronouncements or read dials of instinctual sensors. In making us aware of instinctual needs a fundamental role is played by emotions. The word emotion is used in many different ways describing a variety of mechanisms (Juslin & Västfjäll, 2008). For this paper purposes, I consider the following mechanism within the mind system: emotional signals evaluate concepts for the purpose of instinct satisfaction (Grossberg & Levine, 1987). These evaluations do not operate according to rules, but to direct instinctual evaluations: if a particular concept (object, situation, etc.) has a potential to satisfy a specific instinctual need, as measured by the instinct-sensor, then this concept receives

[2] Terminology for these mechanisms, and particularly use of the word "model" was subject of extended debates discussed in the referenced publication; alternative words include: representations in the mind, internal models, ideas, understandings, thoughts, notions; the word models was selected for several reasons discussed in the reference. What these models are made of? What do they look like? This might be a subject of a separate book. For the purpose of this article the model is defined by two properties: it "sends down" neural signals that match (or do not match) patterns in bottom-up neural signals, and it sends up a signal indicating that it is active (matched) or does not. A reader may imagine what is most adequate to one's intuition: an image, a mathematical equation, a pattern of active (or potentially active) neural cells.

preferential attention and processing resources. These emotional evaluations[3] occur in the process of cognition, before concepts are recognized in the world. In this way emotions participate in allocation of mental resources to processes of cognition. Objects and situations that can potentially satisfy instinctual needs (as indicated by emotional neural signals) receive preferential recognition and understanding.

Concepts represented in memory as internal models do not correspond exactly to objects and situations in the world because of multiple variations such as aspect angles, lighting, and also surrounding objects are always different. To understand the world, concept-models constantly have to be modified to fit patterns in sensory signals. Otherwise we will not be able to satisfy any of our bodily needs. Therefore we have an inborn mechanism, acting independently of our conscious desires: we always fit concept-models to the world, in other words, we constantly improve our knowledge, we increase correspondence of concept-models to the world. The mechanism that drives this process is a "sensor" measuring correspondence of concept-models to the world; I call it the knowledge instinct. Biologists and psychologists have been describing related mechanisms since the 1960s (Harlow & Mears, 1979; Berlyne, 1960; 1973; Festinger, 1957; Cacioppo, Petty, Feinstein, & Jarvis, 1996). The need to match internal mind concepts to the world might seem obvious; still, it was never mentioned in psychological literature on a par with "basic" needs, like sex or food. Mathematical modeling made clear the fundamental instinctual nature of this mechanism. All mathematical algorithms capable of learning (tens of thousands of publications) use some form of this mechanism. To satisfy bodily needs we have to understand the surrounding world, which requires modifying concept-models to fit the world, therefore the knowledge instinct is no less fundamental than needs for sex or food.

As mentioned, satisfaction or dissatisfaction of instincts we feel emotionally. How do we feel emotions related to the knowledge instinct? They are felt as harmony or disharmony between the knowledge (concept-models) and the world. They are not related directly to "lower" bodily needs, but only to "higher" need for knowledge. In this (and only this) sense I call them "spiritual." Emotions related to knowledge (at least since Kant 1790) are called aesthetic emotions. I would like to emphasize that aesthetic emotions are not peculiar to perception of art; they are inseparable from every act of perception and cognition. Relation of these emotions to the beautiful, and to aesthetic emotions considered in psychology will be discussed later. During the perception of everyday objects these emotions usually are below a threshold of conscious registration. We do not feel emotionally elated when we correctly understand a simple everyday object in front of our eyes. But, due to scientific knowledge of cognitive neural mechanisms, it is known that these emotional neural signals are there. And it is easy to prove experimentally. As soon as perception and understanding of the surrounding world does not work we feel disharmonious, disturbed, or even threatened – this is the routine matter of thriller movies, which show us situations that do not fit our concept-models. At the level of simple objects this perception mechanism is mostly autonomous, like workings of our stomach. As long as stomach works perfectly, we do not notice its existence emotionally. But as soon as it

[3] It might be difficult to imagine that human emotions can be represented by a neural signal and modeled mathematically. Let's remember that in fact emotions are much older and simpler mechanism than concepts. Lower animals do not have conceptual representations, they may have no brains, but they do have emotional signals that connect instinctual sensor measurements (e.g., hot-cold) directly to muscles. These are mechanisms of emotional judgments. Aesthetic judgments are considered in the next section.

fails, we feel it emotionally right away.

