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A Naturalistic and Behavioral Theory of Aesthetics

Abstract

Aesthetic reactions occur when cognitive and affective elements interact, in diverse arts. Affective elements result from past Pavlovian conditioning events and other sources. Compounding raises these effects to the level of aesthetic reactions. Properties of domains in which aesthetic reactions occur are identified. Cognitive ability is selected phylogenetically by the discernment of beauty. Aesthetic reactions help maintain competencies like language, conceptualization, and abstract thinking.

Keywords

Aesthetics Theory, Behavioral Aesthetics, Pavlovian Conditioning, Operant Behavior, Beauty in the Arts

1. How the Topic is Addressed

1.1. The Empirical-Naturalistic Approach

To some, a behavioral and biological approach to the study of aesthetic reaction may seem strange, but to a behavioral and biological scientist, it is the only possible approach. The goal, after all, is to gain an understanding of a natural phenomenon—of something that is *consistently observed and reported independently by different observers* who agree that the phenomenon is real. Real, in this context, means that independent observers will make the same observation, and make it in more than one way so as to make sure it's not illusory. The value of any scientific account depends on the extent to which it meets this standard.

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A useful first step is to partition the task into component questions:

1. What is the natural phenomenon being studied and our basis for believing it exists?
2. Where, when, and under what conditions do reactions termed "aesthetic" occur?
3. How do aesthetic reactions form?
4. How are aesthetic reactions primed or potentiated?
5. How do they change as a function of number of exposures?
6. How did it come about that humans exhibit aesthetic reactions and sensibilities?
7. What is their domain and their relation to the perception of beauty?
8. Did aesthetic sensibilities perform a useful function during our biological evolution?

Three previous articles (Mechner 2018a, 2018b, 2019) were directed at these questions. I adopted an essentially empirical, naturalistic approach that defers hypotheses or theories until sufficient data are on hand—a strategy for the exploration of uncharted territory that I learned in the Columbia University Psychology Department of the 1950s.[1]

1.2. Private Sensations and Events

This general approach, variously characterized as "logical or empirical positivism," (Bridgeman 1927, Carnap 1928/1967, Hempel 1952) or "naturalistic," presents special challenges when applied to sensations that are inherently private or "subjective," like pain, hunger, thirst, nausea, sorrow, joy, and so forth. What makes such sensations "real" nonetheless is that independent observers can agree that they occur. Since aesthetic sensations and

[1] Columbia's Psychology Department, was, at that time, one of the spawning grounds for naturalistic approaches to the study of behavior. I arrived there from a youth dominated by art, music, literature, and burning questions about the nature of aesthetic sensibilities. My Columbia professors Fred Keller, W. N. Schoenfeld, Ernest Nagel, and Lofti Zadeh then steered me in the direction implied by this article's title.

In 2017, *The Psychological Record* and its Guest Editor Marcus J. Marr organized a special issue featuring commentaries by nine prominent behavioral scientists regarding my original 2018a article "A behavioral and biological analysis of aesthetics" and my reply to those commentaries.

reactions are members of that set, it is worth reviewing the general process by which private or subjective sensations come to be observable and thus qualify as "real" and therefore suitable for scientific investigation.

How can I know that you have a private sensation, such as a certain pain? Here is how. You observed that when I pricked my finger with a pin, I said "ouch." When *you* then pricked your finger with a pin, you imitated what I had said in that circumstance and also said, "ouch." When I subsequently hear you say "ouch" in the context of a pinprick, I am *observing* your pain (without actually feeling it). I "*explain*" your pain by pointing to the pinprick. Physiologists may amplify this explanation with a reductionist approach that identifies such mechanisms as pain receptors in the skin, and neural pathways to brain structures that are activated.

This same epistemological paradigm is applicable to all instances in which we observe private sensations of others, including aesthetic reactions. The first level of evidence consists of another individual's verbal utterance or other overt reaction that occurs in conjunction with certain observed and specifiable circumstances (the counterpart of the pinprick.) Physiologists may be able to observe correlated physiological events (e.g., dehydration when thirst is reported, pupillary dilation when pleasure or excitement is reported, or autonomic nervous system activity when fear is reported.) Neuroscientists have begun to use fMRI technology to identify neural correlates of other physiological events and verbal reports.

