

Emotion, Attention, and the Startle Reflex

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This theoretical model of emotion is based on research using the startle-probe methodology. It explains inconsistencies in probe studies of attention and fear conditioning and provides a new approach to emotional perception, imagery, and memory. Emotions are organized biphasically, as appetitive or aversive (defensive). Reflexes with the same valence as an ongoing emotional state are augmented; mismatched reflexes are inhibited. Thus, the startle response (an aversive reflex) is enhanced during a fear state and is diminished in a pleasant emotional context. This affect-startle effect is not determined by general arousal, simple attention, or probe modality. The effect is found when affects are prompted by pictures or memory images, changes appropriately with aversive conditioning, and may be dependent on right-hemisphere processing. Implications for clinical, neurophysiological, and basic research in emotion are outlined.

Recent evidence suggests that the vigor of the startle reflex varies systematically with an organism's emotional state. A theory is presented to elucidate this relationship, suggesting how the amplitude of the eyblink response to an abrupt, task-irrelevant probe may be modulated by the affective content of ongoing perception and thought.

The present approach defines emotions as *action dispositions*, founded on brain states that organize behavior along a basic appetitive-aversive dimension. It is postulated that all affects are primitively associated with either a behavioral set favoring approach, attachment, and consummatory behavior or a set disposing the organism to avoidance, escape, and defense. The efferent system as a whole (including exteroceptive reflexes) is presumably tuned according to the current status of this central affect-motivational organization. Thus, reflexes associated with an appetitive set (e.g., the salivary response to a sucrose probe) would be enhanced if activated when a subject was already engaged in a positive emotional response; conversely, the startle reflex to a sudden loud noise is viewed as an aversive or defensive response and would be augmented if it occurred in the context of an ongoing aversive emotion. In short, reflexes that match a concurrent, tonic affective process will be amplified. A reciprocal rule is also postulated: A mismatched reflex (e.g., a defensive reflex initiated during a pleasant state of affairs) will show relative inhibition or attenuation.

The following discourse explores these general propositions, focusing on the hypothesized modulation of an aversive reflex when evoked in the context of various affective states. Analyses are based on a specific data set comprising the results of re-

search in which startle stimuli were used to probe cognitive (perceptual and learning) tasks. We begin with a description of the eyblink reflex, because this is the component of the startle response that has been measured in most probe experiments with human subjects. Previous research is then reviewed that suggests that blink amplitude varies both with attention allocation to foreground tasks and with fear conditioning. Problems in the theoretical interpretation of these data are elucidated, and the view that the startle-probe response is modulated by emotional valence is offered as an integrative solution. The relationship between reflex excitation and the dimensional organization of emotion is elaborated later in this article. An explicit theory is described: Five hypotheses are generated (two primary and three ancillary), each of which is tested by experiment. The results consistently support the view that the startle reflex is modulated by the valence of ongoing affective responses, independent of probe modality and regardless of whether the affective foreground content is perceptual or imaginal. These data prompt a reevaluation of attention- and arousal-theory explanations of probe findings. This new affect-startle effect is then critically examined. Issues addressed include the relationship of the blink reflex to concurrent facial and visceral response patterns, possible neurophysiological limitations, the significance of emotional intensity for startle modulation, and the effects of conditioned changes in emotional responding. The final section is a deliberation on the role of affect in information processing and proposes new directions for the study of emotion.

The Startle Reflex and the Eyeblink

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Early interest in the human startle response was stimulated by the work of Landis and Hunt (1939). A pistol shot activated the startle reflex in their experiments, and subsequent movement was recorded with high-speed motion pictures. Drawings of the rapidly unfolding, whole-body startle were frequently reproduced in textbooks (e.g., Woodworth & Schlosberg, 1956).

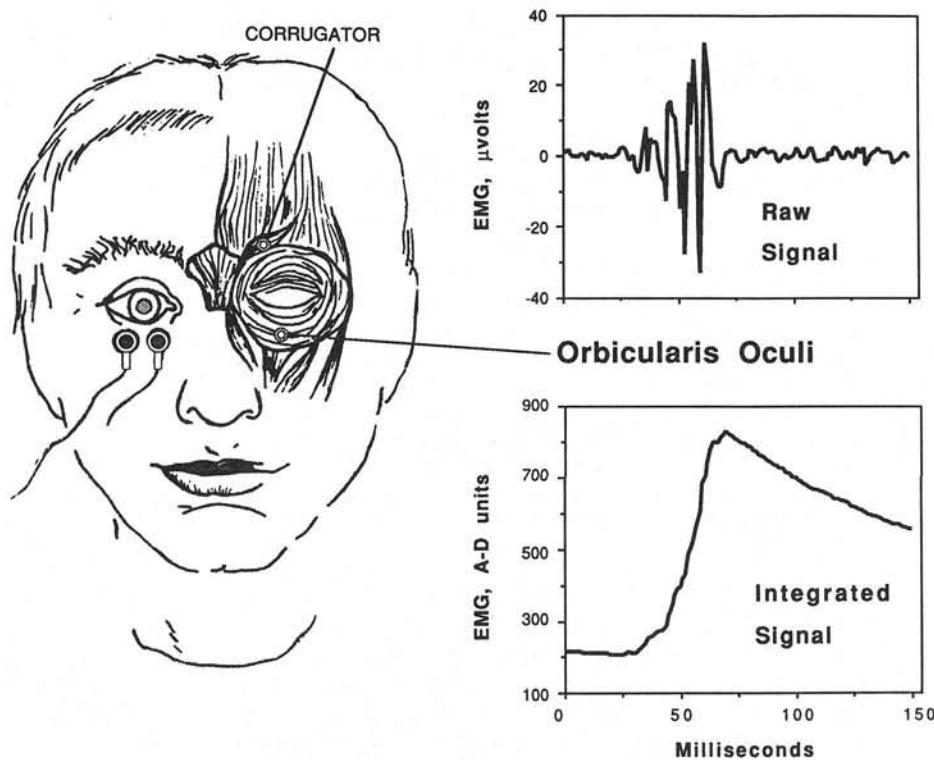


Figure 1. Left panel: Illustration of the orbicularis oculi and corrugator muscles on the left side of the face and the placement of the eyelink recording electrodes when positioned beneath the right eye. Top right panel: A muscle action potential from orbicularis, recorded during a blink reflex. Bottom right panel: An integration of this same signal, which is the response waveform scored for peak amplitude and latency in most human subject studies of the probe reflex. (EMG = electromyogram; A-D = analog-to-digital conversion.)

Its gross features include a forward thrusting of the head and a descending flexor wave reaction, extending through the trunk to the knees. The first, fastest, and most stable element in the sequence is the sudden closure of the eyelids. The primacy of the eyeblink has been confirmed by subsequent research, which further showed that lid flexion alone may occur to stimuli not sufficiently strong to engage the whole reflex. Because of these response properties, the eyeblink has become an important tool in experiments probing such diverse phenomena as classical conditioning and cognitive resource allocation in attention. Although studies vary widely in subject population and theoretical orientation, they consistently show that variations in the intensity of the blink indexes the brain's receptivity to information input.

Eyeblink is occasioned by rapid contraction of the orbicularis oculi muscle (see Figure 1). It occurs reflexively 30–50 ms after the onset of an abrupt acoustic stimulus. The primary characteristic of the eliciting stimulus is its rapid rise time (ideally, instantaneous), with intensity secondary. The blink reflex shows a regular course of habituation with repeated presentation at short interstimulus intervals. However, it dishabituates quickly and thus can be evoked repeatedly within a relatively brief period (as many as 40–50 probe trials are practical in a half-hour experimental session). The response is variously recorded—by photography; by using a potentiometer attached

with a thread to the eyelid; by the electro-oculogram, where abrupt pen movements indicate the lid passing rapidly over the corneal surface; or indeed, inadvertently by electroencephalogram, in which the recording of the reflex may appear as a troubling artifact. The electromyographic measurement of orbicularis muscle during eyeblink is shown in Figure 1. This method captures events most proximal to the neural path of innervation and is thus preferred by most investigators.

Context and Reflex Evocation

The reliability of the knee jerk as a neurological sign depends on the bedside manner (as well as the motor skill) of the diagnostician who delivers a percussive tap to the patellar tendon. This fact, that reflexes vary with the psychological context in which they are evoked, has long been practical knowledge for health-care workers and was a focus of study for scientists before the turn of the century (Bowditch & Warren, 1890; Ison & Hoffman, 1983; Sechenov, 1863/1965). More recent research on the startle reflex has contributed importantly to two major topics in psychology—the study of attention and the study of conditioned fear.

Attention

Frances Graham and her associates have reported a series of experiments based on an innovative startle-probe methodology

(e.g., Anthony & Graham, 1985; Graham, 1975, 1979). In this research, various stimuli, tasks, and instructional manipulations are used to guide the subject's attentional focus. While the subject is thus engaged, brief nonsignal startling stimuli are presented, with the expectation that the eyeblink reflex will be enhanced or attenuated according to the amount of attentional resources allocated to the primary task.

Several important phenomena have been shown in this work. For example, instructions to attend to the probe stimulus itself prompt an augmentation of the reflex (e.g., Bohlin & Graham, 1977; Hackley & Graham, 1984). Conversely, reflex attenuation results if unsignaled probes are presented in the foreperiod of a reaction time task. In this latter case, attention is not directed to the startle stimulus but is presumably focused on the anticipated go signal. This probe reflex reduction is greatest, furthermore, when the go signal is imminent (and attention to it most needed), as corroborated by greater late-foreperiod heart rate deceleration—a common measure of stimulus "orienting" (Graham & Clifton, 1966). These studies and related work, as well as an attentional theory of the startle probe, have been admirably reviewed by Anthony (1985).

Of particular interest for this presentation are a group of cross-modality experiments. In this procedure, the subject's attention is directed to either a visual or auditory foreground task while startle probes are administered in either the same or the alternate sensory channel. The hypothesis examined is that attentional resources are limited and are allocated *a priori* according to modality. Thus, when subjects engage in a visual task (e.g., viewing pictures), resources available to the auditory system are reduced, and the reflex response to an acoustic startle probe is expected to be attenuated. Results from Anthony and Graham's (1985) test of this view are presented in Figure 2. Both infants and adults show blink reflexes that are smaller and slower when the modality of the probe does not match the modality of foreground stimulation.

A further aspect of this research concerns the interest value of the foreground stimulus. Anthony and Graham (1985) proposed that more interesting stimuli (e.g., slides of human faces, or music) engage attention to a greater extent than do less interesting stimuli (e.g., blank slides or single pure tones), and thus cross-modality probe response attenuation should be greater with interesting than with dull foregrounds. Again, both infants and adults show this effect. Recently, Simons and Zelson (1985) undertook a test of the hypothesis, using stimuli that were more evocative of emotion. Subjects viewed two content classes of photographic slides as a foreground task: *interesting content*, a varying series of attractive nude men and women, and *dull content*, a picture of a small wicker basket, repeatedly presented. Unpredictable auditory startle probes were presented during both slide presentations. As expected, the blink reflex was significantly smaller for interesting than for dull slide content.

