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The Pleasures of Thought: A Theory of Cognitive Hedonics

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A theory of hedonic tone in "disinterested" states is proposed. It is hypothesized that the laws governing the amount of pleasure induced by fairly neutral stimuli are analogous to but not identical with laws governing recognition memory and a number of other cognitive phenomena. The amount of pleasure induced by such stimuli is held to be a hyperbolic function of the degree to which the cognitive units coding the stimulus are activated. Difficulties with competing hedonic theories, which led to formulation of the present theory, are noted. A number of predictions derived from the cognitive theory are discussed. In cases where empirical data are available, it is shown that these data conform to theoretical predictions. Several counter-intuitive predictions—along with supportive data—are presented. Finally, a number of as yet untested predictions are presented.

We constantly choose among alternatives. When we are confronted by no alternatives, we seek out one source of stimulation from among many possibilities. In either case, we make a choice. Ultimately, this choice must be based upon our preferences for the alternatives confronting us. Presumably, we choose whatever affords us the most pleasure. What determines pleasure in the first place? Psychology has been surprisingly mute on this point for the last 50 years. Since Beebe-Center's (1932) book, only one volume (Berlyne and Madsen, 1973) has appeared on the topic. The introspectionists were focally concerned with hedonics (the study of the causes of pleasure and displeasure) and aesthetic hedonics (the study of such causes in respect to artistic stimuli). Fechner (1876), Wundt (1905), Külpe (1893), and their colleagues devoted considerable thought to both topics. Behavioristic psychology, although it might have been based squarely upon hedonics, almost altogether skirted the question of pleasure. Rather than studying the determinants of pleasure or preference, the behaviorists selected a few rewards (e.g., food for a hungry rat) and punishments (e.g., strong electric shock) and studied how they influence behavior when delivered in varying amounts or according to various schedules. Such studies tell us little about what determines preference or pleasure in the first place. While early behaviorists (e.g., Thorndike, 1914) did attempt to relate behavior to pleasure and displeasure, later theorists avoided refer-

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ence to such subjective variables and attempted to relate reward or punishment to behavior (e.g., Hull, 1943) or reinforcement to behavior (e.g., Skinner, 1953). Hullian notions tying reward to drive reduction have turned out to be simply incorrect, while the Skinnerian definition of reinforcement is self-admittedly circular. Thus, even if we tried to infer hedonic laws from behaviorist laws concerning these variables, we might get hints but no laws.

The cognitive approach has now replaced behaviorism as the dominant paradigm in psychology. However, it has perhaps removed us even further from a science of hedonics. As Zajonc (1980) and Tomkins (1981) have noted, cognitive psychology is almost exclusively a science of "cold" cognition. Cognitive theorists tend to deal with neutral or affectless cognition. To the extent that cognitive psychology is to be a paradigm for psychology as opposed to a subdiscipline of psychology, it will have to deal with all mental activity rather than with a very limited subset of such activity. To date it has not done so. By default, the study of "hot" cognition has been left to social psychology. With the exception of Tomkins' and Zajonc's own work, social psychology has provided us with nothing much of interest concerning hedonics. There is a vast literature on attitudes and attitude change; however, it tells us little about the determinants of pleasure per se. There is also a large literature on interpersonal attraction. It does tell us what makes one person like another person. However, trying to infer general laws of preference from this literature is likely to be as fruitless as trying to infer what would happen to an object falling in a vacuum from studies of rocks rolling down mountainsides or feathers falling from flying birds.

The Promise of a Cognitive Approach

Although cognitive psychology has as yet shed no light on hedonics, I shall argue in this paper that it can indeed provide the basis for scientific hedonics. According to cognitive psychology, mental activity—whether it be perception, memory retrieval, imagination, mere awareness, or focused attention—corresponds to the activation of sets of pre-existing cognitive units or psychical elements (Martindale, 1981). The degree to which these cognitive units are activated determines the degree to which perception is clear, memory retrieval is veridical, and so on. I shall argue that degree of activation of these cognitive units also determines degree of pleasure or displeasure. Thus, for example, the laws of hedonic tone are analogous to—but not identical with—the laws of recognition memory and of perception.

Cognitive psychology is the study of internal or mental representations of reality. It is widely agreed that beautiful or pleasure-inducing objects constitute a fuzzy set (Dickie, 1971). Like other natural categories, objects that are beautiful—or ugly—share virtually no common properties or features. What good will it do, then, to move the question of hedonics from the objective to the subjective realm? If beautiful or pleasure-inducing objects share no features, should we expect their internal representations to share any features? Certainly not if internal representations bear a one-to-one relationship to the objects they represent. However, they definitely do not bear such a relationship (Martindale, 1981). They are in no sense images or copies of the objects that they stand for. Rather, they are qualitatively different, and, in general, have no quantitative relationship to the external objects that they represent. This given, it is at least possible that the internal representations of beautiful objects do share a set of attributes and are exclusively defined by this set of shared attributes. I shall argue that this is in fact the case. While beautiful objects are dissimilar, the mental representations that code them are similar, and this similarity defines pleasure and beauty. More generally, physical objects that engender the same hedonic tone may share no features; however, the internal representations of these objects do share a set of properties. It is this set of properties that hypothetically determines hedonic tone. Before describing the cognitive theory of hedonics, several alternative theories will be described and problems with them noted.

Hedonic Calculus

Psychobiological Aesthetics

Berlyne (1971) has formulated the most comprehensive current theory of hedonics. Briefly, the theory involves the contention that hedonic tone is determined by the arousal potential of a stimulus in the manner indicated by the solid curve in Figure 1. The curve is called the Wundt curve, since Wundt (1905) observed—on the basis of casual observation—that hedonic tone must vary in this way with the intensity of stimulation. Berlyne generalized Wundt's observation from stimulus intensity to arousal potential in general. Arousal potential is the amount of general arousal elicited by a stimulus. Arousal is "delivered" to the cortex by the reticular activating system, which originates in the mid-brain and has diffuse excitatory connections with all areas of the neocortex. On its way from the midbrain to the cortex, reticular-system fibers pass through lower brain centers, stimulation of which produces pleasure and displeasure (Olds and Milner, 1954). Theoretically, these centers are activated by the reticular system. The threshold for activation of the pleasure center is hypothetically lower than the threshold for activation of the displeasure center. Once activated, the degree of activation of these centers increases as a function of arousal as indicated by the dashed lines in Figure 1. Hedonic tone is determined by summing the outputs—pleasure (p) and pain or displeasure (d), from the two centers. The result is indicated by the solid line in Figure 1.

The arousal potential of a stimulus comes from three sources: psychophysical, ecological, and collative characteristics of the stimulus. Psychophysical

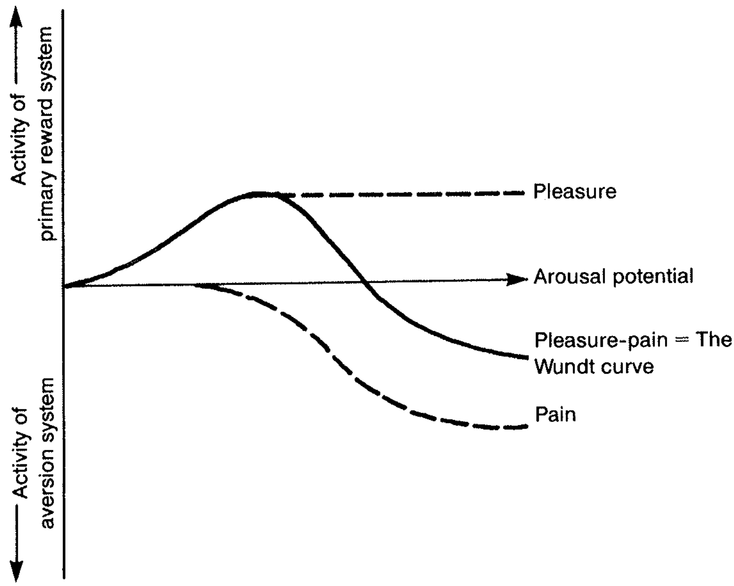

Figure 1: The Wundt curve (from Martindale, 1981).

characteristics refer to physical qualities of the stimulus (e.g., intensity, pitch, brightness, saturation). Ecological characteristics refer to the biological or learned meaningfulness or signal value of the stimulus, and collative characteristics refer to "collating" different aspects of a stimulus (e.g., complexity, incongruity, novelty, surprise). Though Berlyne's theory is elegant and general, there are some serious problems with it. These are discussed below.