1.3. The Broad Conceptualization of Behavior

Behavior is any activity of an organism—a conceptualization that is broader than some others. It includes the activities of the body's muscles and systems—nervous, vascular, endocrine, etc.—and such interactions with the environment as perceiving, reacting, avoiding, escaping, discriminating, or generalizing.[2]

[2] This conceptualization encompasses such cognitive behavioral events as learning, conceptualizing, categorizing, choosing, visualizing, and complex skills like calculating, reading, and writing. It also encompasses more complex behaviors based on more elaborately derived relations such as analyzing, imagining, deceiving, seducing, envying, competing, and so forth. All of these behaviors, no matter how complex, can be defined operationally and analyzed in terms of simpler behaviors and specifiable events that comprise the contingencies that define them (Mechner 2010, 2011).

Some of these behaviors are readily observable by others when they occur, while those that are purely neural and occur only covertly (privately,) are not, and may be described as "thinking" or "feeling." But all of these behaviors are observable and measurable, at least in principle if not with existing technology. Direct observability, being purely a matter of current technology, does not enter into the definition of behavior.

It is useful to divide the behavior of vertebrates into two broad categories: (1) ***operant*** or "instrumental" behavior, which operates on the organism's environment; and, (2) ***respondent*** behavior (like digestion, reflexes, vascular function,) which is elicited by certain ***stimuli.*** Instances of operant behavior may be referred to as ***operants*** and of respondent behavior as ***respondents***.

Respondents are generally subject to Pavlovian conditioning; when a stimulus that normally elicits certain respondents is paired with a previously neutral stimulus, the previously neutral stimulus may come to elicit similar respondents and is then termed a ***conditioned stimulus***.

Both operant and respondent behavior can be either overt and readily observable, or entirely neural. Behavior that is entirely neural, though difficult to observe, can still be operant. The chess player's thinking behavior is operant because it will have an effect on the environment when the move is made. All operants have an initial neural component, which is only sometimes followed by muscle contractions. Affective reactions may include overt or covert respondents (Lane & Nadel 2000). When strong, they may include overt operants, such as exclamations.

Reinforcement: Operants sometimes have consequences whose effect is to increase the frequency, rate, or probability of future occurrences of similar operants. Such consequences are termed ***reinforcement,*** and events that ***reinforce*** behavior may be termed ***reinforcers.*** Reinforcement thus maintains the operant behavior that generates it, but a reinforcer's effectiveness depends strongly on the delay with which it follows the behavior—the longer the delay, the smaller the effect.

Operants, whether simple or complex, change with successive occurrences, becoming ever more stereotyped, rapid, and automatized, less susceptible to modification by consequences, and ever less dependent on reinforcement for their maintenance.

1.4. Mind, Cognitive Behavior, Emotion, and Affect

The fuzzy concept of mind may be defined, as per Aristotle, as "a set of powers and potentialities" (Bennett & Hacker 2003, 53, 62–63), corresponding to the concept of the behavioral repertoire. Mind is rarely invoked in the study of behavior because it is so encompassing, just as the concept of life is rarely invoked by biologists.

Behavior may be termed "cognitive" when it involves the manipulation of concepts and their relations or the use of language, like the behaviors mentioned in Footnote 2, though all such behaviors are analyzable and decomposable into simpler and more directly measurable behaviors. The perception of relations in music or other arts is also often referred to as cognitive when the relations are sufficiently complex (e.g., Hargreaves & North 1997).

As has often been pointed out (e.g., Barrett 2017, Berlyne 1971, Mechner 2018b) the concept of emotion is too fuzzy to be useful in a scientific analysis, carries too many undesired connotations, and is categorized in too many different ways. For present purposes, the term affect is more useful.

1.5. The Aesthetic Reaction

We can now address Question 1 above—the natural phenomenon we are studying and our basis for believing it exists. One of our targets is the aesthetic reaction's counterpart of the pinprick—the combination of objectively described stimuli and circumstances that can evoke aesthetic reactions. When an aesthetic reaction is strong enough to result in observable operant behavior, the counterpart of the overt "ouch" may be some combination of a smile, a gasp, or an oral statement such as "beautiful!" "wow!" "amazing!" "awesome!" "surprising," "magnificent!" or "moving," uttered in the context of perceiving certain stimuli in certain situations and circumstances.

Aesthetic reactions occur in the course of daily living when we see or hear something that we consider beautiful or moving, like a colorful flower garden as we walk along. Vladimir Konečni called weak or private aesthetic reactions "aesthetic mini-episodes imbedded in the stream of daily life" (Konečni 2015).[3] The reaction may be covert, and we may not even be aware of it, even when the reaction has a low-level affective component.

[3] For more detail regarding the nature of the aesthetic reaction, see: Mechner (2018a) Sections 1.3–1.4.