Fear Conditioning

Brown, Kalish, and Farber (1951) undertook a probe study of classical fear conditioning, based on a very different theory of startle modulation. The investigators noted that anxiety patients often show exaggerated startle responses. Presuming this was a function of a high drive state (Hull, 1943), they reasoned

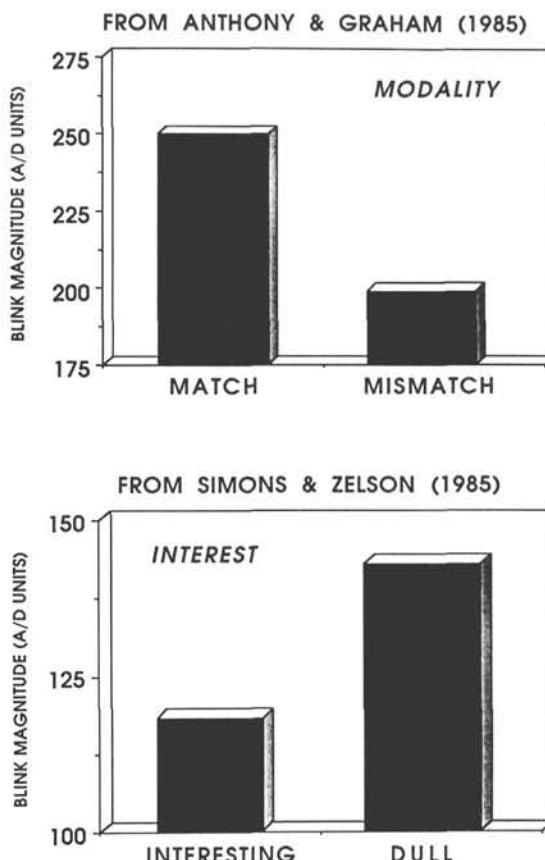


Figure 2. Top panel: Blink magnitude data, which show the difference in mean reflex response when the probe modality matched the foreground modality (e.g., an acoustic probe with a foreground of recorded music) and when there was a probe-foreground modality mismatch (e.g., an acoustic probe with a pictorial slide foreground). Bottom panel: Data obtained using a probe-foreground mismatch design; mean reflex magnitude to an acoustic probe was smaller when a pictorial slide foreground was interesting (attractive nudes) than when it was dull (a household object, repeatedly presented). (A/D = analog-to-digital conversion. Note: Top panel redrawn from "Blink Reflex Modification by Selective Attention: Evidence for the Modulation of 'Automatic' Processing" by B. J. Anthony and F. K. Graham, 1985, *Biological Psychology*, 21, p. 51. Copyright 1985 by Elsevier/North-Holland. Adapted by permission. Data in bottom panel are from "Engaging Visual Stimuli and Reflex Blink Modification" by R. P. Simons and M. F. Zelson, 1985, *Psychophysiology*, 22, p. 46. Copyright 1985 by the Society for Psychophysiological Research. Adapted by permission.)

that animals conditioned to be fearful would show a similar enhanced startle when startle probes were presented during the conditioned stimulus (CS) at extinction. Their experiment used male rats as subjects, a light-buzzer compound CS, and a shock unconditioned stimulus (US). The startle probe was a toy pistol shot, and the whole-body startle was measured by a stabilimeter table. As shown in Figure 3, their results conformed to expectation. Startle probes presented in the context of CSs early in extinction evoked larger reflexes than those presented during control stimuli. These general findings were subsequently replicated with both animal and human subjects (Ross, 1961;

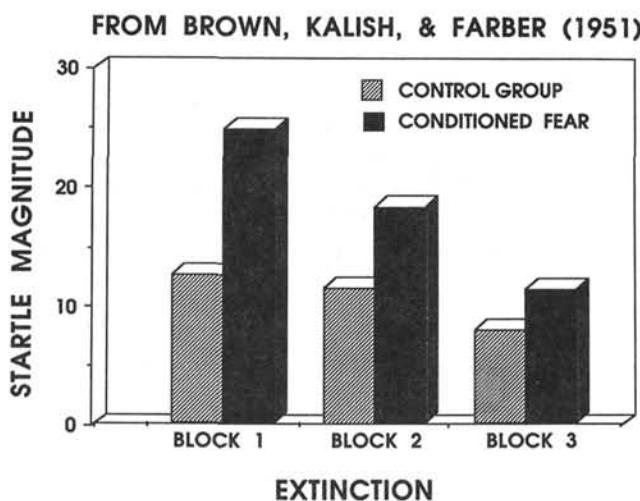


Figure 3. Brown, Kalish, and Farber (1951) reported augmented probe-startle reflexes for fear-conditioned stimuli. (The mean whole-body startle reflex, recorded by stabilimeter, of rats is shown. An acoustic startle probe was presented during extinction of conditioned stimuli, previously paired with electric shock, and nonconditioned stimuli [unpaired].)

Spence & Runquist, 1958). More recently, Michael Davis and his associates produced data further supporting the hypothesis that probe reflexes are enhanced in conditioned fear. For example, consistent with the hypothesis that the probe response is related to level of fear, laboratory rats showed a systematic increase in reflex response to startle probes (presented concurrently with the CS in extinction) with increased intensity of the previously presented shock US (Davis & Astrachan, 1978). Furthermore, significant attenuation of the reflex was found after administration of anxiolytic drugs (Berg & Davis, 1984).

The CS used in Ross's (1961) study of human subjects, as well as that chosen by the Davis group (e.g., Berg & Davis, 1984) for their animal learning study, was a change in illumination. It is interesting to consider these experiments in the context of Graham's attention theory. From this perspective, the light CS presented during extinction was clearly a foreground stimulus, and it was visual. The probe stimulus was acoustic. This amounts to a conditioning version of the cross-modality-attention paradigm (e.g., Anthony & Graham, 1985; Simons & Zelson, 1985). However, the attention theory makes a prediction opposite to drive theory. The CS at extinction is more engaging, or of greater interest, than the control stimulus. A primary visual cue should direct attentional resources to the visual modality, making less attention available for the auditory channel. Thus, a logical conclusion is that a context-irrelevant acoustic probe, presented during this visual signal stimulus, should produce an inhibited startle reflex. As we have seen, the actual results are otherwise. The amplitude of the acoustic startle reflex is significantly increased during presentation of a visual CS.

Emotional Valence and Reflex Excitation: Background

A goal of this article is to present some theoretical considerations that may help to resolve apparently inconsistent results

from these two lines of research. It seems clear that attention and modality modulate startle amplitude, and it seems equally clear that the probe startle is augmented by conditioned fear. The theoretical conflict arises in the neglect of affective motivation. Thus, it is suggested that attentional effects cannot be clearly assessed if the emotional valence of foreground and probe are ignored; with reference to both attention and conditioning research, positive and aversive affective cues may modulate the startle response differently, and a context's emotional valence may have an influence on the reflex that is independent of arousal.

Hebb (1949) suggested that the significant dimensions of behavior are direction and vigor. Similarly, we propose that the emotional significance of behavior can be understood in terms of two primitive strategic dispositions, valence and arousal. *Valence* refers to the organism's disposition to assume either an appetitive or defensive behavioral set. *Arousal* refers to the organism's disposition to react with varying degrees of energy or force. This article focuses on the significance of emotional valence for cognition and behavior. Arousal is considered to be an intensity factor, which must be brought under experimental control if the effects of valence are to be clearly observed.

Strategic and Tactical Aspects of Motivated Behavior

As described by Karl von Clausewitz in his classic treatise *On War* (1832/1976), *tactics* are diverse, specific, context-bound patterns of action; *strategy* is a unitary, underlying organization that marshals individual actions in the cause of broad end goals. Tactics serve strategies but do not mirror them. Thus, a tactical situation may call for defensive behavior, even though the overall strategic plan is to attack.

Applying this metaphor to motivated behavior, the emotions appear to be organized around two broad strategic dimensions, valence and arousal. These dimensions are called *strategic* because they define the general direction of behavior (either appetitive or defensive) and the amount of energy resources to be allocated without specifying exact patterns of action. The organism's strategic state—its valence and arousal predisposition—differentially primes or inhibits subsequent behavior. These parameters are set by conjunctions of internal and external stimuli, integrated through subcortical structures, and represent for a given period the background framework of transactions between the organism and its environment.

Emotions that are subordinate to a specific valence level are various. Several theorists (e.g., Ekman, 1973; Izard, 1977) have suggested that affect is further organized into a set of broad, survival-related categories such as fear, aggression, and pleasure (as in consummatory or sexual approach), each of which has its own associative structure and logic. However, there is no agreement on a fundamental list, and importantly, emotions are clearly tactical in any specific instance of expression. For example, widely different behavioral programs have been classified as fear related. These include anxious vigilance, freezing, spontaneous defecation, disruption of motor control, or headlong flight. Indeed, appetitive-appearing behaviors, such as mock aggressive or sexual displays, also may occur in primates under threat (e.g., van Lawick-Goodall, 1971, p. 172). It is this tactical variability in emotional behavior that has frustrated efforts to

discriminate positive from negative affects (much less individual emotions) in terms of specific and reliable psychophysiological response measures (e.g., see Mandler, 1984, pp. 27-34).

We suggest that the probe reflex methodology may provide a partial solution to the problem of emotion measurement. It is proposed that the exteroceptive reflexes are differentially primed according to the existing, strategic set of the organism. It is further hypothesized that this priming extends across different specific affects and is independent of differences in tactical response pattern. Finally, whereas tonic activation has been shown to sometimes increase reflex strength (e.g., Davis & File, 1984; Putnam, 1976), new research suggests that this effect strongly depends on the valence parameter. That is, individual reflexes are either enhanced or inhibited, depending on whether the organism's strategic, valence disposition is appetitive or defensive.

Emotional Valence and Behavior

Motivated, emotionally relevant behavior is seen as having an underlying biphasic organization, primitively based on functionally opposed approach and withdrawal reactions. A scheme of this sort was proposed formerly by Schneirla (1959). His orientation was biological and evolutionary:

In general, what we shall term the A-type of mechanism, underlying approach, favors adjustments such as food-getting, shelter-getting, and mating; the W-type, underlying withdrawal, favors adjustments such as defense, huddling, flight, and other protective reactions. Also, through evolution, higher psychological levels have arisen in which through ontogeny such mechanisms can produce new and qualitatively advanced types of adjustment to environmental conditions. (p. 4)

Konorski (1967, p. 9) also advocated a biphasic model. Unconditioned reflexes were organized into two classes, preservative (e.g., ingestive, copulation, and nurture of progeny) and protective (e.g., withdrawal from or rejection of noxious agents), based primarily on their biological, motivational role. He was at pains to point out that both types of responses involved arousal, and he thus differentiated his classification from the ergotrophic-tropotrophic distinction of Hess (1957). Dickinson and Dearing (1979) developed Konorski's dichotomy into two opponent motivational systems, aversive and attractive, each activated by a different but equally wide range of unconditioned stimuli. These systems were held to have reciprocal inhibitory connections that modulated learned responses and reactions to new, unconditioned input.