The Glucose Anomaly

It is not clear that the Wundt curve is in fact a general description of how hedonic tone varies with arousal potential. Figure 2 presents hedonic judgments for the taste of four substances based on research conducted by Engel (1928). Preferences for sourness and saltiness do follow the Wundt curve. One might argue that preference for bitterness does also, but it would be equally plausible to argue that the p component is really lacking and only the d component is present. Preference for sweetness definitely does not follow the Wundt curve. In this case, the d component is lacking and only the p component is present. De Villiers and Herrnstein (1976) summarize 12 experiments in which preference for varying concentrations of sucrose and glucose was assessed. In all cases, curves similar to the one in Figure 2 were found. They were, incidentally, best fit by Herrnstein's (1970) hyperbolic equation (see below). It cannot be argued that organisms cannot discriminate increasing concentrations of sucrose or glucose and that, hence, arousal potential cannot rise beyond a level that induces maximal pleasure. When

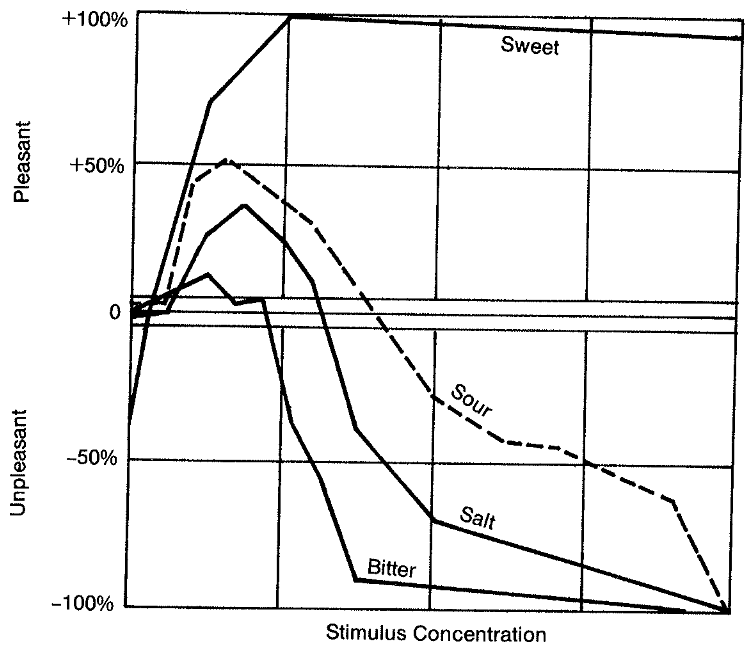

Figure 2: Engel's (1928) results for preference judgments in relation to concentration of taste substances (from Pfaffmann, 1959).

subjective intensity is related to physical intensity by Stevens' (1976) power law, the exponent for sucrose is 1.3—very close to the exponent of 1.4 for salt. The exponent being greater than 1 means that equal increases in concentration are *easier* to discriminate the greater the concentration. Berlyne (1971) was aware of Engel's findings, but he misinterpreted another set of data to solve the "glucose anomaly." Preference for glucose or sucrose does follow the Wundt curve for organisms given prolonged free access to these substances. However, avoidance of higher concentrations in this case is almost definitely due to satiation rather than to arousal potential (Pfaffmann, 1959). In Engel's study and in the studies cited by de Villiers and Herrnstein, satiation was not a factor.

The Meaningfulness Anomaly

Berlyne (1971) attempted to argue that ecological variables are related to hedonic tone by the Wundt curve, but his arguments are not very convincing.

It is difficult to believe that a biologically noxious stimulus—e.g., electric shock or pain of any sort—could be pleasing at any level. By the same token, biologically positive stimuli—e.g., food for a hungry organism—do not become displeasing at any level. Of course, once the organism is no longer hungry, it will ignore food, but this does not mean that food has become unpleasant. Mild shock may be used as a reinforcement in some circumstances, but this is probably because it serves as a signal rather than as a source of pleasure.

On the level of learned meanings, preference seems to increase monotonically with stimulus prototypicality. Prototypicality refers to how typical an item is of the category to which it belongs. Given the argument that categories are defined by prototypes (Rosch, 1973), more prototypical stimuli may be taken as more meaningful. Preference is monotonically related to preference for typicality of furniture (Whitfield and Slatter, 1979) and of faces (Light, Hollander, and Kayra-Stuart. 1981). This is also the case for color typicality and for typicality of exemplars of semantic categories such as fruits, animals, and trees (West, Moore, Martindale, and Rosen, 1983).

The Collative Anomaly

Preference for collative characteristics do seem generally to follow the Wundt curve (Berlyne, 1971), but *only* when psychophysical and ecological variables are held constant. In a factorial study covering the complete range of consonance-dissonance and the complete practical range of intensity (20dB to 100dB), intensity accounted for 96% of the explained variance in preference, while dissonance accounted for only 2% and did not follow the Wundt curve (Nardi and Martindale, 1981). Similarly, in a study of preference for polygons varying in color, color typicality, size, and complexity (number of turns), typicality accounted for 78% of explained variance in preference, while complexity accounted for 1% and again did not follow the Wundt curve (Moore and Martindale, 1983).

Berlyne (1971) put heavy emphasis upon collative variables. Such an emphasis may be appropriate for a theory of aesthetics: In perhaps the majority of cases—at least in modern times—artists do in fact try either to minimize or hold constant psychophysical and ecological variables. What I have called the collative anomaly is perhaps not so much an anomaly as a surprise. Our results suggest that Berlyne had a theory of aesthetics, not a general theory of hedonics. As indicated elsewhere, however, I fear that the aesthetic theory is not quite correct either.

The Possible Redundancy of the Arousal System

While Berlyne's explanation of hedonic tone in terms of overall arousal potential is elegant, it does present problems. Most sense organs have a primary projection pathway via the thalamus to the cortical receiving area and a collateral pathway to the arousal system. Berlyne links preference to the second pathway. However, it is possible to correlate preference with amount of activity along the first pathway. At least in the case of taste, the correlation is very good (Pfaffman, 1960). This suggests that the arousal system may not be necessary in explaining preference.

The collaterals to the arousal system are circuitous, so that sensory information reaches the cortex before it reaches the arousal system (Sokolov, 1960). Hedonic reaction time is very fast (Beebe-Center, 1932). Studies are needed to determine whether it is or can be fast enough to make it impossible to ascribe hedonic tone to the arousal system. It should be noted that reaction times for the sort of hedonic tone most clearly due to the arousal system (e.g., a pleasant or unpleasant surprise, getting the point of a joke) seems to be extremely slow.

Konečni and Sargent-Pollock (1976) found that induced arousal decreases preference for complex melodies but that the effect of arousal seems to be mediated by cognitive processes. Furthermore, increased mental effort was found to decrease preference for complexity quite independently of arousal. Konečni and Sargent-Pollock (1977) factorially induced different levels of arousal and different types of emotion while asking subjects to judge preference for paintings. Type of affect (positive or negative) was a good predictor of preference, while level of arousal was a poor predictor. Indeed, in some cases, results for level of arousal were contrary to Berlyne's predictions.

The Isohedonic Trap

Berlyne's theory requires that any two stimuli with the same arousal potential must be equally preferred. Is this really true? I know of no systematic work on the topic, but it seems extremely doubtful that it is the case. Consider several thought experiments. It is possible to obtain cross-modal matches of the intensity of stimuli. For example, subjects can reliably adjust a noise so that it is subjectively as loud as a light is bright (Stevens, 1976). Preference for subjectively equal stimuli in different modes should be equal so long as the stimuli do not differ in ecological or collative ways. Brightness, loudness, roughness, visual length, heaviness, etc., of equal subjective intensity should be equally preferred. This seems possible but unlikely. Consider more complex stimuli. By adjusting clarity, exposure duration and other variables, we could certainly create a picture of an attractive nude member of the opposite sex and a frightening picture of a snake that evoked equal arousal responses as indicated by a variety of psychophysiological measures. Berlyne's theory says that preference for the two pictures should be equal. Again, this is conceivable but seems extremely unlikely. Consider another possible thought experiment: We determine the amount of arousal produced when we show a mother her child. Then we adjust the intensity of a pure tone so that it produces the same amount of arousal. Finally, we present the tone and the baby and ask the mother which she prefers. Since the two stimuli produce equal arousal, they should be equally preferred. However, we know that this will certainly not be the case.