As already mentioned, most of these mechanisms are not available for consciousness. Recognition of even well known objects takes about 150 to 200 ms and only at the end of this process we experience conscious perception of an object. Another related fundamental property of cognition processes discussed earlier is that concept-models are not crisp, not logical but vague during this process. Vague states of the mind are less conscious (or not conscious at all). These predictions of the mathematical-cognitive theory (Perlovsky 2006a), that early stages of perception and cognition are vague and unconscious, can be proved experimentally as follows. Relying on tremendous recent progress in understanding neural mechanisms, this proof is easy and can be done in few seconds. There are ways in which we can consciously perceive vague states. Close your eyes and imagine an object in front of you. This imagination is not as clear and crisp as perception with open eyes. It is known (from neurophysiology) that these vague imaginations are created by neural projections of concept-models from memories onto visual cortex, which also participate in the early stages of perception processes. The projection processes as well as vague projections are unconscious as long as eyes are opened. Recently, these kinds of experimental proofs were performed with much more detail by using neuro-physiological brain imaging techniques (Bar et al., 2006). Specific brain regions involved in these mechanisms were identified, as well as timing of activations of these brain regions, and timing of unconscious and conscious mechanisms.

The Mind Hierarchy

The mind is organized into an approximate hierarchy (Grossberg, 1988). Perception, described above, can be considered as one step in this hierarchy (perception actually involves several hierarchical levels). Signals within the hierarchy are generated by concept-models. Those signals moving "down" the hierarchy (e.g. from concepts to perceptual signals) are called top-down signals, and those moving "up" are called bottom-up signals. Top-down signals generated at a particular level of the hierarchy are matched to bottom-up signals that are recognized and understood at lower levels. The mind involves a hierarchy of multiple levels of concept-models, from simple perceptual elements (such as edges, or moving dots), to concept-models of objects, to complex scenes, and up the hierarchy… toward the highest concept-models. These highest concept-models near the top of the hierarchy are essential for understanding the nature of the beautiful (Perlovsky 2002, 2006a) as I discuss below.

Let us first attend to the perception-cognition of a simple situation-scene, say a concert hall. It is not sufficient for the knowledge instinct to understand individual objects in the hall such as chairs arranged in rows, a scene, piano, ceiling… we can sit in a chair, but this understanding will only take us so far (animals also understand objects and what they can do with some of them). The knowledge instinct drives us to understand "a concert hall" in its unity of constituent objects. For this purpose we have a higher-level concept-model of a "concert hall." Similarly, we understand a restaurant, a professor's office, and any other situation by using appropriate-level concepts that we have learned for this purpose. Let me repeat this word: purpose; every higher-level concept has a purpose to make a unified sense out of individual lower-level concepts. In this process lower-level concepts acquire higher-level "sense" or meaning of making up something "bigger," something more meaningful than their lower-level meanings. In this way our understanding of the world can move from a "book" to "office," to "university", to

"educational system," and so on… to concepts near the top of our minds. These concepts "attempt" to unify our entire life experience, to make sense, to understand it in its unity. Is this possible? Not quite as clear as a simple object in front of our eyes. We understand-perceive-feel them as related to the meaning and purpose of our lives, but does such a thing exist?

Let us look at this in more detail. Even a simple object as discussed, when imagined with closed eyes is vaguer and less conscious than when perceived with open eyes. But abstract concepts at higher levels of the mind hierarchy can not be "perceived with open eyes." Correspondingly they are forever vaguer and less accessible to our consciousness than simple objects. We do not necessarily experience all abstract concepts this way. The reason abstract concepts sometimes seem crisp, clear, and conscious is due to language (Perlovsky 2006b). Language is clear and conscious in the mind by age of five. Similar to open eyes, it "masks" from our consciousness vaguer and less conscious cognitive models. This explains the neural mechanism of the fact that a child can talk about almost everything, but does not "really understand" like an adult: contents of child's cognitive concepts are vague. As far as contents of the highest cognitive concepts, we all are like children; these highest contents are vague and barely conscious (at best).