Our belief that aesthetic reactions exist at all is based largely on consistent and universal verbal reports of private events generally described as "pleasurable" and "involuntary." The reaction is generally reinforcing, but not reinforcing like eating when hungry or drinking when thirsty. Rather, it is of a distinctive type that is independent of the satisfaction of "drives" (Rolls 2005).

1.6. Essential Defining Components of the Aesthetic Reaction

The defining behavioral components of the aesthetic reaction are covert, private, and therefore not readily observable. Some of them are *covert cognitive operant behavior* (e.g., perceiving conceptual relationships like incongruity, analogy, differences, similarities, "surprisingness," parsimony, etc.) and some are *affective* (e.g., moving associations and recollections, positive affect produced by reinforcing effects, reactions to emotionally charged stimuli, etc.) As will be seen, *the affective reactions are normally elicited by the cognitive components* functioning as conditioned stimuli. But for these interactions to produce even covert aesthetic reactions, they must be amplified by interactive effects like compounding and synergy, as will be explained.

The aesthetic reaction's strength is a function of many potentiating variables in addition to the properties of the stimulus. Potentiation results from the level of attention the stimulus receives, the level of arousal (as defined by Berlyne (1971)), the reacting individual's physiological and mental state, learning, priming, and socio-cultural history, and the socio-cultural context of the situation. Defined in this way, the reality of aesthetic reactions is supported by their consistency and universality across cultures and eras, much like the universality of pain or thirst. Neuroscientists, using fMRI technology, have begun to identify the neurological structures and pathways of the neural activity correlated with these types of reports and observations (e.g., Salimpoor, Benovoy, Larcher, Dagher, Zatorre 2011), though that methodology is still being refined (Mechner 2018b, Section 5.2). But neuroscience technology may be pointing to ways to observe individuals reacting aesthetically.[4]

[4] A neuroscience methodology that attempts such an approach, and its related methodological issues, is described and discussed in: Mechner 2018b, Part 5.

2. The Formation of Aesthetic Reactions

2.1. The Process

Figure 1 offers a schematic overview of how aesthetic reactions form. Cognitive and affective events come together, and when they do, they interact transformatively.

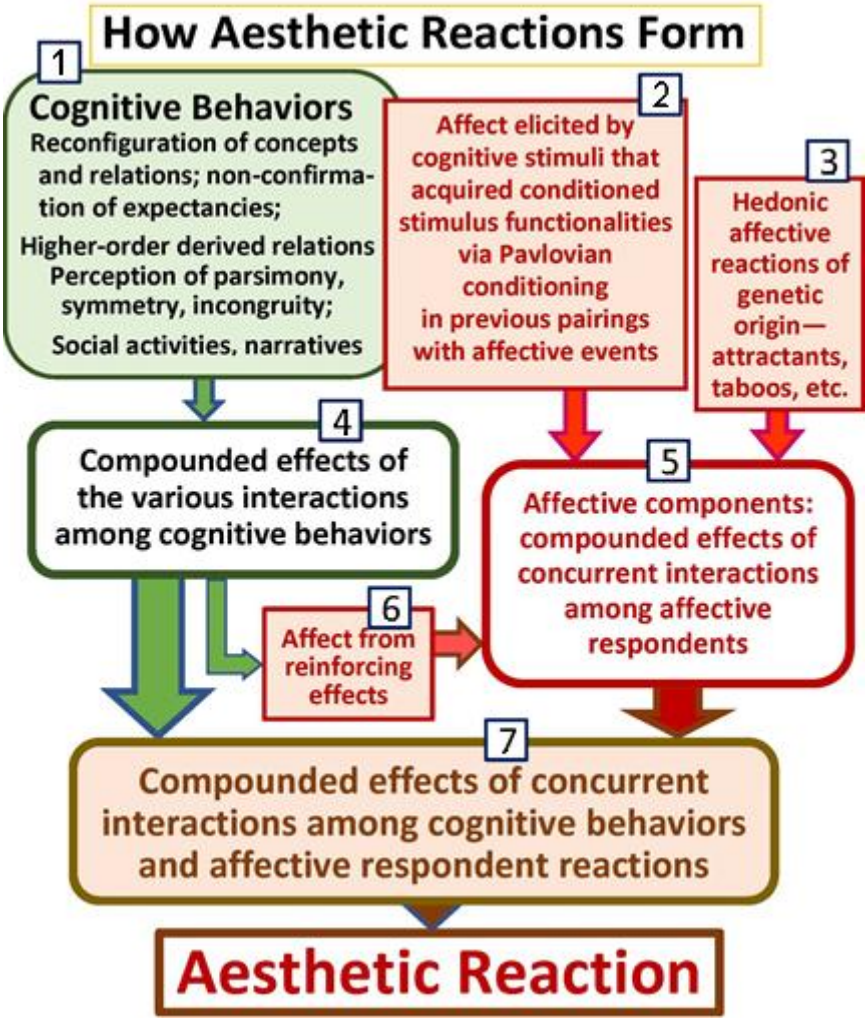

Figure 1 (Adapted from Mechner 2019)