More recently, making a similar distinction between approach and avoidant behavior in animals, Masterson and Crawford (1982) conceived negatively valent behaviors to be organized into a "defense motivation system"; this system "selectively potentiates or primes a set of innate defense reactions that include fleeing, freezing, fighting and defensive burying" (p. 664). They suggested that affective reactions in humans (e.g., fear, anger, anxiety, and apprehension) can be construed as a phylogenetic development of the mammalian line and represent output of the same defense system. Presumably, positive affects would be similarly related to an appetitive motivational system.

Emotional Valence and Semantic Judgments

The conclusion that emotion-motivational systems are biphasic has also been reached by most investigators studying verbal behavior. For example, recent work on natural language categories (Ortony, Clore, & Collins, 1988; Shaver, Schwartz, Kirson, & O'Connor, 1987) suggests that people's knowledge about emotions is hierarchically organized and that the superordinate division is between positivity (love and joy) and negativity (anger, sadness, and fear). A similar deduction was made by Osgood and his associates (e.g., Osgood, Suci, & Tannenbaum, 1957) on the basis of their classic studies of the semantic differential. Using factor analysis, they determined that emotional descriptors were mainly distributed (in terms of the most variance accounted for) along a bipolar dimension of valence. Despite wide differences in the dictionary definition of the words used, the primary affective meaning of stimuli was captured by a single dimension from attraction to aversion, pleasure-displeasure. A smaller but significant portion of the total variance was controlled by a second dimension, arousal or engagement. Although minor details vary, this general conception has received wide support from a host of independent investigators (e.g., Mehrabian & Russell, 1974; Russell, 1980; Tellegen, 1985).

Biobehavioral and language dimensions of arousal and valence are presumed to be roughly coupled. That is, language and behavior (and even to some extent its physiology) can be shaped independently (Lang, 1968, 1985), but central associative connections are assumed to exist between semantic and behavioral representations of emotion. Thus, barring an active dissociative process, subjective affective judgments about stimuli are expected to be positively correlated with related emotional behaviors.

Biphasic Emotion Theory

The Startle Probe in an Affective Foreground

The overview developed earlier asserts that affective behavior is organized biphasically at all levels of response complexity, from cognitive events to the exteroceptive reflexes. Many reflexes can be classified as either appetitive (e.g., the salivary reflex) or defensive (e.g., pain withdrawal and startle). Both classes are seen to be augmented or diminished, depending on whether the behavioral context in which the specific reflex is instigated is a valence match or mismatch. For example, when a foreground stimulus engages an appetitive response, a negative probe of that foreground should prompt a reflex of lower amplitude and slower latency; if the foreground stimulus is aversive, an augmented reflex is anticipated.

Theoretical Hypotheses

Several hypotheses are derived from this position. They concern how startle amplitude varies with the perception of aversive or appetitive stimuli and with the retrieval of pleasant or unpleasant memories. The first two are basic and can be derived neither from the attentional explanation of the startle probe nor from the view of activation (drive) as a nonspecific motivating

factor in behavior. The remaining hypotheses are parsimonious collaterals, also generated from the biphasic emotion view:

1. The startle-probe reflex indexes the strategic valence disposition of the organism. Thus, reflex amplitude will be enhanced linearly as foreground stimuli vary from highly positive, appetitive content to highly negative, aversive content. This effect is determined by valence and is not a simple function of the interest value or arousal level of the foreground.

2. The covariation between probe reflex amplitude and foreground valence is based on an affective (not modality) stimulus match or mismatch. Therefore, it is independent of probe modality and should occur with a visual as well as an acoustic startle probe.

3. Probe reflex amplitude will change if the affective valence of a foreground changes. Thus, following conditioned association of a foreground stimulus with an aversive event, the probe response to that foreground will be increased in magnitude, relative to a control stimulus.

4. Research suggests that the right cerebral hemisphere is dominant in the processing of emotional stimuli. Thus, it is presumed that the emotional valence of foreground stimuli will have a greater influence on reflex amplitude when acoustic probes are presented to the left ear.

5. If reflexes are modulated by a central, affective response disposition, then the reflex-valence relationship should hold even when there is no sensory foreground, that is, when subjects retrieve and process emotional memories.

Experimental Investigations of Emotion and the Startle Probe

The paradigm used to test many of the predictions just described is similar to that used by Anthony and Graham (1985) and Simons and Zelson (1985). Visual stimuli were photographic slides of various contents, and the blink reflex was measured with cross-modality or same-modality probes. The emotional stimulus values of the slides were determined by prior affective ratings obtained from a large sample of college students (see Greenwald, Cook, & Lang, 1989; Lang, Öhman, & Vaitl, 1988). The slides were rated on valence (e.g., pleasure-displeasure) and arousal (e.g., excited-calm) with bipolar graphics scales (Hodes, Cook, & Lang, 1985; Lang, 1980) derived from work on the semantic differential by Mehrabian and Russell (1974). Negatively valent slides included pictures of victims of violent death, snakes, bloody wounds or burns, disasters, aimed guns, medical injection, and angry, destitute, or starving people; neutral slides were generally of common household objects, such as a hairdryer, a book, and shoes; positively valent pictures included opposite-sex nudes, romantic couples, babies, cuddly animals, sports scenes, and appetizing food. The standard valence and arousal ratings of slides used in these experiments are presented in Figure 4.

1. Valence, Arousal, and Interest

Vrana, Spence, and Lang (1988) addressed the first prediction, that acoustic startle probes would be augmented during a negatively valent slide foreground, relative to neutral slides, and reduced during positively valent slides. Twenty undergraduates

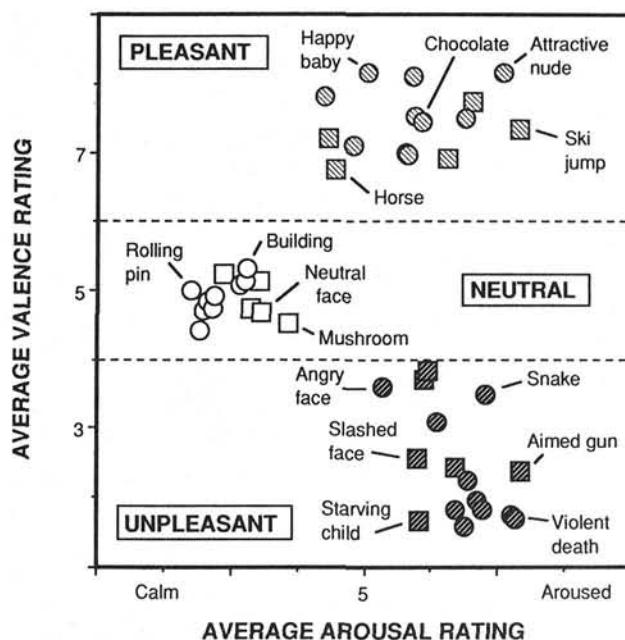


Figure 4. Scatter plot showing valence and arousal ratings obtained for a slide subset of the International Affective Picture System (Greenwald, Cook, & Lang, 1989; Lang, Öhman, & Vaitl, 1988). (These ratings, obtained from a large subject sample at the University of Florida, were used in selecting slide materials for the startle studies. Circles represent slides used in the Vrana, Spence, & Lang [1988] and Bradley, Cuthbert, & Lang [1988, in press] studies; squares represent slides used only in the latter experiments. Representative slide contents are indicated on the figure. In this research, the slides were organized into three, non-overlapping valence groups: pleasant = light shaded symbols; unpleasant = heavy shaded symbols; neutral = open symbols.)

(10 men and 10 women) viewed 36 slides divided into three categories on the basis of independent ratings of positive, negative, and neutral valence. Slides were exposed for 6 s, with 16–24 s between slides. Acoustic startle probes were binaurally presented 50-ms, 95-dB (A) white-noise bursts, with instantaneous rise time. They occurred unpredictably during the course of slide exposure and between slides.

Mean startle magnitudes are presented in Figure 5 for the three slide valence types. The pattern of means is consistent with the hypothesis of an affect-reflex relationship. Blink magnitude increased significantly from pleasant to neutral to unpleasant slides. Furthermore, this pattern was exactly replicated in a second experiment (Bradley, Cuthbert, & Lang, 1988; see also Figure 5) with a new group of 36 subjects, a new 54-slide set that was again categorized according to valence, and monaural probes of 105 dB (A) presented with equal frequency to either the left or right ear.

The valence-reflex relationship found in these experiments may have been secondary to chance differences in the subject's attention to (or interest in) the different slide categories, as originally emphasized by Anthony and Graham (1985). It is also possible that the effect was determined by slide category differences in the other strategic variable defining an emotional response—arousal. The following procedures were undertaken to assess these alternative hypotheses.

In both experiments, after initial presentation of the slide series, the presentation was immediately repeated (this time, without startle probes). In the second series, slide exposure was freely controlled by the subject, and time of presentation was recorded as a behavioral indication of the slide's interest value. After each slide, the subjects rated the slide for emotional valence, arousal, and subjective interest. As shown in Figure 6, only the subjects' own reports of emotional valence followed the pattern of startle reflex magnitudes: Smaller eyeblink responses were associated with pleasant slides relative to unpleasant slides. Furthermore, the smaller response to pleasant material does not appear to be a function of interest value. In both experiments, subjects reported the pleasant and unpleasant slides to be equal in interest, and significantly more interesting than the neutral pictures. This result was paralleled by the pattern of exposure times, with subjects watching pleasant and unpleasant slides for equal periods, and for a longer time than neutral slides.

The affect-startle effect also appears to be independent of arousal. This conclusion is warranted whether activation is defined by subjective report or by physiological measurement. In both experiments, subjects judged that the pleasant and unpleasant slides prompted an equal arousal experience, greater

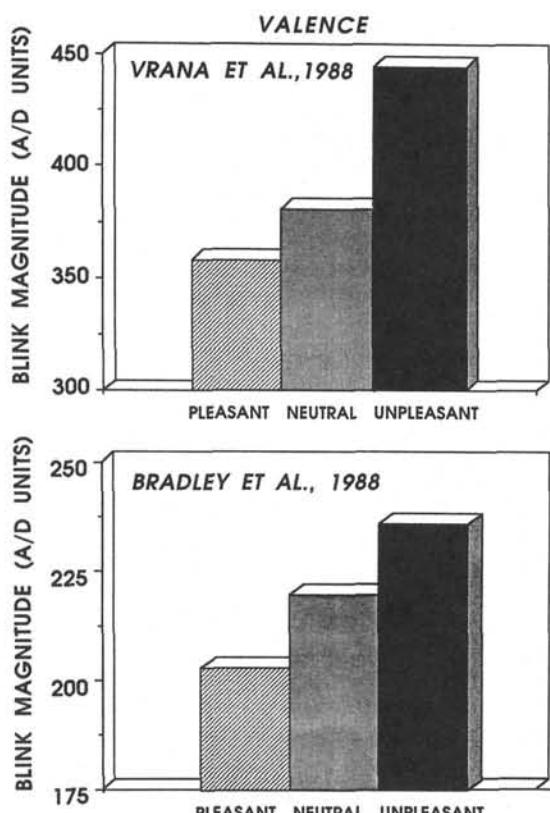


Figure 5. Vrana, Spence, and Lang (1988) found that the magnitude of acoustic probes varied linearly with the judged emotional valence of a pictorial slide foreground. (Mean reflex responses are presented for pleasant, neutral, and unpleasant valence categories, each of which included nine probed slides. The experiment was replicated by Bradley, Cuthbert, and Lang, 1988, using a monaural probe [bottom panel]. A/D = analog-to-digital conversion.)