Vaguer and less conscious concepts are mixed up with emotional contents. For example, thinking about some difficulties in your family life may require special efforts to separate conceptual understanding from emotional involvement. This is why concepts at the top of our mind at once are less conscious and emotionally charged. This combination makes it difficult for us to discuss these concepts. Many of my friends (scientists) when asked: "Does your life have a meaning and purpose?" will reply with great doubts. However, as soon as the question is asked differently: "So your life does not have any more meaning and purpose than that piece of rock at the side of the road?" At this point most of people agree that the idea of the meaning and purpose of life might be vague and barely conscious, but it is so important that we cannot live without it. In fact reading this paper would be a very boring exercise if you did not believe that there was a purpose to what you do. It would be more fun to get drunk or high on drugs. The purpose of art and religion[4] for millennia was to help our minds to create more concrete contents for these highest concept-models. But no teacher, artist, writer, or priest, however genial, however deeply he or she has penetrated into the meaning of life, can put this content in other people's minds. Cultures create cultural models, like language creates linguistic contents. Still it is up to everyone personally to use art, religious teachings, or poetry to guide oneself toward creating one's personal cognitive contents from one's own experience.

Let me repeat, no everyday experience convinces us that our lives have meaning and purpose. But believing in one's purpose is tremendously important for survival; it is necessary for concentrating will and power for surviving, or achieving higher goals in life. This is why even partial understanding of contents of the highest concept-models is so important. When we feel that indeed our lives have meaning, in these rare fleeting moments we feel the knowledge instinct satisfaction at the highest level as an aesthetic emotion of the beautiful.

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[4] The emotion of spiritually sublime is not a subject of this paper, although it cannot be avoided. It is similar and different from the beautiful. Whereas the beautiful is related to understanding of conceptual contents of the highest models, sublime is related to understanding of behavioral contents of the highest models. One feels religiously sublime emotions when he or she better understands (or even feels the possibility) of behavior and actions, which could make this highest meaning to be a part of one's life.

Other Theories of Aesthetic Emotions

Evolutionary Psychology Theories

The proposed theory has an evolutionary flavor. But it implies cultural evolution, not genetic evolution. The knowledge instinct mechanism is separate from sexual drive and procreation instinct. The reverse is not true; sex is a powerful instinct that uses all our abilities, including the ability for knowledge, for creating and perceiving beauty. Therefore in everyday life sex and beauty may not be easy to separate. But for theoretical analysis proposed here the separation is clear: different instinctual mechanisms are involved. Sexual and aesthetic could be mixed up in behavior and thinking, but neural mechanisms are different. Genetic evolution does not lead to aesthetically beautiful. The knowledge instinct exists in all higher animals; therefore they experience aesthetic emotions that are related purely to learning, to improving their knowledge. This is obvious in young animals, they enjoy learning (puppies learn objects around, learn their muscle operations, learn relations with their siblings). But animals do not have the hierarchy of the mind extending to abstract concepts, which could not be directly perceived by sensors. This hierarchy is uniquely human ability; the reason is that it requires a human type language (Perlovsky 2006b), which builds a parallel hierarchy in our mind; this parallel hierarchy of language serves almost literally as a scaffolding for the cognitive hierarchy.

Because of this separation between genetic and cultural evolution, which is fundamental for psychology, attempts by evolutionary scientists and evolutionary psychologists to explain higher cognitive functions failed. Tooby & Cosmides (2001) wrongly assumed that "natural selection is the only explanation presently known to the scientific community" for the mind evolution. Such categorical statements are difficult to reconcile with Dawkins (1976, 1986) recognition of the superior power of "new replicators," memes (language concepts), and his conclusion that language evolution has to overtake genetic evolution. But they and other evolutionary scientists do not know mechanisms of "memes" or their interactions with cognition. Higher cognitive functions, including human level of aesthetic ability cannot be understood without understanding mechanisms of the knowledge instinct, the mind hierarchy, and cognition-language interaction (Perlovsky, 2006a, b).

Appraisal Theory

The proposed theory corresponds in many points to appraisal theory of aesthetic emotions (Silva 2005). What is appraised at the highest level of the emotion of the beautiful, according to the theory in this paper, is the conceptual content of meaning and purpose of life. This conceptual content is vague, unconscious (or barely conscious in inspirational moments), and inseparable from the very feeling of the beautiful. If one experiences a distinct appraisal structure at this highest level, it is not the content of the cognitive concept per se, but cultural (artistic, religious, poetic, literary) concepts at this level, which guide us toward creating cognitive contents; ideas such as God, Testament, Ten Commandments, Crucified God guided contents of the highest models and inspired hundreds of generations, and continue inspiring millions of people. If a thoughtful person feels inadequacy of these contents, possibly experiencing them as too concrete and inadequate to inspire the awe of eternity, and does not see the highest beauty in century-old masterpieces, well, it is the scientifically expected result of the knowledge instinct mechanism that drives us to search for the new content of these highest models. In

particular, differentiation of these highest models separated conceptual and behavioral contents, and today we can discuss separately the beautiful and sublime. The feel of emotions of the beautiful is objective and subjective at once, it involves unconscious and vague contents, and it is as rare as any inspirational experience. Most people experience them sometimes, but they are not easy for experimental study in a laboratory. The following paragraphs discuss scientific hypotheses following from the proposed theory, which are potentially testable in psychological laboratories.