Boxes 4 and 5 jointly create the compounded effects represented by Box 7, which in turn gives rise to the affective reaction. The sources of the affective components represented by Box 5 are contributed by Boxes 2, 3, and 6. Box 4 represents the effects of the various possible cognitive behavioral interactions, some of which are listed in Box 1.

Note that the term compounding appears in Boxes 4, 5, and 7 to emphasize the essential fact that the augmentation by compounding is itself transformative. These compounding effects enable the total reaction to reach the threshold for the unique affective and reinforcing qualities of an aesthetic effect.

2.2. Interactions in the Synergetic Brew

A key element of the theory is that aesthetic reactions are produced by *synergetic interactions* among cognitive and affective reactions. The term "synergetics" was introduced by the German physicist Herman Haken (1978) and the American engineering theorist Buckminster Fuller (1975) to describe interactions that are not merely synergistic (as when the total is greater than the sum of its parts,) but *transformative*, where the result is *different in kind* from the interacting elements. Nature is replete with synergetic interactions, examples being chemical reactions, protein synthesis, or fertilization.

I have been using the term *synergetic brew* to refer to simultaneously present synergetically interacting elements (Mechner 2018a, Part 1).[5] These are the elements listed in Box 1—concepts, their relations, perceptions, recollections, situations, sensory stimuli and mental events (Mechner 2018a, Sec. 10.1). One can think of the synergetic brew as a cauldron filled with diverse elements that interact to create novel, surprising, arousing, emotionalizing, reinforcing, and transformative effects.

2.3. Cognitive and Instructional Effects

Cognitive learning generally involves reconfigurations of the concept repertoire. The term "concept," as used here, refers to a class or category within which the behavior generalizes, while that class is discriminated from other classes (Keller & Schoenfeld 1950). All concepts, even the most abstract ones and the relations among them, can be described in terms of discriminations

[5] Artur Koestler's "bisociation" concept has some similarities with the synergetics concept, but Koestler applied it to "the creative act," not to aesthetics (Koestler 1964).

and generalizations. Categories of relations include equivalence (Fields & Arntzen 2018); and relational frames that deal with derived and higher-order relations (Barnes-Holmes, Finn, McEnteggart, Barnes-Holmes 2018; Hayes, Barnes-Holmes, Roche 2001). Examples from the verbal domain are syntax, induction, metaphor, analogy, parable, incongruity, and other devices of poetry, literature, or logic. Mechner 2018a, Part 2, and Sections 8 and 9 discuss concept manipulation devices used in the verbal arts, music, visual arts, mathematics, games, science, and other disciplines.

For most higher species, learning is key to survival and procreation, as it enables adaptation to the environment by increasing the ability to predict and influence it (Mechner 2018a, Section 4.1). Learning acquired its reinforcing effect as individuals susceptible to reinforcement by learning experiences survived and reproduced more successfully than individuals who lacked this susceptibility (Mechner 2018b, Section 4.3). That is also how curiosity, novelty, play, and exploratory behavior may have become widespread in the animal kingdom (Mechner 2018a, Part 3). The film medium may owe some of its unique reinforcing power to its provision of fast-paced learning experiences (Mechner 2018a, Sec.1.7, 9.2). All of the processes listed in Box 1 have some instructional effect via either concept manipulation, non-confirmation of expectancies, narratives, repetition, refreshment, maintenance, parsimony, symmetry, humor, the quality of artifacts, or certain social behavior.

2.4. Devices that Reconfigure the Concept Repertoire

Section 7.4 of Mechner 2018a discusses 16 types of concept manipulation devices that poets, writers, musicians, artists, film makers, humorists, and other creators of aesthetic effects employ to create synergetic brews that have reinforcing properties. Among these devices are parsimony (economy of means), symmetry (system properties unaffected by transformations) (Marr 2013; Petitjean 2007), and in the case of humor, incongruity. Parts 8 and 9 of Mechner 2018a describe how those devices and combinations of them create aesthetic effects. Here are some examples:

2.4.1. Parsimony, Economy of Means

The property of parsimony refers to the achievement of much with little—economy of means or effort. Instances of aesthetics effects due to parsimony are plentiful in mathematics and the sciences. (See also: Mechner 2018a, Sections 9.6, 9.7).