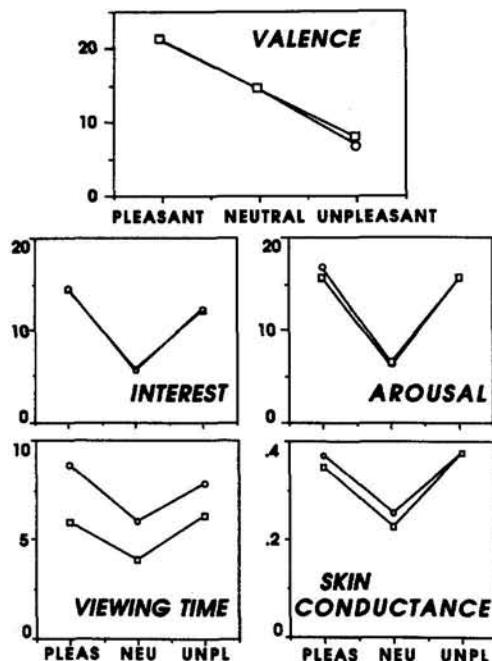


Figure 6. Data from two experiments are presented: Bradley, Cuthbert, and Lang (1988, $N = 36$) and Bradley, Cuthbert, and Lang (in press, $N = 36$). (The response measures shown here include mean reported judgments of slide valence, interest, and arousal; the mean time taken during free viewing of each slide, and mean skin conductance response ($\log [SCR + 1] \mu S$) to each slide. All measures were obtained for the same slide sets—pleasant [PLEAS], neutral [NEU], and unpleasant [UNPL]—for which startle-probe responses were recorded. Only valence judgments generated a significant linear effect over slide pleasantness categories as did the startle-probe reflex. For all other measures, this response function was quadratic.)

than for neutral slides. Furthermore, in the Bradley et al. (1988) experiment, skin conductance was measured during initial slide viewing. Conductance change is a near-direct measure of general sympathetic nervous system activity (i.e., physiological arousal). Nevertheless, conductance responses to the positive and negative slides did not differ and were each significantly greater in amplitude than the response to neutral slides.¹ These U-shaped curves of arousal as a function of slide valence categories (see Figure 6) are clearly different from the monotonic linear function found with the startle reflex. This is also true for the interest measure. These data suggest that the valence-reflex relationship is not fundamentally attentional and that it is not a nonspecific effect of drive or activation, as hypothesized in the

¹ The classification of defense reflexes is different from the distinction between "orienting and defensive reflexes" emphasized by Sokolov (1958/1963). As used here, it is merely a descriptive label for the actions of some exteroceptive reflexes, which are normally instigated by potentially harmful stimuli. In Sokolov's view, however, the defensive reflex is a general mechanism that, to some extent, blocks stimulus intake and cortical processing. Graham (1979) and Putnam and Roth (in press) present evidence that the startle reflex is not the same as Sokolov's defensive reflex.

original probe reflex studies of classical fear conditioning (e.g., Brown et al., 1951; Ross, 1961; Spence & Runquist, 1958).

2. Probe Modality and Affect

There are no definitive measures of attention. Thus, we may continue to ask the questions: Do the subjective, behavioral, and physiological measures of attention used in this research really resolve the issue? Might attention somehow still vary systematically between slide categories and thus confound the experiments? If this is the case, reflex modulation in the experiments discussed earlier could still be a function of modality-driven attention allocation. F. K. Graham (personal communication, October 15–17, 1987) has indeed questioned the adequacy of the attentional measures presented earlier and has encouraged consideration of an alternative interpretation of the results, consistent with previous cross-modal studies (e.g., Anthony & Graham, 1985; Simons & Zelson, 1985).

The diminished reflex to an acoustic probe during visual presentation of positive, interesting material is of course predicted by both a modality-determined attention allocation view and the valence-match hypothesis presented here. It is the augmented startle to aversive slides that is inconsistent with previous cross-modal research and confounds the attention hypothesis. This could be explained as an attention effect, however, if it were assumed that nocent events are implicitly rejected by the organism. Resources are withdrawn from aversive visual stimuli (the unpleasant slides), which are then available to the auditory channel, resulting in an augmented startle to an acoustic probe. The Sokolovian concept of a defense response (Sokolov, 1958/1963) shutting down cortical "analyzers," and Lacey and Lacey's (1970) idea of autonomically modulated stimulus rejection in the context of distressing input, provide a theoretical foundation for this explanation.

There are, however, data inconsistent with this view in the previous research. In the theories presented earlier, stimulus rejection is associated with heart rate acceleration, whereas orienting and attention are indexed by deceleration (Graham & Clifton, 1966). Thus, if unpleasant slides prompt stimulus rejection, they should occasion heart rate acceleration. In the Bradley et al. (1988) experiment, heart rate was recorded during slide viewing: Significantly greater deceleration was observed in response to the slides that were judged unpleasant. This result is opposite to the prediction of Lacey and Lacey's stimulus-rejection model and to the Graham and Clifton (1966) interpretation of Sokolov's defensive reflex.

Nevertheless, it can be argued that the issue cannot be resolved by secondary measures of attention. The previous studies of valence (Bradley et al., 1988; Vrana et al., 1988) were both done in the cross-modal format with visual foreground and acoustic probe. In these experiments, the two alternative theories, attention or emotion, could be said to predict the same pattern of results across affective contents. However, if the foreground and the startle-probe stimuli were of the same modality, emotional and attentional explanations would predict opposite experimental outcomes. According to the stimulus-rejection hypothesis, an aversive visual foreground would act to close down that channel of input. Unpleasant slides would block attentional resources going to the visual modality, and responses

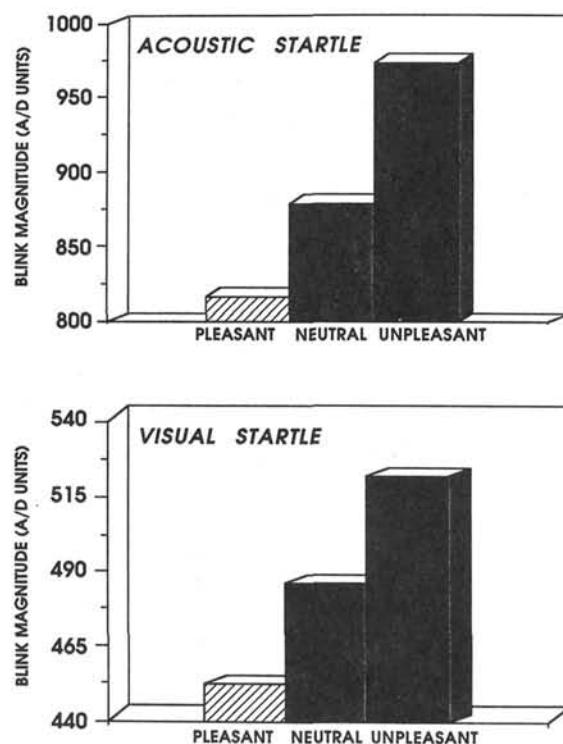


Figure 7. Mean blink reflex magnitudes to acoustic (top panel) and visual (bottom panel) startle probes, presented during viewing of pleasant, neutral, and unpleasant pictorial slides (Bradley, Cuthbert, & Lang, *in press*). (Both the acoustic and visual startle probes resulted in blink magnitudes with the same linear function over valence categories [pleasant, neutral, and unpleasant]. A/D = analog-to-digital conversion.)

to the visual startle probe would be reduced; pleasant slides would attract resources, and the visual probe response would be augmented. On the other hand, if it is emotional context that modulates the reflex, the same covariance with affective valence should be observed as in the previous experiments. Thus, the two views, attention and emotion, make opposing predictions for the matched-modality paradigm.

Bradley, Cuthbert, and Lang (*in press*) performed an experimental test of these hypotheses, comparing the cross-modal paradigm with a procedure in which probe and foreground stimuli were both in the visual modality. Thirty-six subjects saw the same 54-item slide set used by Bradley et al. (1988), presented in two equal blocks. One group of subjects received unpredictable acoustic startle probes during the first block of the slides, and a second group received visual startle probes. During the second slide block, probe modality was exchanged between groups. Thus, by the end of the experiment, all subjects received both probes during an equal number of slides, with the same frequency and timing. The auditory probes were as described previously; visual startle probes were brief strobe bursts from three simultaneously activated flash guns placed below the slide screen and directed at the white ceiling of the experimental chamber.

As shown in Figure 7, blink magnitudes were somewhat larger for auditory than for visual probes. Nevertheless, both show the same linear distribution over valence categories ob-

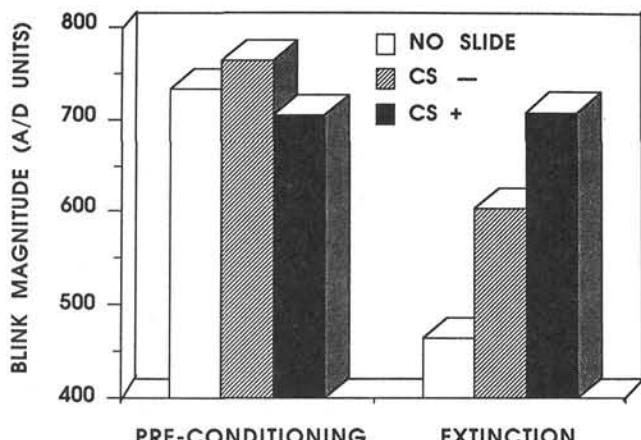


Figure 8. Mean blink reflex magnitude to acoustic startle probes presented during slide viewing, both prior to conditioning, and again following aversive differential conditioning (Greenwald, Hamm, Bradley, & Lang, 1988). (No differences between foregrounds were found in pre-conditioning. During the extinction trials, responses to the conditioned-stimulus [CS+] slide, followed by shock in the acquisition trials, were significantly larger than responses to probes presented during the control stimulus [CS-] slide, or those presented during intertrial intervals [NO SLIDE]. A/D = analog-to-digital conversion.)

served in the previous two experiments—an increase from positive through neutral to negatively valent slides. The overall findings for valence were again highly significant. There was no evidence in these data that slide valence produced different effects as a function of probe modality.