Lower from the top of the highest models are still important models guiding lives. Their understanding inspires high aesthetic emotions similar to the beautiful. The lower a scientific inquiry descends in the mind hierarchy, the more concrete is the content of the models, and according to the present theory, these contents (which summarize much of significant life experiences and cultural knowledge) provide more distinct appraisal structures for aesthetic emotions discussed in (Silva 2005). I would like to emphasize one difference between this appraisal model of aesthetic emotions and the one discussed here. According to (Silva 2005): "appraisal model… explain(s) emotional responses in terms of cognitive evaluations of objects." According to the current theory, aesthetic emotional responses refer not to properties of objects, but to the personal subjective understanding of these properties, this understanding satisfies the knowledge instinct and this is subjectively felt as an aesthetic emotion (when it exceeds the threshold of conscious awareness). This difference seems potentially testable experimentally by evaluating subjects' aesthetic emotional responses in contexts of cognitive dissonance (e.g. Akerlof, G. A. & Dickens, W. T., 2005).[5]

To further illustrate this point, I would analyze the following suggestion from (Silva 2005). "Common appraisal components include appraising something as being *unexpected, relevant to a goal, controllable or uncontrollable, inconsistent with personal standards*…" Let me analyze this one item at a time. The proposed theory view may suggest the following differences, which could be potentially verified in psychological lab. Emotional appraisal of something as being *unexpected*, would first produce a mismatch between the world (or an object of art) and concept-models in the mind. This would produce a dissatisfaction of the knowledge instinct and negative aesthetic emotion. In a simple case this negative aesthetic emotion may last from a split second to a second or few. Then an understanding comes about along with satisfaction of the knowledge instinct, followed by positive aesthetic emotion (likely a stronger one than the initial negative, which could have been below a threshold of consciousness). For example, successful humor acts in a similar way (say on "Saturday Night Live"), the initial puzzle about what is funny may turn into a recognition of the funny aspect of the joke; this is the essence of any joke; a successful joke probably requires no more than a second of the initial puzzlement and a negative aesthetic emotion). This interplay of expected vs. unexpected in aesthetic judgments can be directly tested experimentally.

Of course, the opposite side, "well known, no novelty" does not satisfy the knowledge instinct and therefore it can be a source of negative aesthetic emotion (being bored); it cannot be a source of positive aesthetic emotion. (It could be a source of other positive emotions, considered later). But first I would add that people return time and again to "old favorite" work of art, or to re-read a favorite novel, and feel true aesthetic satisfaction. For example, right now I am re-reading "Anna Karenina" by Lev Tolstoy, a

[5] If cognitive dissonance settings are used to create personal subjective contexts for subjects, then their aesthetic emotional responses, according to the proposed theory, could be demonstrated to reflect personal subjective understandings rather than understanding of objective properties.

novel that I read in my twenties and thought to be the greatest novel I ever read. During my current reading I am surprised how much I missed on my first reading (for example that Mr. Karenin was an outstandingly decent man, that certain words Anna told him I would not appreciate today if said by my friend). I have a collection of paintings; over the course of years I replaced some paintings that I liked initially with others. Similarly, I often return to some musical pieces but not to others. These experiences confirm a theoretical conclusion: a piece of art remains beautiful and inspiring for one as long as it retains novelty and therefore appeals to the unconscious, helps bringing something new to the consciousness. This interplay between novelty, positive aesthetic judgment, and conscious-unconscious cognition, would be important to test experimentally; could this be done? It seems to me it could, and I would appeal to experimental psychologists to design the adequate experimental protocols.

When novelty is "too much," say as was the case with Van Gogh paintings or the Einsteinian theory of relativity, negative aesthetic emotion of not-understanding may last for years. This is the case with most artistic and scientific discoveries; in particular reviewers may feel negative aesthetic emotions, especially if mixed with non-aesthetic negative emotions. If the author of a new theory is lucky (and if the theory is really good), this negative emotion is counterbalanced with positive aesthetic emotions, which Poincare and Einstein referred to as the beauty of a scientific theory as a first proof of its validity. This beauty of course requires novelty, and possibly even bewilderment related to novelty and misunderstanding; the positive side comes from an intuitive feel that a significant area of science that has not been understood, would be possible to understand (it is often related to the ability of a theory to explain a wide area of science with few assumptions). Similar mechanisms apply to discoveries in art or any area of spiritual endeavor. Can these Einsteinian intuitions be tested experimentally? This question seems close to a more general one: can inspirational experiences be tested?