2.4.2. Incongruity

When concepts from obviously different domains are juxtaposed, as in all humor, the effect may be called whimsical, ironic, or incongruous. For a more detailed analysis of humor, see Mechner 2018a, Sections 7.4, 9.5.

2.4.3. Social Activities and Narratives

Many human activities evolved by being selected for the degree to which they contribute to survival and procreation (Mechner 2018b, Part 4). Their results are reinforcing *to the degree that they are performed effectively and well*. Examples of such reinforcers are *the quality* of artifacts like tools, vehicles, domiciles, or weapons; of collections; of social interactions; of acts of love; and of victories over rivals or enemies. Narratives in particular—anecdotes, humor, and little stories (Hineline 2018; 2005), create synergetic interactions that can act as reinforcers.

2.5. Expectancies and Surprises

The transformative nature of the synergetic interactions often resides in unanticipated, surprising, noteworthy, distinctive, or arousing events, as when expectancies are violated (e.g., when a familiar-looking food has an unexpected taste), or when outliers, anomalies, novel events, or accidental occurrences are perceived. In the arts, expectancies are often set up within the work itself, as for instance, in melodic, harmonic, and rhythmic progressions of music (Mechner 2018a, Section 8.4; North and Hargreaves 2017). Violations as well as confirmations of expectancies can result in learning. For a more detailed analysis of expectancies, see: Mechner 2018b, Sections 6.1–6.2.

2.6. Related Prior Work of Others

The present theory has elements in common with the work of Daniel Berlyne who founded "neo-experimental aesthetics" in the mid-1900s. In his book *Aesthetics and Psychobiology* and other writings, he assigned a central role to "arousal," which resembles the traditional concepts of drive and motivation. He said that arousal increases the impact of such stimulus attributes as "novelty, surprisingness, complexity, ambiguity, incongruity, and puzz-

liness" when these are "collated."[6] Martindale and Moore (1988) and others later proposed "prototypicality" (degree of conformity to a template, schema, or idealized version) as a further potential element.

Berlyne conceptualized the aesthetic response mainly in terms of "hedonic impact," "liking," and "preference," and related it to exploratory behavior, curiosity, and "expectations." (Berlyne 1960, 1971).[7] This conceptualization differs from the present one. When defined as in Sections 1.4-1.5 above, *reacting aesthetically is not the same as "liking" or "preferring."* One may "like" cats, jazz, one's work, a certain person, getting up early, or a work or genre, without reacting aesthetically. When a work evokes an aesthetic reaction, usually only a part of the work evokes it, rarely the work as a whole. For instance, the aesthetic reaction to a song may be evoked only by a particular passage, voice, melody, modulation, rhythm, lyrics, or idiosyncratic association. The various possible meanings of liking and preferring depend on context.

Berlyne was prescient in his anticipation of the importance of the then-dawning neuroscience for the investigation of aesthetic reactions, before the advent of MRI and fMRI, or the identification of the roles and interrelated functions of the amygdala, nucleus accumbens, septal areas, and hippocampus.

3. Affective Components of the Aesthetic Reaction

3.1. Sources of Affective Respondents

Part of the reason why the cognitive effects produced by synergetic interactions are often reinforcing is that learning is generally reinforcing, as explained in 2.3 above. Box 6, "Reinforcing Effects," refers to the affective contributions of the total reinforcing effects of interactions described in Box 1. In general, reinforcing events often elicit respondent reactions, especially when they are large (e.g., physiological effects like pupillary contraction,

[6] Vladimir Konečni, a former student of Berlyne's and contributor to the field in his own right, explained that Berlyne applied the term "collative" to the interactions of such stimuli and with stimuli experienced in the past.

[7] But the "Wundt Curve" that Berlyne cites, and the "butterfly" curve in the context of hedonic effects, does not contribute to his theory. It describes not only the effects of hedonic value but also an infinite number of other biological and physical phenomena that have maxima with drop-offs at the extremes.

vascular effects, and neural effects like dopamine and norepinephrine release (Rehfeldt & Hayes 1998). But the affective contributions of such reinforcing effects are rarely sufficient to meet the entire affect requirement of an aesthetic reaction.