The data are clearly consistent with the affective-match hypothesis and disconfirm the modality-driven attention-rejection hypothesis. An unpleasant visual foreground is associated with an augmented startle; pleasant foregrounds prompt relative blink inhibition, regardless of the modality of the startle probe. The results indicate that affective foregrounds do not modulate startle by biasing the attentional system, shifting the allocation of resources toward or away from a particular modality. They suggest that blink modulation is a synergistic augmentation, or inhibitory diminution, prompted by the match or mismatch of reflex and foreground valence.

3. Conditioned Emotional Associations

Research with animals and human beings has consistently shown augmentation of the startle response when probes are presented during an aversive CS. Recently, Greenwald, Hamm, Bradley, and Lang (1988) tested this phenomenon for a subset of the slide stimuli used in the experiments just described. Sixty subjects were presented with two different slides, each for four 8-s habituation trials. The same slides were then repeated, each for 8 acquisition trials, in which only one of the slides was always followed by an unpleasant electric shock. Subsequently, extinction trials were administered (12 for each slide). Subjects rated the whole series of slides used in the experiment for pleasantness and arousal before and after the conditioning series.

Acoustic startle probes (100 dB-A) were presented during initial habituation of each slide and during the interslide inter-

val. This pattern of probe presentation was repeated during extinction trials. The mean reflex responses are presented in Figure 8. The magnitude of the startle response decreased dramatically from habituation to extinction trials for probes administered during slides with no subsequent shock and during the interstimulus intervals. However, probes presented during the conditioned slide stimuli continued to elicit a strong reflex, significantly greater than all other probe responses. There was also a significant increase in ratings of unpleasantness for the slides followed by shocks. These data are consistent with the hypothesis that an aversive association will alter slide valence and result in a relatively increased startle-probe response. In addition, they emphasize the continuity of the startle-modulation phenomenon between conditioning paradigms using nonrepresentational, physical stimuli (with animals and human subjects) and those using pictorial stimuli as CSs.

4. Emotion and Hemispheric Processing

Both clinical (Heilman, Watson, & Bowers, 1983) and experimental (e.g., see Bryden & Ley, 1983) studies encourage the view that the right cerebral hemisphere, more than the left, plays a salient role in the processing of affective information. Better discrimination of emotional facial expressions has been shown when stimuli are presented to the left visual half-field (this is the retinal image represented neurally in the occipital region of the right hemisphere; Ley & Bryden, 1979; Safer, 1981). Similarly, there is more sensitivity to emotional auditory input heard through the left ear (roughly twice as many afferent auditory fibers cross to the opposite hemisphere as those that remain ipsilateral), that is, to the emotional prosody of speech (Haggard & Parkinson, 1971; Safer & Leventhal, 1977) and to the affective impact of music (Beaton, 1979). Furthermore, Carmon and Nachshon (1973) studied the integration of emotional stimuli from different modalities. They presented various affective sounds (e.g., the laughing, crying, and shrieking of adults and children) in a dichotic listening task. Subjects simultaneously viewed cartoon figures illustrating various affective states and were instructed to select the cartoon best representing the sound. Significantly greater accuracy was found for the left ear, suggesting an advantage for the right hemisphere in the cross-modal matching of affective stimuli.

It was proposed at the outset that the acoustic startle reflex is an aversive reaction. Its augmentation, when presented in the context of an unpleasant foreground, is based on a synergistic valence match between the reflex and an ongoing, tonic aversive response. Previous research suggests that the right hemisphere of the cortex is dominant in such affective integration. Thus, one prediction is that the monotonic modulation of acoustic reflex magnitude, according to the valence of a visual foreground, will be better represented when probes are administered to the left than to the right ear.

As noted previously, Bradley et al. (1988) used a monaural acoustic stimulus to probe a foreground of varied emotion-evoking slides. All subjects were right-handed, blink reflexes were recorded from both eyes, and half the group received probes in the left ear and half in the right ear. Combining the data of both groups, they found the same linear relationship—between startle magnitude and the valence of an affective slide

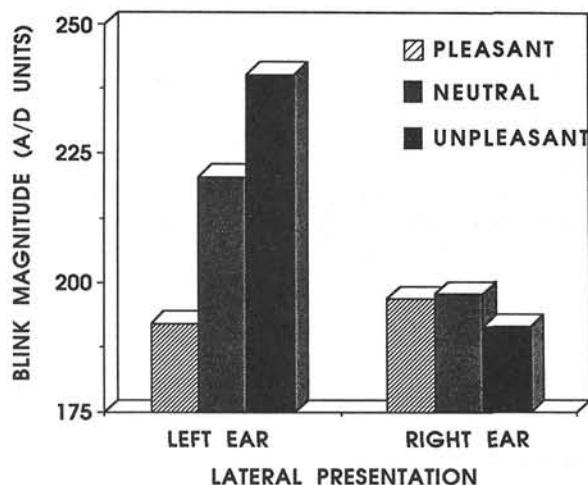


Figure 9. Mean blink reflex magnitude to monaural acoustic probes, presented either to the left or the right ear. (A significant linear trend over slide valence categories was obtained for left-ear probes; this trend was not significant for right-ear probes. A/D = analog-to-digital conversion.)

foreground—previously observed by Vrana et al. (1988). However, as shown in Figure 9, the findings were different when the results from the two ears were analyzed separately. Whether viewed in terms of a priori slide categories or the subjects' own postexperiment ratings, for both right and left orbicularis, the linear trend over slide valence categories was significant only for left-ear startle probes. These data are consistent with the hypothesized right-hemisphere dominance in the affective modulation of the startle response. More broadly, they emphasize the role of higher, cortical centers in emotional information processing and specifically, the significance of response valence information for reflex modulation.

5. Imagery and Emotional Memory

The experiments considered thus far have focused on the perception of external, affectively toned stimuli. Indeed, it might be assumed from this emphasis that modulation of the startle probe occurs only in the context of perception and that it depends on attention to external events (despite the implications of the hemispheric data) and represents an integration of inputs wholly within the sensory system. However, the view presented here is more broadly conceived. We presume that the organism's affective response set (an appetitive or aversive disposition) is tuned internally by physiologically determined motivational states, associative memory, and new sensory input. Thus, an affective sensory foreground may not be necessary to show the emotional modulation of the blink reflex. It is only necessary that emotional responses are ongoing.

There is considerable evidence that the activation of emotional memory images prompts patterns of autonomic and somatic responses that are isomorphic with those observed in the referenced behavioral context (see Cuthbert, Vrana, & Bradley, in press, for a review). Lang (1979, 1985) suggested that such memories are information networks that include response code

and that the processing of response information normally involves at least partial activation of the referenced efferent systems. In several experiments, retrieval of simple phrases that have fearful emotional contents has been shown to be associated with affect-related events such as increased heart rate, skin conductance, and corrugator tension and reports of unpleasant feelings (Jones & Johnson, 1978; May, 1977; Vrana, Cuthbert, & Lang, 1989; York, Cuthbert, & Lang, 1989).

Vrana and Lang (1990) recently undertook a study of emotional memory retrieval, testing whether the magnitude of acoustic startle probes varies with a retrieved sentence's affective quality. Thirty-six students memorized pairs of sentences with either fearful or neutral content. The fearful sentences were designed to activate memories of moderately anxiety-inducing circumstances common to most people. They included descriptions of a dental examination, an intruder in the night, speaking before a group, and an observed automobile accident. After learning a sentence pair to criterion, subjects listened to a series of brief, soft tones, one presented every 6 s. They were instructed to say the word "one" to themselves in the interval after each of these nonsignal tones to relax and clear the mind.² They were told that the tone would sometimes be at a different frequency (higher or lower), and this was a cue for them to retrieve one or the other member of the sentence pair. Immediately on hearing the signal tone, they were instructed to imagine the sentence content as a personal experience (i.e., to retrieve associated affective memories) until the subsequent nonsignal tone occurred. Startle probes were presented unpredictably throughout the session.

The magnitude of the startle-probe response during processing of sentences evoking fear responses was significantly greater than during processing of neutral sentences (see Figure 10, top panel). This result is consistent with the hypothesis that the fear sentences are negatively valent, activate an aversive response disposition, and thus potentiate defensive reflexes. The affective modulation of the blink reflex clearly depends not on a perceptual foreground, whatever the modality, but on the central processing of an affective content.³

In the experiment just described, different groups of subjects received different sentence-processing tasks. Instead of being encouraged to imagine the content of the sentence as a personal experience, different groups were told either to ignore both cue and sentence and to continue the count-one task or, when retrieval was cued, simply to articulate the sentence silently to themselves. These nonsemantic processing tasks resulted in significantly less differentiation between neutral- and fear-sentence blink reflexes than did the imagery task (see Figure 10, bottom panel). Thus, reflex modulation occurs when emotional associations are most activated (i.e., in imagery) and is clearly

² Readers will recognize this procedure as the secular meditation exercise recommended by Benson (e.g., Benson, Rosner, Marzetta, & Klemchuk, 1974; Cuthbert, Kristeller, Simons, Hodes, & Lang, 1981), which tends to inhibit thinking and reduce tonic physiological arousal.

³ Hawk, Davis, and Cook (1989) recently found a similar augmentation of the probe reflex during aversive imagery (either fear- or anger-inducing scenes) when compared with both neutral and positive affective imagery.

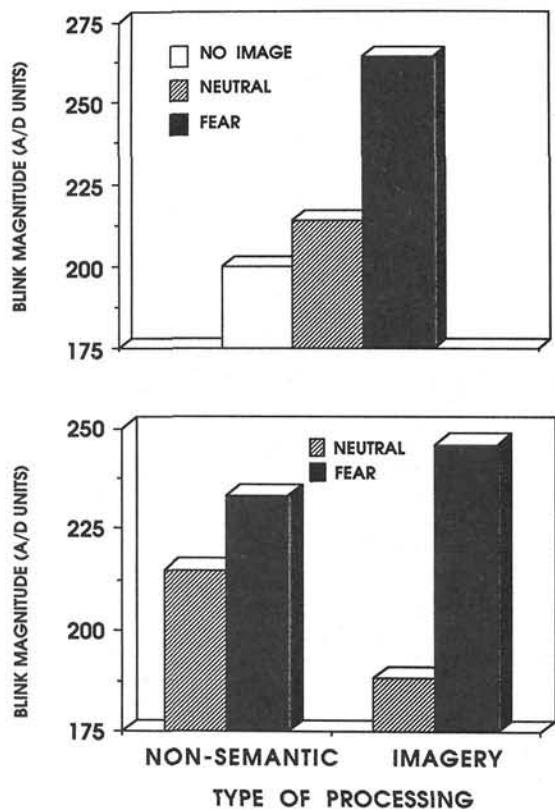


Figure 10. Top panel: Startle-probe responses during recall of fearful (rated unpleasant postexperimentally) and neutral (rated slightly positive postexperimentally) sentences and during the period between trials. (Startle probes presented in the context of fear sentences produced larger reflex magnitudes.) Bottom panel: Probe responses to fear and neutral sentences when the subject was under instructions to vividly imagine the content and when instructed to perform nonsemantic tasks (e.g., "Articulate the sentence silently; do not process the cued sentence"). (The difference between fear and neutral sentences is significantly larger during imagery. A/D = analog-to-digital conversion.)

not secondary to other, chance differences in the sentences themselves.