Returning to (Silva 2005), consider now *relevant to a goal*. This is consistent with the proposed theory if the goal is to *understand* something. If the goal is pragmatic (to get food, or sit down to rest one's legs), according to the proposed theory emotions are not aesthetic. This was considered in detail by Kant (1790); Kant did not know about the knowledge instinct (he assumed concept-models given and fixed). Therefore he could not give a positive definition of the beautiful as given in this paper. So he defined the beautiful from what it is not, and particularly that the beautiful does not serve a pragmatic goal. From current knowledge of neural mechanisms, I can state it more specifically: positive emotions satisfying various bodily instincts or pragmatic goals, but not the instinct for knowledge, are not aesthetic emotions (according to the proposed theory). This might be considered just as a matter of a definition, what is aesthetic, what is not? However, the definition proposed in the current theory is experimentally testable. Current techniques of brain imaging can be used to identify brain areas involved. Involvement of the knowledge instinct (certain cortex areas discussed in Levine & Perlovsky, 2008) would indicate aesthetic emotions; whereas brain areas involved with bodily needs, according to the current theory, are not related to aesthetics. Every year new results are obtained relating brain areas to psychological needs and goals more accurately, and the proposed tests could be performed with more precision.

Let us now look at *controllable or uncontrollable* (Silva 2005). Again, both could be sources of aesthetic emotions, if they serve improving knowledge (conceptual, or behavioral). For example, observing fractal patterns appearing on a computer screen might be aesthetically fascinating. "Too" controllable might be pragmatically good but aesthetically boring; "too" uncontrollable might dissatisfy models-expectations and the

knowledge instinct, and be aesthetically unpleasing.

Inconsistent with personal standards could be trickier to analyze. According to the present theory, to the extent that this inconsistency breaks one's sense of the meaning and purpose in life (or culture), it might stimulate a negative aesthetic emotion. But in the next moment it might free one from outdated parental (cultural) norms and open ways to new knowledge, then, creation of this new knowledge, or even an expectation of this possibility would be accompanied by positive aesthetic emotion. Personal growth and cultural evolution repeat these processes.

Typicality and Prototype Preference Theories

Let us now turn to a different theory of positive aesthetic emotions, "typicality" or "prototype preference" (Martindale et al., 1990; Halberstadt & Rhodes, 2000; Rhodes & Halberstadt, 2003). An infant or a child might enjoy positive aesthetic emotion from recognizing an already seen object. If the knowledge of the world improves in the mind, according to the current theory, it is an aesthetic emotion. I remember once being a kid I have seen a beautiful ancient goblet broken from a minute touch. I was puzzled; I could not believe that such a big beautiful thing could be broken by such a minor force; and I 'repeated an experiment,' I slightly pushed another goblet at an angle. When the second goblet was broken, I was crying because such a beauty was destructed. But my knowledge instinct was satisfied; indeed a big beautiful piece could have been broken by a minor force if applied at a wrong angle. Similarly, a scientist might want to repeat a scientific experiment to confirm-improve knowledge. However, "typicality" or "prototype preference" usually refers not to aesthetic emotions as suggested in the present theory. Recognition of typicality or prototype preference usually does not serve to increase the knowledge and satisfaction of the knowledge instinct. Pleasant emotions from recognition of typicality likely serve different instincts, related to "being in a familiar environment," "being safe;" it might be related to the worst of human emotions, such as racism, which we would not like to mix up with our highest endowments of the beautiful, related to the knowledge instinct. This hypothesis might suggest a direction for psychological laboratory studies of the range of innocuousness to morbidity involved in pleasantness of typicality.