3.2. Other Sources of Affect

The affective reactions represented by Box 2 are created by earlier Pavlovian conditioning episodes in which some cognitive behavior coincided fortuitously with a positively affective situation (e.g., a loving parent reading to a child, a significant ritual, a memorable reunion, story-telling, warm shared experiences, and so forth). From time to time, such affective events happen to coincide with certain cognitive events. When they do, the cognitive event may acquire a conditioned stimulus functionality, with the affective situation corresponding to Pavlov's "unconditioned stimulus." The cognitive event may then, on subsequent occasions, elicit the affective reaction without the presence of the original affective circumstance. The two thick arrows leading to the Aesthetic Reaction box at the bottom of Fig. 1 represent the synergetic fusion of the cognitive and affective effects.

A third potential source of affect (Box 3) represents pre-existing affective components like depictions of violence, emotion, sex, loud sounds, hugeness, certain facial expressions, religious themes, or voice effects. Such affect-evoking stimuli are widely used in film, visual arts, music, dance, improvisation, oratory, theater, poetry, literature, architecture, and videogames. Other primal sources of affect are loss of loved ones and various types of parent-child interactions. Sophocles' *Oedipus Rex* invokes the affect-linked taboos of incest and patricide when events reveal that the man Oedipus had slain was his father and the woman with whom he had been sleeping was his mother. The tragic aspect, given its instructional value, does not override the aesthetic impact. The incest taboo can also be used to create comical effects via incongruity, as in Mozart's *The Marriage of Figaro*, when Figaro escapes his obligation to marry Marcelina by the incongruous revelation that he is her long-lost son.

3.3. The Strength and Longevity of Aesthetic Reactions

The *sheer number* of compounding synergetic and synergistic effects may take the total effect to a threshold beyond which the reaction becomes aesthetic. Parts 8 and 9 of Mechner 2018a present instances of compounding where the magnitude of the effect is a function of the number of interacting

elements. Each of the boxes in Fig. 1 lists synergetic and synergistic interaction effects that can be at play simultaneously. The magnitude of the total impact increases in compounding fashion according to the number of interacting elements. This effect is seen in the evolution of film over the past century. The medium's immersive and aesthetic power kept growing as elements were incrementally added to the brew, starting with mere motion, then sound, plot, sophisticated acting, color, wide screens, and 3D, for ever greater impact (Mechner 2018a, Sections 1.7 and 9.2). As the number of such elements increased additively, the impact increased in a compounding or transformative manner. A similar effect is seen in videogames and opera.[8] In the performing arts, the impact may be compounded by the progressive addition of emotional elements and physical presence. In music, compounding effects can result from the addition of instruments. In the visual arts, from the sheer number of interacting elements like color, composition, size, conceptual associations for the subject, and affective elements. In games like chess or Go, the beauty of an effective move is a function of the number of contributing elements like parsimony (economy of materiel used), uniqueness (no other move works), difficulty, and thematic simplicity (Margulies 1977, Mechner 2018a, Section 9.8). The compounded effect of the dozens of the synergistic and synergetic interactions identified in the chart create the cusp that we describe as an aesthetic reaction.

3.4. Long-Term Retention of Aesthetic Impact

The reason affective reactions are often long-lived may be the biologically important function they served during evolution: recall of affective reactions to odors that signal dangers or opportunities, or to voices of friends or foes (Mechner 2018a, Part 3). It is commonly observed that a piece of music, a poem, or a work of art often evokes an aesthetic reaction even after a thousand exposures (Mechner 2018a, Sections 4.4–4.6; 2018b, Part 7), (though later reactions differ from initial ones). One factor that drives those changes is the interval between successive exposures: the longer the interval, the stronger the reaction to the next exposure. Pavlov named and described this phenomenon as "spontaneous recovery,"—the recovery of the response to the conditioned stimulus as a function of time since the last elicitation (Pav-

[8] Richard Wagner used the term *Gesamtkunstwerk* for a work of art that brings several media together.

lov 1927). One may be moved more strongly by a song (or poem or work of art) after it has not been heard or seen for a time. The longevity of many aesthetic reactions may thus be due in part to their inclusion of affective reactions.