These results support the view that the modulation of the eyeblink reflex in an affective context is not dependent on the immediate presence of emotionally engaging, sensory stimuli. They suggest the key factor is the presence of an ongoing emotional response and that the basic valence disposition of the subject can be initiated through memory association as well as external input.

Emotion and Reflexology: Probe Mechanism and Limitations

To summarize, results of the experimental series presented earlier support the hypothesized relationship between probe reflex magnitude and emotional response valence: In three replicates, the judged unpleasantness of pictorial stimuli covaried monotonically with the magnitude of startle probes presented during slide viewing. This finding of larger reflexes with nega-

tively valent foregrounds, and smaller with positive, was independent of arousal or the interest value of the foreground stimuli. Furthermore, when the valence of such stimuli were altered through association with a negative event (electric shock), probe reflex magnitude increased. Like many other phenomena of emotion, the valence-reflex relationship was enhanced when the experimental procedure emphasized right-hemisphere processing. Finally, the effect was not dependent on cross-modal allocation of attention. In fact, the phenomena emerged in the absence of a stimulus foreground, when subjects were processing emotional memories.

The theoretical model to which these experiments appeal asserts that emotional responses are fundamentally organized in terms of an appetitive-aversive dimension, that new affective responses are augmented or inhibited depending on the ongoing affective valence of behavior, and that this modulating effect extends to the exteroceptive reflexes—notably, the startle blink. The findings support the general theory. However, many fundamental issues have not been addressed. Furthermore, the experiments themselves raise new questions of interpretation and generality of effect that require resolution. Mainly, these questions focus on the mechanism underlying the affect-startle effect, and possible constraints on the use of probe analysis in the study of emotion.

Eyeblink and Facial Muscles

Recent experiments (Cacioppo, Petty, Losch, & Kim, 1986; Greenwald et al., 1989) have demonstrated covariation between the facial muscles mediating frowning and smiling and judgments of the emotional valence of pictorial stimuli. These data prompt the question: To what extent might the affect-startle effect be mediated peripherally, rather than through a general motivational set? More specifically, are these effects secondary to the base tension level of the orbicularis oculi muscle? This is the muscle that propels the blink. Tension in the orbicularis oculi could vary directly with facial expression, and the degree of contraction initiated by a probe could in turn be constrained by this base motor unit activity.

Studies of the relationship between emotional valence and tension in orbicularis oculi have produced mixed findings. Englis, Vaughn, and Lanzetta (1982) reported tension in this region to be related to pain and to squinting. Thus, tension seems in this case to increase with negative valence. However, it could also be related to eye fixation and thus be a correlate of attention or interest. Ekman and Friesen (1982) implicated the orbicularis oculi, as well as the zygomatic muscle, in the mechanism of the human smile, and Cacioppo et al. (1986) reported a positive covariation between tension in orbicularis and the judged pleasantness of their slide series.

In the slide-startle-probe experiments (Bradley et al., 1988, in press), preprobe orbicularis tension varied significantly with slide content but followed the pattern of arousal and interest ratings. That is, tension was equally elevated for positive and negatively valent slides, relative to neutral slides. Thus, orbicularis tension was not a linear covariate of valence but instead was directly related to arousal, that is, part of the more vigorous reaction occasioned by any strong emotional stimulus (e.g., as is skin conductance). Within-subject tests of the correlation be-

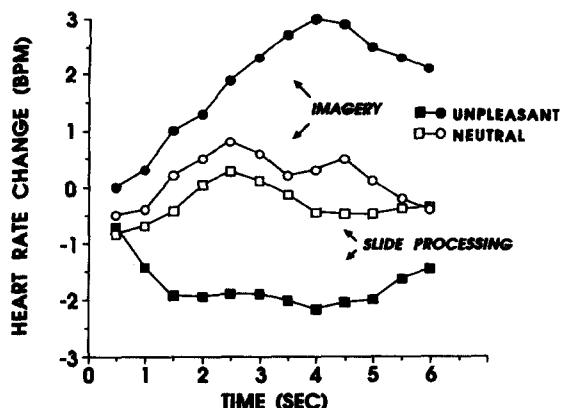


Figure 11. Average heart rate change waveforms for a 6-s period during imagery of unpleasant and neutral sentences (Vrana, Cuthbert, & Lang, 1989) and, for another sample of subjects, during viewing of unpleasant and neutral slides (Bradley, Cuthbert, & Lang, in press). (The pattern of relative acceleration obtained during aversive imagery, and relative deceleration obtained during perception of aversive pictorial stimuli, illustrates how the physiology of an affect is modified by the tactical demands of different processing tasks. BPM = beats per minute.)

tween orbicularis base tension level and magnitude of the reflex have proved to be small and insignificant (mean $r = -.01$).

The above evidence argues strongly that the affect-startle effect is not determined by base tension in the muscle that activates the blink reflex. However, the probe effects could still be modulated by some more general facial action program. The corrugator (frown) muscle, adjacent and above the orbicularis oculi (see Figure 3), increases systematically in tension with increasing unpleasantness of foreground stimuli (Bradley et al., in press). The most compelling evidence against this hypothesis comes from the just-described experiment by Bradley et al. (1988), using monaural startle probes. In this study, slides were the same under both startle stimulus conditions (either left- or right-ear probes), as were the slide-determined facial muscle responses. However, valence modulation of the reflex was clearly present only for left-ear probes. If the valence-reflex covariation is simply secondary to facial tension patterns, the observed individuation of reflex response for left- and right-ear probes should not have occurred.

Valence and Tactical Physiologies

At the outset, it was suggested that the probe response might index the organism's valence disposition, despite palpable differences in the contextual, tactical physiologies required by different behavioral contexts. This phenomenon is addressed by comparing the heart rate responses obtained during perception of unpleasant stimuli with those obtained during unpleasant imagery.

Averaged cardiac-change waveforms to neutral and negative slides (Bradley et al., 1988) are presented in Figure 11. This pattern of significantly greater deceleration to aversive pictorial content has been observed in several experiments in this laboratory (e.g., Greenwald et al., 1989) and elsewhere (Winton, Putnam, & Krauss, 1984) and has sometimes been attributed to

content differences in stimulus orienting (Graham & Clifton, 1966). Waveforms obtained during imagery, prompted by recall of neutral and fearful text, are also shown in Figure 11. In contrast to the slide response, imagery of negatively valent material (Vrana et al., 1989; Vrana & Lang, 1990) produced greater heart rate acceleration. This phenomenon has also been widely observed (see Cuthbert et al., in press; Jones & Johnson, 1980) and has been variously interpreted (e.g., by Lacey, 1967) as evidence of internal processing, stimulus rejection, or both, or by Lang (1985) as activation of encoded response information.

In both imagery and perception, heart rate shows a modest covariance with valence, but the direction of change is opposite. The probe reflex, however, consistently shows increase in magnitude with negatively valent information, regardless of the processing context. Thus, the hypothesis that exteroceptive reflexes are independently modulated by valence, and are relatively independent of context physiology, is supported here.

Whether the valence-reflex relationship found here for affective judgments will also hold over more specific emotional states is not yet clear. Whereas some theorists argue that only the valence parameter is likely to have a stable physiological significance (Zajonc, 1988), others contend that there are several independent emotions—fear, anger, joy, sadness, and so on—each with a specific, reliable pattern of physiological response (e.g., Ax, 1953; Ekman, Levenson, & Friesen, 1983). We propose that such physiological specificity in emotion may be tactical. That is, although specific action dispositions may be implicit in the conception of particular emotions (e.g., avoidance behavior with fear states, inhibition with sadness), they are also heavily modified by the demands of any specific context of expression. Thus, although it is possible that some responses might be stable across different iterations of an affect, most physiological variables will show considerable variation.

In the present view, specific emotions are not the strategic, superordinate level of emotional organization. Assuming equal arousal, startle modulation is presumed to hold both across different, context-determined responses for the same affect, as well as across different affects of similar valence. For example, some research suggests that cardiovascular patterns differ during imagery of fearful and anger-inducing contexts (e.g., Roberts & Weerts, 1982). The present thesis would predict augmentation of reflex magnitude, relative to positive or neutral imagery, for both negative affects.

The slide studies previously reviewed (Bradley et al., 1988, in press) offer presumptive evidence for the hypothesis just presented. That is, large reflex responses were found for unpleasant slides, which subjects described variously as prompting feelings of anger, fear, sadness, or disgust. The incidence of reporting these specific affects, however, varied widely between subjects (and between affects). Without balanced presentation, these data remain inconclusive.

Experiments designed to include a range of well-defined emotional states, reliably evoked across and within subjects (and controlling for arousal level), are needed to assess the strategic primacy of valence over the specific affective context. Whatever the fate of the hypothesis, such investigations could prompt new groupings of or distinctions within affects and significantly advance the understanding of emotion. It may prove to be important, for example, to distinguish between an anger state founded

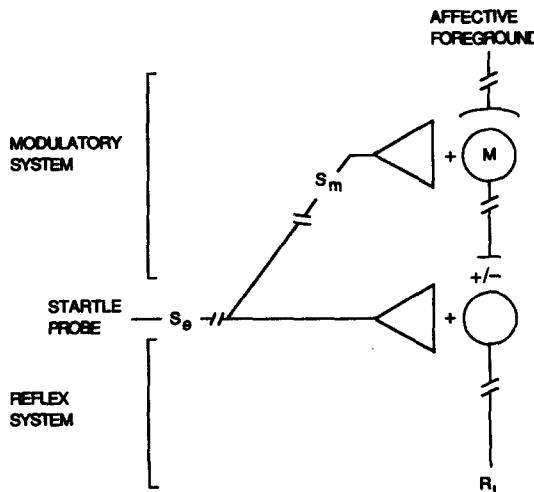


Figure 12. Schematic representation of some potential interactions between a reflex pathway and modulatory system that are required to explain startle modulation in a varying affective context. (The eliciting stimulus, S_e , represents the sensory side of a reflex, R_1 , arc. The same stimulus, then called S_m , may also activate some modulatory system that does not itself elicit the reflex but that facilitates the reflex when it is activated by other eliciting stimuli [in the present model, it is hypothesized to also diminish reflex magnitude]. Breaks in the line indicate an indefinite number of synapses between connections. Note: Data are from *Habituation, Sensitization, and Behavior*, p. 294, by H. V. S. Peeke and L. Petrinovich, Eds., 1984. New York: Academic Press. Copyright 1984 by Academic Press. Adapted by permission.)

on predator aggression and defensive anger. The former may be more closely associated with an appetitive than a nociceptive disposition, and the two responses would have very different neurophysiological structures. An empirically derived, reflex-based valence categorization of affects could prompt a more functional table of emotional organization than any that have been proposed.