An experiment by Steck and Machotka (1975) is relevant. They presented tone sequences varying in complexity to their subjects and asked for preference ratings. Some subjects heard tones varying along the entire range of complexity. Others heard only sequences from the bottom half of the range and others heard only sequences from the top half of the range. In all three cases, preferences followed the Wundt curve. There was no evidence for absolute anchoring. That is, subjects showed maximum preference for sequences with medium arousal potential relative to the range of alternatives, *not* for sequences with medium arousal potential per se.

To my knowledge, Berlyne did not deal with the problem of what I have called the isohedonic trap. This is odd, since the prediction of equal preference for stimuli with equal arousal potential is central to his theory—and it is almost certainly false. He did specify that the displeasure center can be inhibited by a secondary reward center (Berlyne, 1971). Such inhibition might allow for a possible escape from the isohedonic trap. However, the conditions under which this inhibition hypothetically arises are rather limited. I do not think that revising the theory by bringing in such inhibition would allow a complete escape from the isohedonic trap.

Behavioral Theory

Behavioral theory in general is in large part based upon the Law of Effect. As originally stated by Thorndike (1911), this was a hedonic law; behavior associated with satisfaction will be repeated, while behavior associated with dissatisfaction will be avoided. Skinner (1953), in a desire to avoid unnecessary subjective variables, restated the law: behavior associated with positive reinforcement will be repeated, while behavior associated with punishment will be avoided. Positive reinforcement is defined as anything that increases the rate of a response. This is, of course, a completely circular definition. Be this as it may, if we look at the reinforcers commonly used in operant experiments, we might certainly assume that positive reinforcement induces pleasure and punishment induces displeasure. Since behaviorists are interested in the laws governing behavior rather than in the laws governing pleasure, they rightly avoid terms such as pleasure and displeasure. However, since our interest is exactly the opposite of theirs, some subjective reinterpretations of behavioral laws are attempted below.

Herrnstein's Law

Herrnstein (1970) stated the Law of Effect in mathematical terms:

$$P_i = \frac{k\ x_i}{x_i + x_e} \qquad (1)$$

where P_i is the rate of a given response, x_i is the reinforcement for that response, and k and x_e are parameters to be estimated. It is generally agreed that k represents the maximum possible rate of responding and that x_e represents reinforcers from extraneous sources that are available in the environment (de Villiers, 1977). The equation tells us that P_i is related to x_i in a hyperbolic fashion, as indicated in Figure 3. As amount of reinforcement (x_i) is increased, rate of responding (P_i) increases in a hyperbolic manner. As shown in Figure 3, the rate of increase is faster the smaller the value of x_e.

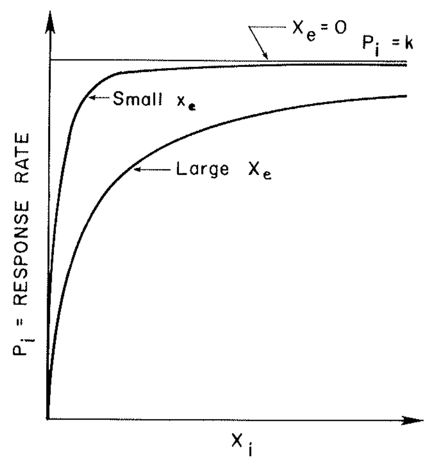

Figure 3: P_i as a function of x_i and x_e according to Herrnstein's (1970) equation (redrawn from McDowell, 1982).

We may safely equate P_i with preference, as de Villiers and Herrnstein (1976) explicitly do. We may take x_i to be the determinant of preference, which is, of course, amount of reinforcement. But what exactly is reinforcement? I shall later attempt to answer this question. Behavioral theory does not give us an enlightening answer. If we are not interested in avoiding sujective variables, we may safely think of P_i as representing amount of pleasure. The equation, interpreted in this way, tells us some interesting things: First, the pleasure given by a stimulus is dependent not only upon the amount of reinforcement, x_i, present, but also upon competing pleasure-inducing stimuli, x_c. The more competing stimuli, the less the pleasure induced by x_i. Second, the pleasure induced by x_i does not grow linearly with amount of x_i. Rather, the greater x_i is, the less value an increment in x_i has.

Difficulties with Behavioral Theory

While Herrnstein's formulation of the Law of Effect tells us something important about preference, it tells us nothing at all about the nature of reinforcement. What is it that causes a reinforcer to induce pleasure? The equation tells us how a reinforcer induces pleasure, not why it does so. For the cases studied, more reinforcement produces more pleasure in a hyperbolic fashion. However, the cases studied are biased, since reinforcers were specifically selected so that more reinforcement would produce more pleasure. Thus, reinforcement consists of things such as amount of water for a thirsty rat or amount of food for a hungry pigeon. What would happen if we took x_i to be the intensity of a tone and measured P_i as we increased x_i. In this case, Herrnstein's hyperbolic equations would fail miserably since preference would vary approximately as shown on the solid line in Figure 1 above. *If* a stimulus yields monotonically increasing P_i with increasing x_i, *then* the hyperbolic equation tells us how P_i will increase.

A Cognitive Model

There is a growing consensus among cognitive psychologists that mind may be conceived of as corresponding to a network of interconnected nodes or cognitive units. Perception of a stimulus corresponds to activation above some threshold of the nodes coding that stimulus. A mental image of the stimulus corresponds to activation of these same nodes by some internal process. Consciousness—or short-term memory—refers to the set of currently activated nodes. Leaving aside perception, consciousness is held to be extremely limited. Only cognitive units coding four or five "ideas" can be simultaneously activated. Of these, the most activated set of nodes corresponds to whatever is being attended to at the moment.

I have elsewhere presented one version of this theory (Martindale, 1981), which is an elaboration and extension of a theory first proposed by Konorski (1967). According to this theory, cognitive units are segregated into a number of analyzers of several types. There is a sensory analyzer for each of the senses. Output from sensory analyzers goes to perceptual analyzers. Theoretically, there is a separate perceptual analyzer for each of the classes of objects we can recognize. For example, there seem to be separate analyzers for printed words, spoken words, faces, small manipulable objects, large stationary objects, and so on. This contention is based upon the fact that localized brain damage can damage ability to recognize or perceive any one of the foregoing classes of percepts without interfering with ability to perceive the others. A typical perceptual analyzer is illustrated on the left side of Figure 4. Input is to the bottom of the analyzer. A few cognitive units coding distinctive features occupy this level. Each of these cognitive units is connected to (uniquely

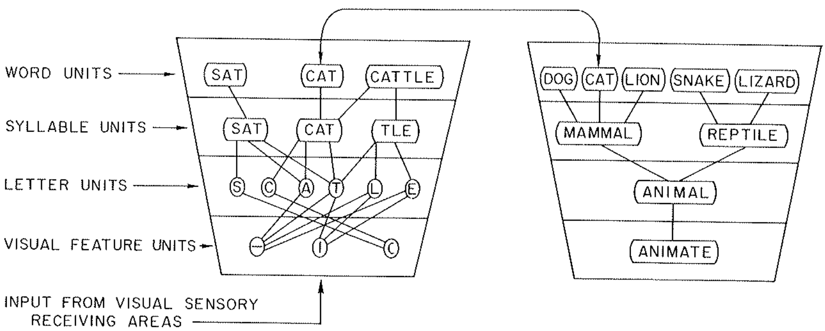

Figure 4: Hypothetical structure of perceptual (left) and semantic (right) analyzers (redrawn from Martindale, 1981).

defines) a unit on the next higher level. In this case, about 10 distinctive feature units coding lines, curves, angles, etc., are needed uniquely to define the 26 letters of the English language. The letter-units are in turn connected to syllable units, of which there are about 10,000 for English, and the syllable units are connected to units coding whole words. Upwards of 50,000 units would be needed at this level. Presumably, all other perceptual analyzers are structured in the same way; a very small number of distinctive feature units ultimately define a huge number of unitary percepts. Perceiving the word CAT corresponds to activation of not only the unitary percept unit but also to the lower-level units connected to it. There is no need to avoid the terminology of the first cognitive psychologist: We shall call each of the constituent cognitive units coding the stimulus a psychical element and the whole ensemble of units coding it a psychical compound (compare Wundt, 1905).

One might wonder why the unitary percept unit is necessary. Why not just define perception of the word CAT as corresponding to activation of the psychical compound (excluding the unitary percept element) coding it. The reason to avoid this is that the psychical compound is associated with other psychical compounds. The unitary percept unit is essentially a chunking unit (Wickelgren, 1979) that mediates these associations. We know what a cat is. This information is presumably stored in semantic memory. The unitary percept coding CAT is hypothetically connected with a unit at the top level of the semantic analyzer coding the concept of 'cat' (see Figure 4). This unit would be connected to other units in semantic memory. The ensemble of connections to these other units preserves or stores our knowledge about what a cat is.