4. Biological Relationships Between Beauty and Aesthetics

4.1. The Epistemology of Perception and Beauty

Without a perceiving individual there is no beauty, just as there is no color without a retina that responds to certain bands of the energy frequency spectrum, and no sound without a cochlea that responds differentially to vibrations. Like other perceptions, "beauty" is not a property of stimuli, notwithstanding the common illusion that it is. Our perceptions of colors, for instance, are due solely to human retinal physiology (other species that have other retinal physiologies respond to different wavelengths and thus "see" different colors.) The same principle applies to more complex stimuli. Our perceptual apparatus and learning history influences what we believe is out there. Narratives, too, are perceived idiosyncratically. Different readers respond in terms of their personal histories and concept repertoires, the point made by Rosenblatt (1978) concerning reactions to poetry and literature. And when people listen to each other speak, "misunderstandings" are common. All perceptions are a function of the biology, learning history, physiological state, and current socio-cultural and physical environment of the perceiver. Most people are familiar with the feeling of being confronted with an objective measurement after having experienced a persuasive optical illusion. More reliable information requires objective measurement. The ancient topic of the relationship between our perceptions and physical reality takes on special significance in the context of aesthetic reactions.

This account may seem obvious to modern behavioral scientists, but in the history of aesthetics research, from Pythagoras and Plato to Gustav Fechner, the focus of attention was generally the stimulus rather than the perceiver. The other focus, especially in writings about the arts, has been the *creation* of the stimulus rather than its perception (e.g., Koestler 1964). Only in recent decades has the attention of researchers, including neuroscientists, begun to focus on behavioral and biological factors.

4.2. The Domains of Aesthetic Reactions

Question 2, where, when, and under what conditions aesthetic reactions occur, is the "domain" question I tried to answer when I analyzed over 200 phenomena one might call aesthetic, in 17 different disciplines including music, poetry, visual art, literature, humor, mathematics, performing arts and various natural phenomena such as flowers and bird plumages (Mechner 2018a, Parts 8 and 9). I also wanted to see if I could identify common attributes that might explain why the terms "aesthetic" and "beautiful" are applied to such a diversity of phenomena. Let us examine what some of these domains have in common:

(a) The music domain. All of the world's musical cultures use scales whose note frequencies stand in certain simple mathematical relationships to one another. Rhythmic patterns and harmonic patterns create additional regularities (Levitin 2006). Conclusion: the music domain has a *penetrable regularity and orderliness*—penetrable in the sense of attributes that can be learned.

(b) The visual domain. The relative intensities, saturations, shapes, configurations, or contrasts of visual stimuli create information-carrying patterns that have orderliness and regularities that humans are able to penetrate. They perceive images, movement, color, form, etc.—for increased recognizability and meaning as learning proceeds.

(c) The domain of rule-based games. Such games as chess, bridge, poker, or Go are defined by rules that generate behavioral contingencies and conditionalities. The resulting regularities make learning and continuing improvement possible.

(d) The domains of beauty found in nature. The colorful plumages of many bird species, the patterns on butterfly wings, the colors and shapes of flowers or tropical fish, and the songs of birds, whales, frogs, wolves, or courtship dances, have biological effects on prospective mating partners. These effects are due, at least in part, to the same kinds of penetrable regularities, order, and patterns that account for aesthetic effects in human works of art.

4.3. Domain Properties that Can Host Aesthetic Reactions

All such domains can evoke the cognitive and affective reactions whose compounding interactions amalgamate into aesthetic reactions, as described in Part 2. By induction, the properties of the four domains described above

suggest that *any ordered or structured space whose regularities and properties can be penetrated is a potential domain for the development of aesthetic reactions.* The natural universe itself is such a domain. Its regularities and order include the laws of physics, and science is the learning activity by which humankind continues to seek to penetrate them.[9]

All of the domain properties described above are present in an infinite number of structured and ordered domains whose regularities can be penetrated and in which aesthetic reactions can develop—not only in the arts but also in cognitive areas. Within these there are domains within domains, specialty areas within specialty areas (e.g., genres within art fields, number theory within mathematics,) and further subdivisions within each of these in an infinite regress. Each of these can host its own aesthetic universe within which cognoscenti who have penetrated its regularities often form special, often trans-cultural, bonds (e.g., Malott 2018).

4.4. Discernment, Beauty, and Cognitive Competencies

Domain (d) above is of particular interest because it provides a clue regarding the biological function of beauty.[10] The clue is the fact that the domain evokes the reaction not only in the species that produces it, but also in humans. These features and behaviors are therefore unlikely to have evolved as species-specific adaptations to their respective environments. In fact, the features are often burdensome to their owners, as Ryan (2018) pointed out. Beauty must therefore have another biological function.