Emotional Intensity and the Reflex Probe

The generality of the hypothesized concordance between probe reflex amplitude and emotional valence is clearly an issue of major theoretical importance. As presented here, the phenomenon recalls a common scene in Hitchcock films: The setting is dark, tense, and full of menace. An abrupt, innocuous sound occurs—the stair creaks, or a window blows open with a bang. An enormous startle reaction is invariably provoked in the viewer. As in films, laboratory inductions of emotion— pictorial perception, imagery, and conditioning—are limited imitations of life and rarely engage highly intense emotional responses. Furthermore, the mechanism by which affective factors modulate the reflex is only beginning to be understood, and there may be significant system limitations.

Davis and File (1984) proposed that the blink response is controlled by two polysynaptic circuits, a direct reflex circuit and an additional modulating system (see Figure 12). The direct circuit is primary, uninfluenced by higher brain centers, and the essential mechanism of the obligatory response. It is presumed

that the second, modulating system alters reflex strength only within a limited range and that it includes the pertinent corticofugal connections and is the path of influence of such factors as attention, arousal, and emotional valence. Davis and colleagues (Berg & Davis, 1984, 1985; Davis, 1986; Davis, Redmond, & Baraban, 1979) have made considerable progress exploring these circuits with electrical and pharmacological probes, tracing a path in the medullary system through the reticular formation to the amygdala.

There is already good evidence that the modulating circuit is activated by increased physical stimulus intensity of the foreground into which a probe is introduced. Davis and File (1984) have shown that for acoustic probes in rats, intense background noise alters reflex strength, which first increases in amplitude at the beginning of noise exposure and then habituates with longer durations. More immediate in significance, Putnam (1976) studied the effects of background noise in human subjects on both acoustic and tactile startle probes. Reflex amplitude was monotonically related to increases in noise intensity through the lower and middle ranges. However, at an intensity where background sound becomes palpably distressing (i.e., over 90 dB-A), reflex magnitude promptly fell off to a lower level. If we presume that a sustained intense noise is highly arousing, aversive, and requires its own defensive reaction, these data suggest a limit on the probe-valence relationship. The sensitive modulation of the blink reflex according to subjects' judgment of pleasure or displeasure (as observed in the previously described slide experiments) may not occur when the organism is fully engaged, actively responding to intense stimulation.

Masterson and Crawford (1982) made a distinction between the priming of a general defense motivation system and more intense, emotional alarm reactions. When the organism is defensively disposed, related reflexes are preset: "An excited defense response is like a cocked pistol ready to be triggered by supporting stimuli" (Masterson & Crawford, 1982, p. 664). However, the alarm reaction involves overt action rather than a preparatory set, involving active engagement, fight or flight. From the perspective of this animal model, it might be presumed that with full engagement in an emotional action—active coping with an immediate stressor or panic—blink reflexes might be insensitive to affective subtleties. In this circumstance, the modulatory system is overwhelmed by comprehensive emotional response engagement.

This affect-intensity dimension has not been broadly explored in human subjects. However, Zillman's (e.g., Zillman, 1983; Zillman, Bryant, Comisky, & Medoff, 1981) studies of excitation transfer provide suggestive, related results. Using emotionally evocative films, his group studied the extent to which a prior affectively arousing stimulus potentiates the affective response to a subsequent arousing film. They found that the enhancing effect of the initial experience depended on delay and, important for this discussion, on partial habituation of the physiological response to the initial stimulus. In short, the emotional response to a new stimulus was optimally primed (i.e., augmented by a prior affective input) not when the new stimulus immediately followed the initial experience (and background arousal was highest), but when the new stimulus was presented somewhat later, in the context of a reduced, partially habituated level of emotional excitation. In an analogous way,

the extent to which startle probes are primed by an aversive foreground may be constrained by the intensity of the foreground affect. The startle reflex, as an index of emotion, may be a better monitor of dispositions to behave affectively (i.e., of feelings or action tendencies) than of the fully activated, overt emotional displays that are readily observed in behavior.⁴

Changing Affective Associations

A basic assumption of this view is that the match or mismatch between a startle probe and a foreground context is based not on sensory similarities or differences, but on the fact that these stimuli activate common (or opposed) motivational response systems. To the extent that subjective report can index motivational states, the data encourage this interpretation. Thus, for example, for subjects who report that the startle probe itself is more aversive, blink reflexes are larger overall than for subjects who report that the probe is less aversive (Bradley et al., in press). Furthermore, for visual probe stimuli, the affect-startle effect is significantly more pronounced for subjects who later describe the probe stimulus as more unpleasant. These data are consistent with the hypothesis that unpleasant foregrounds and affective startle probes engage the same aversive motivational response system.

The notion of two general motivational systems was invoked by Konorski in explaining such phenomena as counterconditioning: "Appetitive and aversive reinforcers as events . . . generate, through the affective systems they arouse, mutually inhibitory and opposite effects on behavior" (Mackintosh's 1983 discussion of Konorski's theory, p. 115). Konorski (1967) emphasized that all positive reinforcers engage the same, basic positive response system; similarly, all negative reinforcers engage the same negative system. Thus, aversiveness (or pleasantness) is independent of the specific reinforcer that occasioned the affective reaction, and new reinforcers can be expected to modulate hedonic quality previously conferred by different, otherwise unrelated unconditioned stimuli.

The Rescorla-Wagner rule. Earlier, we proposed that the photographic slides used in this research engaged, to various degrees, these same appetitive and aversive response systems. If such stimuli, already affectively charged, are then used as CSs in an aversive conditioning experiment (i.e., if the slides are newly associated with unpleasant electric shock), what changes in the hedonic value of different slides should be expected? Except for studies of stimulus preparedness (e.g., Öhman, Fredrikson, Hugdahl, & Rimmö, 1976), classical conditioners have preferred to study stimuli that were initially neutral—pure tones, circles and triangles, and the like—and there is little data that bear directly on this question.

However, Rescorla and Wagner (1972) have described a law of conditioned association that is highly pertinent to the question of affective slide conditioning. They presumed that conditioning, in general, depends not only on the fact of an association between a stimulus and some reinforcer but, critically, on the degree to which a particular reinforcer is an expected sequel to that stimulus. Described as human experience, "a subject's beliefs about the consequences of a stimulus or of his [or her] own actions will change only when that stimulus or [the person's] actions are followed by an otherwise unexpected conse-

quence" (Mackintosh, 1983, p. 189). Described as a phenomenon of conditioning, the extent to which the pairing of a stimulus and a reinforcer will prompt a response change is constrained by the prior strength of association between that stimulus and reinforcer.⁵ Described in terms of the present view, the effectiveness of aversive conditioning (i.e., in making a stimulus more nocent) depends on the discrepancy between the strength of any nocent association originally attached to the stimulus and the strength of the aversive reinforcer. Thus, initially positive hedonic stimuli should show good conditioning to an electric shock stimulus; on the other hand, shock may be a redundant affective association for negative hedonic stimuli, and unpleasant slides should show relatively poorer conditioning.

Hedonic conditioning. In most previous conditioning studies using the startle probe, the CSs were assumed to be neutral (e.g., a brief light of moderate intensity; see Berg & Davis, 1984; Ross, 1961). However, in the Greenwald et al. (1988) experiment described earlier, there were five independent groups, each given different pairs of slide stimuli that varied systematically in affective valence: positive-A (nature scenes), positive-B (opposite-sex nudes), neutral-C (household objects), negative-D (feared animals—snakes and spiders), and negative-E (mutilated bodies). All groups demonstrated autonomic conditioning, such that the slides followed by shock subsequently occasioned larger skin conductance responses than did control slides of similar content. Furthermore, as previously noted, significantly larger probe blink responses were found for the slides conditioned to shock, relative to control slides.

An important hypothesis is that the startle probe measures hedonic association strength. If this is the case, the Rescorla-Wagner rule predicts that there will be systematic differences between slide groups in the strength of differential conditioning

⁴ Lang (e.g., 1984) defined emotions as "response dispositions or action sets" (p. 195). Similarly, Frijda (1986) stated "that 'action tendency' and 'emotion' are one and the same thing" (p. 71) and noted that Arnold (1960) described emotion as "felt action tendency." To the extent that theorists have identified emotion with the disposition to act, rather than the act itself, the startle probe would appear to be assessing the phenomenon that is currently of greatest interest to the field.

⁵ Rescorla and Wagner (1972) expressed this fundamental law of conditioning in the equation $\Delta V_{CS} = \alpha_{CS} \cdot \beta_R (\lambda_R - \bar{V})$. According to this formulation, the change in associability to a CS (ΔV_{CS}) is primarily a function of the discrepancy between the reinforcer actually occurring (λ_R) and the expected response (\bar{V}). When shock is the US, λ_R represents the aversive response set produced by this reinforcer. To the extent that an aversive response is already predicted on the basis of the CS (e.g., when it is a highly unpleasant slide), \bar{V} approaches the value of λ_R , and little change in associability to the CS occurs. On the other hand, when the CS does not predict an aversive response (e.g., when the slide is initially pleasant), there is a large discrepancy between the subsequent aversive reinforcer (λ_R) and \bar{V} , and larger changes in associability are observed. Thus, when applied to affective matches (and mismatches), the logic of this formula suggests that the amount of conditioning will be a function of the extent to which a CS is already associated with (or already predicts) the reinforcer's affective response set. The Rescorla-Wagner rule has recently been recognized as a special instance of a more general learning rule, termed the delta rule. For more discussion of the relationship between these learning rules, see Lynch, Granger, Larson, and Baudry (1989).