Theoretically, all analyzers are constructed in the same way: They are multilayered, with more elements the higher the level. On any level, the principle of arrangement is one of similarity: The more similar the information coded by two units, the closer together they are. Cognitive units are connected in several ways. The vertical connections are excitatory. On the other hand, on any one level, cognitive units are hypothetically connected in a lateral inhibitory fashion. Units inhibit neighboring units in proportion to their distance. Given the principle of arrangement, this means that the more similar two units are, the more they will inhibit one another. There are also indirect excitatory lateral connections. While the units coding the concepts CAT and DOG should laterally inhibit each other because of similarity, there are also mediated or chunked excitatory connections between units on the same level (e.g., DOG-chases-CAT).

All cognitive units presumably receive non-specific input from the arousal system, which in a normal state merely keeps the spontaneous activation of a unit from falling to zero. Some cognitive units are also connected to limbic-system centers for specific emotions. Thus, for example, the cognitive units coding snakes are for many people connected to fear-centers in the limbic system. It should be noted that the strength of the associations among cognitive units can vary. Thus, for example, a highly typical animal—e.g., DOG— seems to be more strongly connected to the superordinate unit coding MAMMAL than an atypical animal—e.g., ANTELOPE (see Martindale, 1981). Finally, cognitive units themselves seem to differ in strength. This would explain why it is easier to see a frequent than an infrequent word with a brief presentation. Strength can be modelled in several ways: stronger units have lower thresholds (Morton, 1969), stronger units are redundantly coded (i.e., more units code the same stimulus; Konorski, 1967), or by a combination of these ways.

We may describe the amount of activation, x_i, of a cognitive unit, i, by the equation,

$$x_i = E_i - \sum_{j=1}^{n} k_{i,j} (x_j - I_j), i \neq j, \qquad (2)$$

where E_i is excitatory input, $k_{i,j}$ is the amount of inhibition that unit j exerts on unit i, and I_j is the threshold below which j does not inhibit i. This equation ignores the spontaneous activation of unit i (compare Ratliff, 1965). Actually, a set of simultaneous equations are needed because all cognitive units are similtaneously inhibiting all other nearby cognitive units. However, the equations can be solved using an iterative procedure (Bridgeman, 1971). Exactly how inputs from the arousal system influence x_i is unclear. Walley and Weiden (1973) argue that they directly influence the value of the inhibitory coefficient, $k_{i,j}$. It seems more likely, however, that they would directly influence E_i in a multiplicative fashion (see Martindale, 1981).

Cognitive Hedonics

Types of Hedonic Tone

Philosophical aestheticians have often made the argument that aesthetic pleasure is different from other sorts of pleasure in that it is disinterested (e.g., Burke, 1757; Stolnitz, 1960). Psychologists have generally been rather puzzled as to what—if anything—these philosophers mean. Clearly, disinterestedness means that no desire for the stimulus comes into play. As Dickie (1971) points out, a close reading of such philosophers' comments suggests that attention is also rather weakly focused on the stimulus. This suggests that disinterested perception is a state where there is little or no limbic-system activity (absence of desire) and only the usual level of arousal-system activity (increases in arousal lead to increased focusing of attention). In other words, disinterested contemplation or perception would seem to correspond to a state where the cognitive system is active but the arousal and limbic systems are comparatively inactive. Such a state can certainly be pleasurable. There is some question as to whether it can ever be displeasurable. Perhaps for this reason, virtually all epicurean and hedonistic philosophers recommend seeking mental pleasures and avoiding pleasures of other sorts.

Given the above discussion, we may conceive a state of "interested" perception or cognition. By this is meant a state where the arousal system and cognitive system are active but the limbic system is quiescent. This would seem to be the state that Berlyne (1971) dealt with. Depending upon amount of arousal-system activity, either pleasure or displeasure are possible in such a state. Finally, we can define a state of emotional perception where cognitive, arousal, and limbic systems are all active. (Given that the limbic system is active, it is essentially necessary that the arousal system will also be active; compare Eysenck, 1967.) Extremes of both pleasure and displeasure are of course possible with limbic system activation. Such drive- or incentive-based hedonic tone is likely to overshadow hedonic tone based on purely cognitve considerations. Solomon and Corbit (1974) have described an opponent-process model of such limbic-system hedonic tone. It will not be considered further in this paper.

Pleasure in Disinterested States

Perceptual recognition occurs when activation of the set of cognitive units coding a percept rises above threshold levels. Partial activation—as achieved, for example, by a brief tachistoscopic presentation—leads to less accurate perception. A psychical compound has an asymptotic or ceiling level of activation. If I show you a picture of a cat for five minutes you do not see it any more fully or vividly than if I show it to you for one minute. The same is true of memorial recognition. We hypothetically recognize that we have seen a word or a word-pair in a memory experiment when the relevant cognitive units in episodic memory are fully activated. Again, partial activation leads to worse performance than full activation, but there is a ceiling on activation (Wickelgren, 1979). I would propose that similar considerations apply to hedonic tone. For the moment, we shall consider only pleasure.

The pleasure, P_i, induced by a stimulus must correspond in some way to the degree to which the set of cognitive units coding the stimulus is activated. What is the form of the function relating activation of a cognitive unit and pleasure? At present, the best guess would be that the relationship takes the form of Herrnstein's hyperbola (Equation 1). At first glance, this seems reasonable, but it implies that very frequently encountered stimuli should consistently induce pleasure, since we know that such stimuli are coded by strong cognitive units. In order to avoid this, we could move the hyperbola over by introducing a threshold value. It would also be possible to handle this problem by assigning a very small value to k in such cases. Interpretation of k in the equation is easy: it is simply the asymptotic level of pleasure that can be induced by the stimulus. We shall take x_i to be the activation of the cognitive units in question.

Should x_e be taken as the activation of other currently activated units in the analyzer? This is conceivable. To the extent that x_i is greater than x_e unit i will be attended to, and we know that a stimulus must be attended to in order to produce any appreciable pleasure (Beebe-Center, 1932). If all currently activated units were of about equal pleasantness, such an interpretation might work. However, we know that pleasantness ratings are strongly influenced by simultaneous hedonic contrast. At least for relatively indifferent items, the mere presence of less pleasant items will increase the pleasantness of a stimulus and the mere presence of more pleasing items will reduce the pleasantness of the stimulus (Helson, 1964). Since we shall argue below that unpleasantness is generally produced by a higher level of activation than pleasantness, it would not make sense to take x_e simply as amount of activation in units other than i. We also know that successive hedonic contrast modifies ratings of pleasingness (Beebe-Center, 1932; Fechner, 1876; Helson, 1964): Prior pleasant stimuli decrease the pleasingness of the current stimulus, while prior unpleasant stimuli have an opposite effect. It must be the case that x_e is some function of the ratio p_e/d_e (the pleasurableness, p_e, and displeasurableness, d_e, of other current contents of consciousness) and p'_e/d'_e (the pleasantness, p'_e, and unpleasantness, d'_e, of past contents of consciousness). The ratio p'_e/d'_e would of course have to be a time-weighted average. If we include the present moment, $t=0$, then simultaneous and successive hedonic contrast could be grouped together,

$$x_e = \sum_{t=0}^{-n} W_t \frac{p_e}{d_e} \tag{3}$$

where W_t is the time-weighting factor—presumably a decaying exponential of some sort. (In order to make the equation work, x_e must be expressed in "units" of x_i.)

Displeasure in Disinterested States

There is some question as to whether displeasure can occur in a purely disinterested state. Consider a study of polygons varying in complexity. If people are asked to rate them on a scale anchored with words such as "displeasing" vs. "pleasing," some polygons will certainly be rated as displeasing. However, one wonders whether this is real displeasure. Would subjects object if one anchored the bottom end of the scale with words such as "neutral" or "like a little"? Though I have not tried it, I rather doubt that they would. On the other hand, consider using the latter scale in a study of the hedonic tone engendered by electric shock. It seems certain that even the most compliant subjects would point out that the low end of the scale was mislabelled. Thus, it may be that subjects merely tend to use the full range of a rating scale and that rated displeasingness of weak stimuli only means relative lack of pleasingness rather than actual displeasure.