It helps to reverse the question. Instead of asking how beauty relates to fitness or how it attracts mates, let's ask, instead, how the often-superhuman abilities to discern regularities, order, relations, patterns, motion, and detail might have evolved in many species—the discernment capabilities that enable them to decode and navigate their challenging environments, perceive and evade dangers, seize opportunities, make complex decisions in spit seconds and perform amazing acrobatics. Anthropocentrism may be responsible for the widespread underestimation of the sophistication, elaborateness, and complexity of the cognitive competencies that many animal species possess.

[9] I do not include "complexity" as one of the domains' attributes because it a relational concept that has no benchmarks: events are complex or simple only in relation to other events. I prefer the attribute "parsimony," an inverse of complexity—one that has meaning in relation to "minimal complexity consistent with the functionality."

[10] The term beauty is used here for the stimulus properties that evokes aesthetic reactions.

4.5. The Assessment of Discernment

My thesis is that mating partners present each other with discernment challenges—domains (as defined in (d) above) that are sufficiently ordered and regular to serve as virtual discernment tests. It is usually the male that creates and presents a stimulus with domain properties, thus challenging the breeder candidate's ability to penetrate its regularities, patterns, and subtleties. The result amounts to an assessment of the female's discernment and the simultaneous assessment of the male's competency in creating the (beautiful) domain.

Among evolutionary biologists who have studied the functions of beauty in animals are Prum (2017) and Ryan (2018). Prum's thesis is that beauty evolved by virtue of its power to attract breeding mates (as Darwin (1871) also postulated), and Ryan's thesis focuses on the co-evolution of beauty and sexual attraction. Jabr (2019) wrote about the disagreements between these biologists and the shortcomings of their theses in a New York Times Magazine article. But when we shift the focus to the evolution of discernment, these disagreements and shortcomings disappear. Domain beauty is then seen to have a far more profound biological function than mere sexual attraction.

4.6. The Selection of Discernment

Discernment of regularities, order, and relationships is a set of cognitive competencies. How can selection of discernment occur in nature? It is easy to see how mating partners can assess physical characteristics, but how can they assess cognitive competencies—the sensitivities to subtle visual, auditory, and motion-related nuances, the behavioral capabilities that are needed to perceive camouflaged dangers or find hidden foods or shelters, or for identifying the juiciest and ripest caterpillars or berries?

The selection of cognitive competencies, which is at work in most sexually reproducing species, often begins with the assessment processes described in 4.5 above. The courted (usually the female) either penetrates the regularities and orderliness of the domain presented by the suitor, or she does not. In either case, she then makes her decision. If she rejects him, the reason may be that she lacked the required discernment or that his domain fell short. Either is a valid justification for non-copulation. If she accepts him, she passed the discernment test and he passed the performance test and again, either case provides a valid basis for proceeding.

The validity of such tests for the selection of discernment is a function of the degree to which the assessed discernment capability transfers to other, more survival-related, domains. The degree of transfer to other domains would range from total species-specificity to the high degree of generality seen in humans, where discernment in a given domain (e.g., humor, mathematics, music, language) is known to transfer to other domains.

4.7. The Maintenance of Modern Cognitive Competencies

Aesthetic reactions help maintain certain phylogenetically recent biologically valuable skills and competencies. These include the use of language; facility in the manipulation of concepts and abstractions; and such competencies as organization, inquiry, and communication (Mechner 2018a, 2018b, 2019).

The term "Modern Cognitive Competencies," MCCs, reflects their phylogenetic recency. Unlike much older behaviors like eating or drinking, the reinforcers of most MCCs are too delayed to maintain them at useful levels. Since they appeared too recently to have had the phylogenetic time to evolve sufficient self-maintaining properties, their maintenance requires continuing boosts, which they receive from the reinforcers that their linked aesthetic reactions provide.

MCCs acquire conditioned stimulus functionalities when they coincide, as often happens, with affective stimuli, resulting in Pavlovian conditioning events. Such coincidences occur frequently, as both MCCs and affective events pervade normal lives. When conditioning events thus confer affect elicitation functionality on an MCC, *aesthetic reactions that may result reinforce the eliciting MCC*. Since reinforcement promotes repetition and repetition promotes refreshment and maintenance, aesthetic sensibilities may have acquired their role in the maintenance of MCCs by evolving with them in tandem.

The phylogenetic development of aesthetic reactions may thus have been a significant milestone in human evolution. Such phylogenetically modern competencies as language, concept manipulation, music, the arts, abstract thinking, planning, and inquiry might not have emerged without the functions performed by aesthetic reactions.

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