Complexity, Simplicity, and Aesthetics

Is appreciation of *complexity* usually an aesthetic emotion? Possibly. But I would not answer this question offhand. I know people who like meaningless complexity as a confirmation that there is no meaning or purpose, and that knowledge is useless. As I understand this attitude, accepting that there is a meaning and purpose to one's life imposes a lot of responsibility. And many people would like to avoid it. According to discussions in Levine and Perlovsky (2008), refusing the responsibility of making decisions (and ultimately refusing knowledge) was the reason Adam was expelled from paradise. Being his descendants (in terms of specific neural mechanisms), we cannot avoid this predicament. In that reference, refusing knowledge is further related to a recent award of Nobel Prize for the work of Tversky and Kahneman (1974, 1981). Contradictions discussed in this paragraph could be a separate topic of study in psychology labs continuing Tversky-Kahneman findings. For example, together with colleagues we attempt to relate Tversky-Kahneman "rationality" to neural mechanisms of the knowledge instinct involving cortex (uniquely human part of the brain); while we attempt to relate "irrationality" to amygdala (an ancient part of the brain) and to the opposite to the

knowledge instinct "minimization of cognitive effort" (see Chaiken, Liberman, & Eagly, 1989).

A beauty of scientific theory is in its simplicity, but this simplicity is of peculiar and complex nature. Arguments and confirming experiments could be very complex. Simplicity in this regard is measured by a variety and complexity of what is explained and predicted versus scarcity of assumptions or postulates. This line of thinking ascends to Occam's Razor (Ockham, XIV CE/1990); Einstein, Poincare and other scientists, as mentioned previously, considered beauty a first indication of the validity of a scientific theory (Wechsler, 1978). Can this connection between beauty, simplicity, and science be tested in a lab?

Another view on complexity vs. simplicity can be explored by analyzing a beauty of a flower. It may seem beautiful, because it combines simplicity of form with complexity of purpose, which some people perceive in a flower intuitively. Possibly, because a flower is full of biological meaning, it hints to our unconscious about their joint evolution lasting billions of years and reminds about the purpose of existence beyond individual life. The fullness of meaning in a simple object gives us a possibility to feel meaning in nature in general, and in particular, the meaningfulness of our existence. The beauty of a flower is a perceived possibility of improving ourselves, improving the inner concept-models of our purposiveness toward the aim that is hidden from us as of yet. Objects of art that we perceive as beautiful remind us of our purposiveness and thus improve the highest models of the meaning. I would like to see these hypotheses tested in psychology labs, but it might be awfully difficult to do. Still, many issues discussed in above paragraphs in this section are potentially testable in the lab.

Conclusions

Discussions in this paper contain several scientifically novel arguments, and an additional novelty is that conclusions are in agreement with oldest intuitions in the history of philosophy. Aristotle and Kant discussed similar ideas. Aristotle wrote (IV BCE/1995) that the beautiful is a "unity in manifold." The only way to understand the world in its unity, he wrote, is as if it had a purpose. Here, these philosophic intuitions receive scientific foundations. Kant (1790) understood the beautiful as "aimless purposiveness" of the faculty of judgment (sometimes translated as "purposiveness without purpose"); Kantian judgment corresponds to mechanisms of aesthetic emotions discussed here with one exception already mentioned. Kant did not know about the knowledge instinct and could not formulate the beautiful as in this paper. Similar to the proposed theory he associated aesthetic emotions with knowledge; emphasized that the beautiful is not aimed at satisfying any pragmatic goal or lower bodily needs. "Aimless" in Kant means that purpose of the beautiful is not aimed at any concrete finite goal. Again, philosophical intuitions formulated long ago, held in high regard and discussed for centuries, affecting the entire philosophy of aesthetics and art criticism, received scientific foundations for the first time.

The paper discussed several experimental tests of the proposed theory; other testable areas include a need for knowledge and related emotions. The mind hierarchy is well established at lower levels (Grossberg, 1988), still more tests can involve higher levels. Particular areas requiring testing involve relations between cognitive and language models at higher, abstract levels; relative vagueness of cognitive vs. language models; development of vague models during childhood into more crisp models with age; relative

role of conceptual and emotional contents and its change through the hierarchy; relations of these emotional contents to aesthetic perception of art; meaning of life judgments vs. perception of the beautiful.

The proposed theory of psychological and cognitive foundations of aesthetics has selected among various definitions and interpretations of many relevant experimental and theoretical ideas. These ideas are sometimes contradictory and inconsistent; therefore it has been essential to combine psychology, cognitive and neural sciences, as well as mathematics to select consistent set of ideas among many possible. In this role mathematics has been most helpful.

The knowledge instinct foundation of aesthetic emotions, proposed in this paper, suggests that psychological experiments for testing this theory may be more complex than in the past. Not only emotions should be measured, but they should also be attributed to motivations with control for conscious and unconscious. Still it is not beyond sophistication of existing experimental methods.

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