The clearest examples of displeasure occur in cases where it is likely that there is activity of the arousal system or the limbic system—e.g., presentation of very intense or fear-arousing stimuli. A very loud noise is indeed displeasing, but with such an intense stimulus, the arousal system will be active. One possibility, then, is that displeasure can only occur when the arousal system is activated above usual levels. Were this the case, then a testable prediction arises: For otherwise neutral stimuli that induce displeasure at high intensities, subjectively equal high intensities in different modalities should produce about equal amounts of displeasure. This should be the case because the displeasure is produced by arousal-system activation of displeasure centers. However, equal amounts of pleasure should *not* be produced by equal intensities at lower intensity levels that produce pleasure, since the *k*-values of the cognitive units coding the stimuli in question probably differ. The hedonic tone based on activation of cognitive units coding stimuli that induce limbic-system activity of any magnitude is essentially "undefined." For a person who fears snakes, presentation of a snake will activate limbic-system centers and these—*not* the nodes coding perception of the snake—will determine the amount of displeasure.

Another possibility is that the value of Equation 3 is not 0 when x_i is very low, but that the equation continues through the x-axis to produce negative values for very weak levels of x_i, as shown in Figure 5a. Although the taste of sweetness involves some limbic-system activity and is hence not a purely

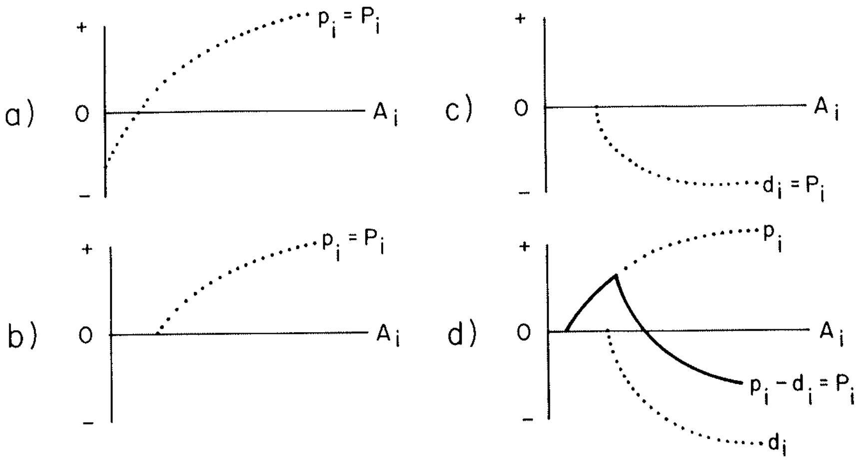

Figure 5: Possible relationships between P_i and x based on Equations 3 and 5.

cognitive stimulus, Engel (1928) did find exactly this sort of preference curve for concentration of glucose (see Figure 2 earlier). There is also indirect evidence for such a possibility. Tachistoscopically presented stimuli displayed too briefly to be perceived may engender a state of displeasure, while clear perception of the same stimuli engenders pleasure (Beebe-Center, 1932). Everyone reading this article has certainly been confronted with listening to a lecture or colloquium that produced fairly extreme displeasure not because it was too arousing but because it was not arousing enough. More careful work needs to be done on the unpleasantness of weak stimuli above the perceptual threshold. Rashevsky's (1938) explanation of why extremely complex polygons are disliked makes sense in this context: inhibitory effects may decrease excitatory effects to the extent that x_i is very low and P_i thus takes on a negative value. Note that this is in direct contradiction to Berlyne's (1971) attribution of disliking for such forms to too much arousal.

A final possibility is that activation of cognitive units can produce displeasure in a manner analogous to that in which pleasure is produced. That is, a cognitive unit may have a displeasure threshold. When activation of the unit rises above this point, displeasure is produced by some sort of hyperbolic function. If this displeasure is produced without intervention of the arousal system, it would not necessarily be the case that this threshold will always be higher than the threshold for the induction of pleasure, as is the case with Berlyne's formulation. If either this formulation or the formulation in terms of arousal-system production of displeasure is the case, then the full equation for the hedonic tone engendered by a given stimulus would be $P_i = p_i - d_i$ or, in expanded form,

$$P_i = \frac{k_i\ (x_i - I_{p_i})}{(x_i - I_{p_i}) + x_e} - \frac{m_i\ (x_i - I_{d_i})}{(x_i - I_{d_i}) + x_e'} \qquad (4)$$

where I_{p_i} is the threshold for induction of pleasure, I_{d_i} is the threshold for induction of displeasure, and x_e and x_e' are the weighting factors for hedonic contrast. While the equation can produce curves similar to the Wundt curve (e.g., Figure 5d), a variety of other forms are also possible. We might refer to this family of curves as Engel curves in honer of the investigator (Engel, 1928) whose research first suggested that the Wundt curve is not the correct general description of the relation of hedonic tone to stimulus intensity.

Hedonic Tone in Disinterested States

We have argued that any stimulus activates a set of cognitive units. Depending upon factors such as attention and stimulus intensity or duration, this set of units may include the units coding the stimulus, the units coding its meaning, the units coding episodic memories concerning it, and positive associates of all of these units. The activation of these units will be decreased by lateral inhibition from other activated cognitive units. This inhibition may arise from extraneous cognitive units or it may arise directly from units activated by the stimulus itself. The pleasure induced by the stimulus is hypothetically a function of the degree of activation of the units activated by the stimulus. The pleasure is "scaled" in relation to the pleasure induced by other currently and recently activated units and is limited by an asymptotic level of pleasure that can be induced by the stimulus in the (empirically impossible) case of no other currently or recently activated units. My guess—and it is purely speculative at this point—is that displeasure in a disinterested state can only be induced by low levels of activation—when $x_i < I_p$ and Equation 4 passes below the x-axis—and that displeasure induced by high levels of activation always involves above-average activation of the arousal system. A crucial experiment for testing this speculation was described above.

In passing, it should be noted that in the equations above, only supraliminal activation of psychic compounds is considered. We assume that all cognitive units—like all neurons—have some resting level of activation and that this resting level of activation can increase or decrease without crossing the threshold that brings the stimulus coded into consciousness. I have assumed that a stimulus cannot induce pleasure unless one is aware of the stimulus. However, this assumption may be wrong. What might happen if we did take into account total amount of activation rather than only supraliminal levels of activation? If we could lower x_c sufficiently and raise x_i to a level where it was high but not high enough to enter consciousness, then P_i might increase without any conscious awareness of stimulus *i*. This may be what happens in certain types of meditation. On the other hand, if we could increase x_c but not so much as to bring the relevant cognitive units into consciousness, while holding x_i constant, pleasure should decrease. When one has a lot of concerns in the back of one's mind the pleasure of just about any stimulus does in fact seem to be decreased.

Biological Basis of Hedonic Tone

The reader may be concerned about the mechanism whereby activation of cognitive units engenders pleasure. Berlyne's theory explains pleasure and displeasure elegantly by reference to activation of established pleasure and displeasure centers. But, though elegant, the theory does not seem to be entirely correct. Cognitive units must be composed of neurons. Neurons communicate with one another with a number of different neurotransmitters. A variety of evidence tells us that anything that increases the amount of norepinephrine will increase general pleasure. In one way or another, drugs such as cocaine and the MAO-inhibitors do this (McGeer, Eccles, and McGeer, 1978). However, the effect of increased levels of norepinephrine is probably too general: The pleasantness of everything is increased. The endogenous opiate-like substances do not seem promising either, since they seem to decrease the unpleasantness of everything. That is, these substances seem to influence overall mood rather than being related to the hedonic tone elicited by specific stimuli. However, the interaction of the neurotransmitter GABA and the as yet unidentified endogenous benzodiazipine substance seems more promising. Benzodiazipines interact with stimuli in an interesting manner. They have virtually no effect unless the organism is subjected to stress or stimulation. More stress leads to *less* anxiety. Apparently this is because increased arousal increases the activity of GABA neurotransmission, but occupation of GABA receptors "opens" endogenous benzodiazipine receptors which, when occupied, decrease arousal (Klein and Rabkin, 1981). This as yet incompletely understood interaction raises the possibility that a variety of Engel curves could be produced by the relative concentration of GABA and benzodiazipine substances in the central nervous system. It should be noted that benzodiazipine receptors are concentrated in the cortex (Klein and Rabkin, 1981). This, and the very mild euphoriant qualities of the benzodiazipine drugs support the idea that they may be relevant to the "computation" of disinterested hedonic tone. Without referring to these substances, Staddon

(1977) borrowed chemical formulas to derive Herrnstein's equation. Once we know more about GABA neurotransmission, Staddon's equations may turn out to be more than metaphors.