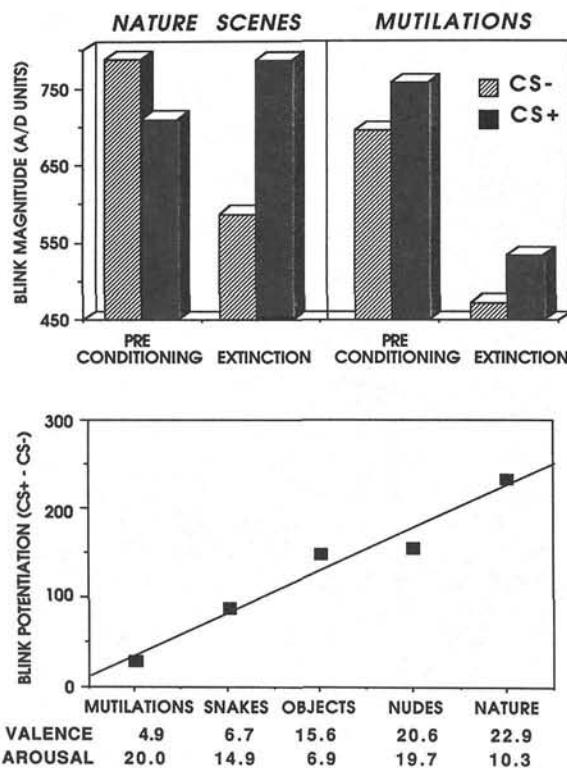


Figure 13. Top panel: Changes in the acoustic startle response as a function of aversive conditioning (shock) with pleasant (nature scenes) and unpleasant (body mutilation) slides. (For the nature scenes, CS⁺ probes were larger in amplitude after conditioning. Whereas a conditioning effect was apparent for the mutilation slides [CS⁺ is larger than CS⁻], probe magnitude at extinction was considerably less than during pre-conditioning slide trials.) Bottom panel: Mean difference in startle magnitude between CS⁺ and CS⁻, after conditioning, for each of the five valence categories. (Mean valence and arousal judgments, obtained prior to conditioning, are listed below each valence category. CS⁺ = conditioned stimulus, CS⁻ = control stimulus.)

at extinction, as measured by the startle probe. Startle-reflex amplitude to the CS (relative to a control stimulus probe) should be a monotonic function of the preconditioning hedonic value of the to-be-conditioned stimulus. Stated more prosaically, the strength of conditioning, as measured by the startle probe, should vary systematically with slide valence; it should be greatest for pleasant stimuli and least for unpleasant stimuli, where shock is more likely to be a redundant affective association.

Results for the groups with the most negatively and most positively valent stimuli—that is, slides of mutilation and of pleasant nature scenes (landscapes and flowers)—are presented in Figure 13. Prior to conditioning, for both contents, there were no within-group differences in amplitude of the probe reflex between the to-be-conditioned and control slides. Furthermore, both groups clearly showed a conditioning effect (during extinction, reflexes were larger for the CS than for its control stimulus). However, the amplitude of these conditioning effects clearly differed. For mutilation slides, the difference between the control and the conditioned slide (the one followed by shock)

was clearly smaller than that obtained for the initially pleasant nature scenes. Furthermore, the probe response to the conditioned mutilation slide habituated and at extinction did not exceed its preconditioning level. For the initially pleasant pictures of nature scenes, however, the conditioned slide clearly increased startle-probe amplitude after conditioning, and there was a larger difference between conditioned and control stimuli. When differences in probe responses between conditioned and control stimuli are examined over all groups (Figure 13, bottom panel), there is a significant linear increase in magnitude, according to the standard pleasantness ratings of the CSs. Furthermore, the effect is again not secondary to simple arousal. Initially pleasant, highly arousing slides (e.g., attractive nudes) generated relatively large startle reflexes during extinction, whereas for aversive slides of similar high arousal value (mutilations) the extinction probe responses were small.

These comparisons were also made after regrouping subjects according to their own preconditioning ratings of the conditioned and control slide stimuli. The valence-startle pattern was again confirmed; there was a greater conditioning effect for initially pleasant slides than for unpleasant slides. Furthermore, subjects showed a greater postconditioning increase in judged aversiveness to slides they had initially reported to be more pleasant, exactly paralleling the startle-probe results.

Unlike valence ratings, changes in reported arousal levels for the conditioned slide stimuli were not linearly related to probe amplitude. However, skin conductance, a reliable index of activity in the sympathetic chain, showed straightforward covariation with reports of arousal change. Smaller conductance differences between CSs and control stimuli were found for slides that were initially highly arousing (i.e., attractive nudes or mutilated bodies); larger conditioning effects were obtained for slides initially relatively low in arousal (i.e., spiders and snakes or nature scenes).⁶ These arousal effects were not related to the direction of hedonic valence. Thus, in this conditioning experiment, as in studies of the basic affective response to slide stimuli (e.g., Bradley et al., 1988, in press; Vrana et al., 1988), probe amplitude and skin conductance appeared to be independent measures of valence and arousal, respectively.

In its general statement, results for the conditioned startle probe and skin conductance were both consistent with the Rescorla-Wagner rule (i.e., conditioning is constrained by the extent to which the to-be-conditioned stimulus already evokes the to-be-conditioned association). The data point up, however, that modulation of these two measures by this learning rule is distinctly different, according to the nature of the conditioned association (i.e., valence or arousal). Furthermore, they suggest that if changes in hedonic valence are to be tested in future research, the probe reflex, rather than skin conductance, is the measure of choice.

⁶ Subjects were reorganized into three groups (each $N = 20$) on the basis of their own preconditioning arousal ratings of the slides. The difference in skin conductance response between conditioned and control slides for each of these groups was as follows: low slide arousal = .11, medium slide arousal = .06, and high slide arousal = .04. The linear trend over arousal groups was significant. Conditioned responses were defined by the formula, $\log(1 + \text{conductance change})$.

Conclusions: Attention and Emotion

Processing Categories: Modality and Affect

Organisms are always processing information, generated both internally and externally and varying continually in content and organization. From an empirical perspective, *attention* might be defined as the information that is being processed at a given period in time (presumably, organisms are always attending to something). If multiple time samples were obtained, clearly specifying information content and organization (no simple task), the primary attention question would become, What aspects of such information show either significant continuity or reliable patterns of change? To take the analysis a step further, are there *a priori* categories of information content (in terms of both ongoing processing and input) that describe these stable or repeatable changes in information patterns?

Work on the blink reflex in auditory and visual foregrounds, and with instructions specifying the modality of expected stimuli (see Anthony, 1985), suggests that sensory modality is one such category, that is, a classification parameter according to which the brain habitually organizes information. Thus, when input within a modality is being processed, new input in the same category (modality) has a higher probability of being processed than information from a different category (modality). This analysis also implies that the brain operates on a broad principle of associative match and that the categories of information currently active help determine what new information will be most easily integrated into current processing.

Anthony and Graham (1985) were quite specific about the mechanism of sensory information match:

An increase in response to a probe whose modality matched rather than mismatched that of the attention-engaging stimulus would be consistent with the hypothesis that activity in low-level afferent pathways can be modified selectively by attentional sets acting on automatic sensory-perceptual processing. (p. 45)

Their paradigm involves two external information sources, which encourages a theory of afferent system modulation. The neurophysiology, however, has yet to be clearly explicated. Thus, (as was suggested for the affect-startle effect) modality modulation may be based on perceptual response matching, rather than sensory system tuning, and the significant physiological control system may be predominantly efferent rather than afferent.

Similarities between these emotion and attention experiments, in both their logic and result, suggest that both affective valence and modality are basic categories of human information processing. For example, modality bias in reflex response clearly does not depend on an active sensory foreground. Several experiments have shown modality-determined reflex changes with verbal instructions (i.e., to attend to the auditory or visual channel, see Anthony, 1985). Similarly, we found that valence modulation of the probe occurs without affective stimuli being physically present; that is, the affect-startle effect can be demonstrated in imaginal recall. Anthony and Graham (1985) pointed out that because of the design of their experiments, "modality-match effects could not have been the result of a general, non-specific activation process" (p. 54). The same conclusion was drawn here for the valence-reflex relationship,

specifically, that it is not an artifact of differences in arousal level. Earlier, we showed that the sensory-selection hypothesis of the Anthony and Graham (1985) type cannot explain the reflex results for affective valence. However, in experiments where emotional excitation is controlled or minimized, modality appears to determine significant response variance. In effect, both parameters (modality and affect) may be natural categories into which the brain organizes information and according to which responses are deployed.

Summation and Directions for Research

We propose that emotional valence is a general information-processing category, with sensory, central, and response processing implications. A very broad associative link is suggested—from abstract affective judgments and sentence memory retrieval to obligatory reflex. The reflex priming noted here does not appear to be based on processing specific emotion schemata (e.g., a particular context-related information network as described by Lang, 1985) or on a tactical response match between the blink reflex and either an attentional response to external stimuli or the specific facial configuration in fear or distress. In this sense, the organism's valence disposition is seen to be strategic, representing a general response disposition.

The heuristic value of this view depends on obtaining specific, supporting data. Neither the mechanism by which common valence information is integrated centrally nor the paths of signal conditioning or reflex control are clear. In this regard, the importance of studying the interaction of strategic valence and arousal, and using probes to assess affects that show different tactical response patterns, has already been noted. It will also be necessary to confirm that reflexes other than the startle blink are modulated by valence. Requin (1988) has suggested that the proprioceptive reflexes of the limbs are good candidates. For these reflexes, the afferent and efferent physiologies are clearly delimited, and they can represent both an opening and closing response consistent with accepting and protective input postures. The broad assumption of emotion-strategic category processing suggests that appetitive reflexes (e.g., salivation in response to a sucrose probe) should also be investigated, because they are hypothesized to show effects reciprocal to the blink. Other defensive reflexes, such as withdrawal from pain, also need to be tested within this paradigm to determine whether they show the expected parallel with the startle response. Finally, this view implies overlap between independent neuromotivational systems in the brain—for example, between the fear, rage, and social loss systems described by Panksepp (1982). The search for an overall biphasic level of neurophysiological integration is encouraged by this reflex analysis.

In bringing this discussion to an end, several promising clinical applications of probe reflex analysis merit listing. First, the methodologies we have described could be of particular value in assessing pathological distortions of emotional reactivity: For example, psychopathic people have been viewed as affectively underresponsive (Cleckley, 1976), particularly when anticipating negatively valent, aversive stimuli (Hare, 1978). Anhedonic people, on the other hand—in the context of schizotypy, depressive pathology, or as a consequence of the aging process—are

described as underresponsive to positively valent stimuli (Chapman, Chapman, & Raulin, 1978; Simons & Russo, 1987). Probe analysis of these populations, in affective imagery and perception, could provide an illuminating test of both hypotheses. Second, the reflex probe could be of considerable value in the nosological analysis of anxiety-disordered patients (exaggerated startle is one of the diagnostic signs of posttraumatic stress disorder, *DSM-III-R*, American Psychiatric Association, 1987) and in evaluating fear responses to phobic material before and after therapy. Finally, these methods have application in both behavioral medicine and neuropsychology. Pain, for example, involves both sensory (attentional) and affective components (Tursky, 1976) and should systematically modulate probe responses. Affective disorders created by brain insult or injury may be indexed by changes in startle-probe modulation. This approach offers a new tool for analyzing all these phenomena and for monitoring pertinent aspects of treatment progress.

The main promise of this formulation, however, is in basic research on emotion. Its strength rests on a foundation of quantitative measurement of obligatory reflexes. It is thus easily related to both ontogenetic analysis (already shown in the attention studies of young infants) and to the phylogenetic study of animal models of emotion. Because of this measurement orientation, the approach is on the one hand less vulnerable to subjectivist error and on the other, demonstrably useful for the study of soft phenomena, such as feeling states, moods, or mental images. Finally, the theory shows promise for integrating the often conflicting affective dimension and state views of emotion, accommodating results from cognitive, behavioral, and psychophysiological research, and suggesting a link to the neurophysiological study of the brain.

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