Predictions from the Cognitive Theory

The basic hypothesis is that disinterested pleasure, P_i, generated by a stimulus can be predicted from Equation 4, where the second or subtractive part of the equation may usually be taken to be zero. In this section, I shall discuss predictions that can be derived from this equation and from Equation 2, which describes how x_i is determined in the first place. Instantaneous or simultaneous effects will be discussed first. Then, effects dependent upon the repetition of stimuli will be described. Unless otherwise mentioned, it will be assumed that the subtractive component of Equation 4 is equal to zero.

Simultaneous Effects

Effects of activation. If we hold k and x_e constant, pleasure should be a monotonically increasing function of activation, x_i, best described by a hyperbolic function. We know that this is the case for glucose and sucrose, but these can hardly be conceived of as activating purely cognitive units. In fact, we know that it is true for virtually any positive reinforcer, but, again, most reinforcers involve limbic-system activation. However, several other types of perceptual and cognitive stimuli seem to be related to preference in a monotonic fashion:

1. Color typicality (West, Moore, Martindale, and Rosen, 1983)
2. Typicality of other categories—e.g., birds, trees—(West, Moore, Martindale, and Rosen, 1983)
3. Polygons varying in complexity (Rashevsky, 1938)
4. Saturation of color holding hue and brightness constant (Guilford, 1939)
5. Brightness of color holding hue and saturation constant (Guilford, 1939)

Perhaps the point upon which aesthetic theorists are most in agreement is that maximal pleasure or beauty is produced by a stimulus with maximal uniformity in variety (Berlyne, 1971; Eysenck, 1941; Fechner, 1876; Hegel, 1835; Hutcheson, 1725; Rashevsky, 1938). However, why this should be the case has been a point of contention for several centuries. The explanation follows in a straightforward manner from our definition of how x_i is determined. Recall from Equation 2 that x_i is the net sum of excitatory inputs to a psychical compound minus inhibitory inputs. Why uniformity in variety is maximally preferred is best illustrated by a diagram (see Figure 6). In Figure 6a is diagrammed a psychical compound composed of elements that are maxim-

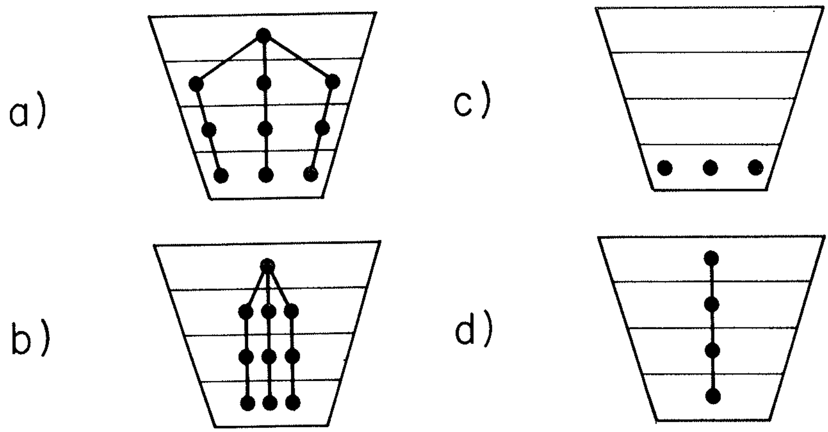

Figure 6: Hypothetical patterns of activation in a perceptual analyzer for a) uniformity and variety, b) uniformity and lack of variety, c) maximal variety, and d) maximal unformity.

ally dispersed (variety) on each level but connected by excitatory vertical associations (uniformity). Here, lateral inhibition will be minimal and excitation will be maximal. In Figure 6b is depicted a psychical compound with the same degree of uniformity (vertical associations) but with minimal variety (units on each level are similar and, thus, near to each other). In this case, there will clearly be more inhibition and, hence, less net activation. Because cognitive units on higher levels can only be activated by those on lower levels, maximal variety with no uniformity (Figure 6c) would only produce activation on the lowest level of the analyzer and net activation would be low. By the same token, maximal uniformity (Figure 6d) would produce low activation, since only one unit on each level would be activated. The pleasure afforded by incongruity and by sudden insight (as to the similarity of items previously thought to be unrelated) may be explained in the same way that the pleasure induced by uniformity in variety is explained.

Effects of extraneous activation. The effects have already been built into the equation. As indicated above, there is good evidence that both simultaneous and recent values of x_e affect the amount of pleasure induced by a stimulus. We could use some good experiments concerning exactly how simultaneous and recent pleasures and displeasures influence P_i for constant x_i, but the fact that the influence does in fact occur is beyond question.

Effects of asymptotic level of pleasure (k). Presumably, the asymptotic level of pleasure that a stimulus can produce, k, is related to the strength of cognitive units. Stronger units can become more activated and thus, other things being equal, should be able to produce more pleasure. Why different cognitive units have different values of k is, however, not completely clear. This is distressing, since explanation of the asymptotic level of pleasure is one of the fundamental questions to be answered by a theory of hedonics. All other factors held constant, why is a beautiful face more beautiful than the most beautiful combination of phonemes or the most beautiful musical chord? Is this altogether due to the strength of the relevant cognitive units? There seems to be systematic variation in the average level of k among analyzers. The average value of k seems to be higher in sensory analyzers than in perceptual analyzers. Among sensory analyzers, k seems to be higher for the more primitive senses, such as olfaction, than for the more advanced senses, such as vision. There is a good deal of variation in k among perceptual analyzers. Thus, for example, printed words *per se* cannot evoke as much pleasure as the sound of spoken words, and the latter cannot in general evoke as much pleasure as can singing. It would seem that the average value of k is higher in perceptual analyzers than in conceptual analyzers. On the level of conceptual analyzers, the average value of k would seem to be lower for semantic-memory units than for episodic-memory units. However, this difference may be due to associations. Episodic memories tend to be associated with or realized by visual and other mental images, while semantic memories tend to be associated with or realized by inner speech; the average value of k seems to be higher for visual perceptual analyzers than for the speech-perception analyzer. In ability to induce pleasure as in other realms, it seems to be the case that a picture is worth a thousand words.

It is important to keep in mind that preference for an object is determined not only by the cognitive units directly coding the object but also by cognitive units positively associated with them. To the extent that there are more of such associations, pleasure will be greater so long as the associations do not laterally inhibit one another. Thus, many and diverse associations will produce maximal pleasure. In courses on art and literature, one is essentially trying to program such associations into students. Empirically, it should be the case that preference for stimuli is a function of number and diversity of associations. I know of no work directly relevant to this prediction. It is notable, however, that poets do tend to use words with multiple meanings and that the possibility of multiple interpretation is often taken as a criterion of value in poetry and literature in general (Empson, 1930).

Serial Effects

Serial or repetition effects involve changes in the threshold or activation level of cognitive units. A decrease in threshold or an increase in resting activation level makes a cognitive unit easier to activate. We may think of the resting activation level of the unit and the activation produced by stimulation as adding together. Thus, a lower threshold and/or a higher resting level of activation produce greater net activation when the unit is actually stimulated.

An increase in threshold or a decrease in resting level of activation has an opposite effect. Marshall (1894) argued that pleasure results when the capacity to respond of what we would call a cognitive unit is hypernormal and displeasure results when this capacity is subnormal. Thorndike (1914) and Troland (1920) proposed similar hypotheses. The model proposed in this paper leads to the same hypothesis, though for somewhat different reasons.

Habituation: Massed Repetition of the Same Stimulus

There is a large body of non-hedonically oriented work on habituation. The general finding is that each successive presentation of the same stimulus elicits less of a general arousal response. Two dominant theories have been offered to explain this. Sokolov's (1960) theory is that on each successive presentation, a more complete "cortical model" is constructed. To the extent that a stimulus fits this cortical model, the "amplifying" system is inhibited (prevented from diffusely activating the cortex). Groves and Thompson's (1970) dual-process theory holds that habituation is not due to such a general process but rather is due to processes more closely related to the neurons responding to the stimulus. As illustrated in Figure 7a, repetition leads to two processes:

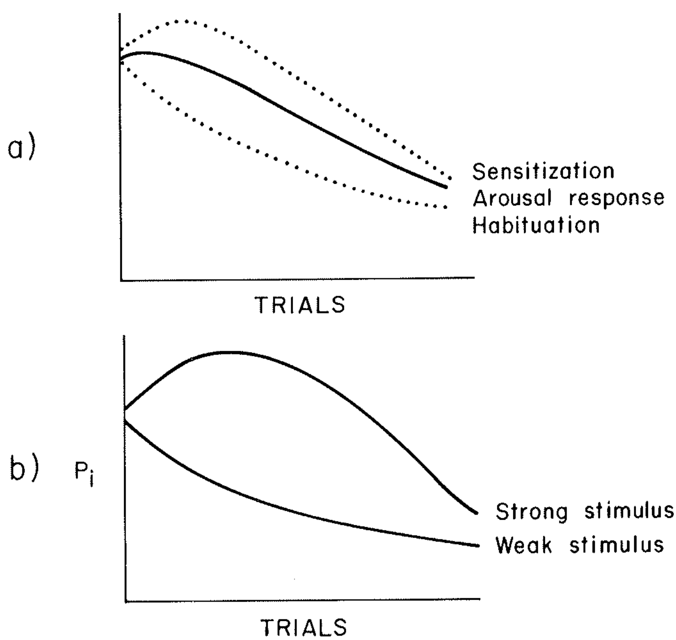

Figure 7: Effects of habituation: a) Groves and Thompson's two-process model; b) Effects of repetition on P_i for strong and weak stimuli.

habituation (fatigue or decline in firing rate) of the sensory neurons in question and sensitization of associated neurons. The arousal response is the sum of these two processes. For strong stimuli, with many associates, sensitization is strong, so there is an actual increase in arousal response for the first few trials (see Figure 7b). For weak stimuli, sensitization is weak, so that the arousal response declines from trial to trial (see Figure 7b). In our terms, we might say that strong psychical compounds (those where the focal units are strong and have a number of positive associations) should show net activation, the time-course of which is similar to the curve at the top of Figure 7b, while weak psychic compounds should show net activation with a time-course similar to the curve at the bottom of Figure 7b. Hypothetically, the curves in Figure 7b show what happens to hedonic tone with repetition. Many experiments show that there is decreased liking for simple stimuli across trials, but complex stimuli show an increase followed by a decrease in liking (Berlyne, 1971). While Berlyne explains these findings in term of Sokolov's model, we would explain them in terms analogous to the Groves and Thompson model. The latter model is more parsimonious. Further, Sokolov (1975) has done Berlyne the disservice of moving the amplification component of his model from the reticular system to the hippocampus. Projections from the hippocampus to the cortex do not pass through the pleasure and displeasure centers. This, of course, destroys the underpinnings of Berlyne's theory.

Mere Exposure Effects: Distributed Repetition of the Same Stimulus

For certain types of stimuli, Zajonc (1980) has shown that mere distributed exposure leads to increases in preference. The more exposures, the greater the preference. The functional relationship used by Zajonc is that preference is related to the log of number of exposures. However a hyperbolic function can also be fit to the data. The mere-exposure effect works for unfamiliar stimuli (e.g., Chinese ideograms, Turkish words, paralogs, irregular polygons). It does not generally work for familiar stimuli or for aesthetic stimuli (Stang, 1974). Original explanations of the phenomenon were that recognition of the stimuli determines preference for them: More frequently repeated stimuli are more easily recognized and this leads to pleasure. This hypothesis turned out to be incorrect. Moreland and Zajonc (1977) showed that the relationship between number of exposures and preference is present even when subjects fail to recognize that they have in fact seen the stimuli. Using a dichotic listening task, Wilson (1975) presented tone sequences to the unattended ear. Preference for the tone sequences was related to number of exposures although recognition memory for them was at essentially chance levels. Kunst-Wilson and Zajonc (1980) presented polygons for one millisecond each—too brief an exposure duration for subjects to see them. Again, preference was related to number of exposures, although recognition memory was at chance levels.

Zajonc (1980) attempts to explain these findings by arguing that hedonic tone is determined at some precognitive level, but he is quite unclear as to how this is accomplished. It would seem that Zajonc has confused perceptual recognition (perceiving something) with recognition memory (recognizing that one has perceived something before). Wickelgren (1979) points out the importance of this distinction. Consider a recognition-memory experiment where subjects are shown a set of words. Later, they are presented with words—e.g., CAT—and asked if they recognize them. Obviously, they recognize them in that they perceive the words (activation of units in the perceptual printed word analyzer), but they may have no recognition memory for them (activation of units in the episodic memory analyzer). The fact that subjects in mere-exposure experiments may show faulty recognition memory does not mean that affect is determined at a precognitive level. Zajonc seems to have come to this conclusion because he confused perceptual recognition and memory recognition. His subjects recognized (perceived) the test stimuli perfectly; they simply did not recall that they had perceived some of them recently. If we can attribute the changes in preference to the perceptual system, it is unnecessary to attribute them to vague precognitive mechanisms.

Each presentation of a stimulus in a mere-exposure experiment hypothetically leads to activation of the perceptual units coding it and/or to a drop in the threshold of these units. Invisible or unattended stimuli will induce less activation, but we know that they, too, will induce some activation (Marcel, 1978). In the case of unfamiliar stimuli, a unitary-percept unit will also be "constructed," and in the case of visible or attended stimuli, a unit in episodic memory will be "constructed." In any event, the more times a stimulus is presented, the more activated the cognitive units coding it will be. At the end of the experiment, subjects are asked to give preference judgments for the stimuli that were shown as well as for stimuli not shown. Since units coding the previously exposed stimuli are already partially activated, they are easier to activate or become more activated. Assume that Figure 8 graphs the

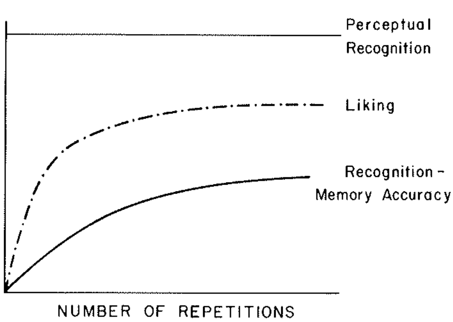

Figure 8: Hypothetical effect of number of repetitions on perceptual recognition, recognition memory accuracy, and preference.

functions relating preference, perceptual recognition, and memory recognition to the activation of a set of cognitive units in episodic memory or in a visual perceptual analyzer. To explain the mere-exposure effect, it is only necessary to assume that preference is more tightly or strongly related to x_i than is memory recognition. Note, however, that perceptual recognition (whether a subject actually sees or hears the stimulus) will be essentially unrelated to the pre-existing partial activation. (This would not be the case for a very brief presentation of the stimulus. In this case, perceptual recognition would show a curve similar to that for pleasure.)

The point is that affect need not be based on different cues than perception and cognition. The same units are used to compute preference and recognition. Only the shapes of the functions relating these variables to x_i differ. For the mild changes in preference found in mere-exposure experiments, it would seem to be a mistake to implicate precognitive mechanisms given that it is more parsimonious to explain these changes in terms of activity of the cognitive system.

Presumably, habituation does not occur with distributed presentations because fatigue can dissipate between presentations. Killeen, Hanson, and Osborne (1978) argue that each presentation of an incentive produces arousal. When incentives are presented in an aperiodic fashion, this arousal can cumulate and produce certain behaviors. Killeen et al. attempted to explain behaviors such as schedule-induced polydipsia, where a hungry animal drinks a lot of water between deliveries of food. The idea is that each food delivery produces a dose of arousal. Once the arousal cumulates, it activates drinking behavior even though the animal is not thirsty. Something similar may happen in mere-exposure experiments. We take each stimulus to be analogous to delivery of an incentive. Surplus activation may spread to associates of the cognitive units coding the stimulus (compare Groves and Thompson's sensitization process).

Repetition of Positively Associated Stimuli

Priming techniques involve presentation of a positively associated stimulus prior to presentation of a test stimulus. The idea is that the prime should partially activate the cognitive units coding the test stimulus. Thus, when the latter is presented, it should show a greater amount of activation than were it not primed. This does seem to be the case. Priming makes a briefly presented word easier to recognize and speeds reaction time on a number of cognitive tasks such as lexical decisions and semantic memory decisions.

Rosch (1975) used a priming technique in a color decision task. On each trial, subjects were shown two colors and asked to indicate whether they were physically identical or not. Half of the trials were primed (the experimenter said the name of the color to be presented) and half were unprimed (the experimenter said "Blank"). For "yes" decisions, priming speeded reaction time for prototypical colors and slowed reaction time for nonprototypical colors. Martindale (1981) explained this as follows: The prime activates the superordinate unit coding the color name. It in turn activates all of the cognitive units coding examples of the color. However, the more typical an example is, the stronger is the association to the superordinate unit. The result for units coding nonprototypical colors is that they are activated by the prime but more strongly laterally inhibited by neighboring units coding prototypical colors. Thus, their spontaneous level of activation is actually lower than it would have been without priming.

Moore and Martindale (1982) essentially repeated Rosch's experiment. The only difference was that on each trial only one color chip was presented and subjects' task was to indicate their liking for the color on a scale ranging from −3 to +3. As expected, priming produced a marked increase in preference for prototypical colors and a decrease (though not statistically significant) in preferences for non-prototypical colors. In two unpublished studies, the same technique was used with words drawn from various categories (e.g., ROBIN is a highly typical bird and OSTRICH is a non-typical bird). Subjects were asked to rate their liking for the object represented by the picture and the word. In this case, priming increased preference for both typical and atypical instances. Perhaps this is due to the weakness of the stimuli involved. That is, subjects were essentially rating mental images rather than physically present stimuli. In any event, it is quite surprising that priming should have such profound effects on preference, but it is in conformity with theoretical predictions. It should be noted that priming may affect not only x_i but also x_e. That is, with priming, x_e may in large part represent alternatives from the same category, whereas with no priming, x_e may represent a larger and less controlled set of alternatives. If priming does influence x_e, then systematic differences in preference due to category size should exist. Thus, on primed trials, x_e should be smaller—and P_i thus larger—for small categories than for large ones.

In recognition-memory experiments, false recognitions often occur. That is, a subject falsely recognizes a synonym, antonym, or other positive associate of a word actually presented (e.g., Anisfield and Knapp, 1968). Presumably, this is because cognitive units coding the falsely recognized word were partially activated. It should be possible to produce "false preferences" in a similar way, but I know of no experiments on this topic.

Repetition of Negatively Associated Stimuli

Priming. It should be possible to decrease preference by priming with a stimulus that will laterally inhibit a test stimulus. Inhibitory associations seem to be too weak to produce much of any effect with only one presentation. However, lateral inhibition can be built up. Consider the effects of proactive inhibition in short-term memory. A subject is given several items to remember, engages in a distracting task that prevents rehearsal, and is then asked to recall the items. Across trials, performance becomes worse and worse. This is conventionally attributed to proactive inhibition (Keppel and Underwood, 1962). Wickens (1973) used such a procedure in which, on each trial, three words from the same category were to be recalled. After three trials, performance had fallen considerably. On the fourth trial, three items from a different category were presented, and a release from proactive inhibition was found. Memory for the items was better than on the prior trial, and degree of improvement was a function of the conceptual distance of the new category from the old one. I interpreted the decline of performance to a buildup of lateral inhibition among the units coding items from the first category (Martindale, 1981). The further one moves from this center of inhibition, the easier it is to activate and recall the new items. If this line of reasoning is correct, then we should be able to find an analogue of release from proactive inhibition in preference ratings. Preference does tend to decline across trials when similar stimuli are presented (e.g., Martindale, 1982). Preference should increase if, after rating a number of similar stimuli, dissimilar stimuli were presented.

Novelty and surprise. While there are no systematic experiments on release from proactive inhibition in preference, evidence concerning preference for novel stimuli are indirectly confirmatory. Generally, novel stimuli are preferred (Berlyne, 1971). Novelty is essentially the degree to which a stimulus is dissimilar from recently encountered stimuli. At least a certain sort of novelty consists of presenting a stimulus that activates an uninhibited cognitive unit remote from a set of mutually inhibiting cognitive units. Novelty is thus the hedonic analogue of the von Restorff (1932) effect—an item that is markedly different from other list items is better recalled in a memory experiment.

It is important to differentiate novelty from surprise or disruption of expectation. Consider the sentence, "The jeweler sold the beautiful diamond sky." The first part of the sentence will strongly prime the cognitive unit coding RING. If the last word had been RING it would have been much easier to recognize and more quickly recognized if presented tachistoscopically (Tulving and Gold, 1963). Due to the mismatch between expectation and stimulus, the arousal system is hypothetically brought into play to "boost" activation of the cognitive unit coding SKY. Thus, if positive or negative affect is produced, it is probably due to "interested" perception. Though there is no systematic work on the topic, we should expect that the reaction time for the pleasure of surprise would thus be much longer than the reaction time for the pleasure of novelty or other disinterested affects.

Disinhibition effects. Consider two cognitive units, i and j, exerting mutual lateral inhibition on one another. If we can activate i sufficiently, we should be able to decrease activation of j and preference for whatever it codes. However, if we fatigue or inhibit *i*, then unit *j* should be disinhibited because we have temporarily removed the inhibitory inputs coming from *i*. Now, presentation of the stimulus that *j* codes should produce an abnormally high level of activation in *j*. Such disinhibition effects are found in a variety of perceptual and cognitive contexts (e.g., Carpenter and Blakemore, 1973; Crowder, 1978; Deutsch and Feroe, 1975; Eimas and Corbit, 1973). The hedonic disinhibition phenomenon is clear in the case with colors. Prolonged staring at a patch of red produces fatiguing of the sensory units coding red and a disinhibition of units coding green. A green color after-effect then results. However, if a green stimulus is actually presented and "superimposed" on the after-effect, hedonic tone is influenced: one sees a supersaturated green that is "spectacular" (DeValois and DeValois, 1975).

Repetition of Unrelated Stimuli

We have already incorporated successive hedonic contrast into our equation: The pleasantness of a current stimulus is scaled in terms of the pleasantness of prior stimuli. Hedonic time error may be merely a special case of this. Although more systematic studies are needed, it seems to be the case that, as in a variety of other judgments, there is a systematic time error in hedonic judgments: If two equally pleasant stimuli are presented for paired comparison, the first will be preferred if the inter-stimulus interval is short but the second will be preferred if the interval is long (Beebe-Center, 1932). Beebe-Center (1932) explains this with a variant of Köhler's (1923) general explanation: at a short interval, the memory trace of the first stimulus is stronger than the still developing memory trace of the second stimulus. At a longer interval the trace of the first stimulus has decayed to a level below that of the second. This may be taken as an explanation in terms of x_i. The phenomenon may also be explained in terms of x_e: After a short interval, the contribution of the first stimulus to x_e is large and this reduces P_i for the second stimulus. At a long interval, x_e has decayed, so that P_i for the second stimulus is larger.

Concluding Remarks

In this paper I have focused upon disinterested pleasure. Thus, the theory and predictions are most applicable to a variety of seemingly rather diverse pleasures—e.g., those of solitary thinking, calm contemplation of aesthetic objects, and perception of neutral stimuli in psychological laboratories. We have seen that in such situations, the laws of hedonics seem to be remarkably similar to the laws of perception and cognition. Similar functions differing only in their parameters seem to describe the relationships between stimulation and subjective response. This is perhaps not remarkable at all, since if perception and cognition gave us no pleasure, the Law of Effect suggests that we should not engage in them unless forced to do so by other considerations.

A complete theory of hedonics must of course describe the contribution not only of the cognitive system, C, but also of the arousal system, A, and the limbic system, L. Presumably, the hedonic tone induced by a given stimulus is a weighted sum of contributions from each system,

$$P_i = \alpha C + \beta A + \gamma L. \tag{5}$$

We have assumed that $\gamma > \beta > \alpha$. We may assume that each of the systems works in somewhat the same way as the cognitive system. This seems clearly to be the case for the limbic system. It seems to be the case that Herrnstein's equation applies, but either pleasure or displeasure can occur depending upon the centers activated. The apparent opponent-process linking of emotions and anti-emotions (Solomon and Corbit, 1974) in the limbic system adds a complication not found on the cognitive level. In the case of the arousal system, the possibility of curvilinear relationships between activation and hedonic tone adds a further complication.

Hypothetically, the pleasure induced by aesthetic stimuli is largely due to cognitive factors. However, this is certainly not always the case. Aesthetic stimuli characterized as being *sublime* as opposed to *beautiful*, probably involve more than just cognitive factors. Some classes of aesthetic objects, such as paintings of nudes, certainly must generally involve more than pure perception and cognition alone. Thus, even a theory of aesthetics must take arousal-system and limbic-system factors into account. I have argued that Berlyne's theory, which essentially takes only the arousal system into account, seems to be incorrect as a general theory. Freudian and Jungian theories of aesthetics may be seen as essentially taking only the limbic system into account (see Martindale, 1981) in that they attempt to reduce aesthetic pleasure to activation of primitive drives and emotions (e.g., the Oedipus complex, archetypal figures). Leaving aside their other shortcomings, such psychodynamic theories are hopelessly inadequate, since they cannot account for any of the hedonic phenomena described in this paper. However, while we must base hedonic or aesthetic theory upon a cognitive foundation, in order to be complete the theory must ultimately bring in non-cognitive factors as well.

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