

Chapter 8

The Innate Determinants of Affect

This chapter presents a theory of the most general innate activators of specific affects, and some of the more important implications of that theory. It seems possible to extract communalities from the diverse conditions, internal and external, that give rise to any given affect, and we will suggest that these communalities are the specific innate activators of the given affects. Before presenting the theory, we will begin with a definition of necessary terms and discuss briefly the role of drives as activators of affects and the role of special releasers (stimuli which innately arouse affect). In this connection we will conclude the chapter with a consideration of the imprinting phenomenon in animals, and present our theory of the nature of the imprinting mechanism, which is a derivative of our general theory, and of our emphasis on the central role of the affect system.

WHAT ARE AFFECTIVE RESPONSES?

Affects are sets of muscle and glandular responses located in the face and also widely distributed through the body, which generate sensory feedback which is either inherently “acceptable” or “unacceptable.” These organized sets of responses are triggered at subcortical centers where specific “programs” for each distinct affect are stored. These programs are innately endowed and have been genetically inherited. They are capable when activated of simultaneously capturing such widely distributed organs as the face, the heart, and the endocrines and imposing on them a specific pattern of correlated responses. One does not learn to be afraid, or to cry, or to startle any more than one learns to feel pain or to gasp for air.

DEFINITION OF TERMS

We will use the term affect, or affective responses, to refer both to the total set of components of this complex and as an adjectival term in the following sub-sets which we will distinguish within this complex: 1) innate affect programs, 2) innate affect program activators, 3) learned affect program activators, 4) affect motor messages, 5) affect motor and glandular responses, 6) affect sensory feedback, 7) conscious affect sensory feedback, 8) affect memory traces, 9) retrieved affect images, 10) retrieved conscious affect images, 11) innate affect to transformed retrieved memory images, 12) innate affect to transformed percepts, 13) affect accretions.

Let us now describe and define each of these affect components.

First, by innate affect programs we refer to what is inherited as a subcortical structure which can instruct and control a variety of muscles and glands to respond with unique patterns of rate and duration of activity characteristic of a given affect.

Second, by innate affect program activators we refer to the stimuli, internal and external, which innately activate such an innate affect program as well as the structures by which such stimuli activate the innate subcortical programs. Thus, the awareness of pain will innately activate the affect program which controls the crying response in the human infant.

Third, by learned affect program activators we refer to those modifications in the affect program activators which are the result of learning. Thus the infant who at two months will smile at any human face will smile only at a familiar face five months later.

Fourth, by affect motor messages we refer to the sets of motor messages emitted as part of

an affect program from subcortical sites to motor nerves widely distributed throughout the body.

Fifth, by affect motor and glandular responses we refer to the muscular and glandular responses which are initiated and modulated by innate affect programs transmitted over motor nerves and circulatory pathways. An affect motor or glandular response does not always have a one-to-one relationship with the affect motor message which triggered it off. Thus a message which would ordinarily result in an acceleration of the heart rate might in fact produce a slowing of the heart rate, if the heart is operating at peak rate at the time that the affective message to accelerate arrives at the appropriate site. This would be a special case of the Law of Initial Values whereby the effect of any stimulation is a conjoint function of that message and the particular state of activation of the target organ involved.

Sixth, by affect sensory feedback we will refer to the sensory feedback, direct and indirect, which is the consequence of the muscular and glandular responses activated by the affect program. Thus the messages from the sensory receptors around the mouth constitute part of the feedback of the smile which is programmed from a subcortical joy center. We will call this part of the affective response whether this information is transmuted into conscious form or not. Much of the feedback from affective responses may never reach consciousness, or reach it only in attenuated form.

Seventh, we will use the term conscious affect sensory feedback to refer to the consciously experienced feedback of the innate affect programmed muscular or glandular responses. Even when the same individual twice emits the same set of affective responses, and the target organs are in identical states of receptivity and respond alike, the conscious experience may vary widely as a function of what other messages are simultaneously assembled in the central assembly. The central assembly is a term we shall use to refer to the transmuting mechanism (the mechanism that transmutes messages in the nervous system into conscious reports) plus those components of the nervous system which are functionally connected with the transmuting mechanism at a given moment in time. It is our somewhat unortho-

dox view, which will be elaborated at length later in the third volume, that the components of the nervous system which are functionally joined to the transmuting mechanism vary from moment to moment. This concept of a central assembly whose components change, as well as the concept of changing information within the channels of the components of the central assembly, obviously implies that different parts of the sensory feedback from the same set of affective responses may or may not reach consciousness. At two different times the individual may be aware of his pounding heart but not of the perspiration on his brow, and conversely. At different times the same part of the affect set may receive differential conscious representation. Both the heart beat and perspiration may at one time be in the background of awareness as the individual's consciousness is primarily engaged, for example, in the tactics which will avoid what appears to be an imminent automobile accident. At another time the same affective information may flood consciousness with free-floating objectless anxiety when there is no apparent cause, attention to which might have attenuated the intensity of the experienced affect by competition for the limited channel capacity of consciousness.

Eighth, we will use the term affect memory traces to refer to memory traces of past experience of affect. Along with every other kind of past experience which was once conscious, we assume that the experience of affect is automatically registered as a memory trace. We conceive of such registration of affect as an automatic process, independent of learning.

Ninth, we will use the term retrieved affect images to refer to affect imagery which is retrieved from memory, and which may be conscious or unconscious. We assume that in perception incoming sensory information is compared with a centrally constructed analog which is retrieved from long-term storage. The conscious experience of the sensory information is indirect, through the constructed central imagery which ordinarily matches the input in varying degrees: In the dream or in the phantom limb, however, it may be emitted only from memory. Just as sensory information may or may not reach

conscious form, we believe that centrally retrieved information may or may not reach consciousness. Since there is competition from several sources for a mechanism which has demonstrable channel limitations, affect imagery retrieved from memory may not reach conscious form if it encounters a full channel. Thus an individual may have retrieved specific affect messages which continued to bombard him throughout a busy day but which could reach awareness only when driving home from work, when he may suddenly become aware that today is an anniversary and that he is happy or sad.

Tenth, we will use the term retrieved conscious affect images to refer to such imagery when it is transformed into conscious form. In much the same way that one can play blindfold chess through reliance upon centrally retrieved visual imagery, so we argue that there is affect imagery which is indistinguishable from perceived affective sensory feedback, as the nightmare may be indistinguishable from the waking world or as a "phantom limb" is indistinguishable from a real limb. Such conscious affect imagery may in turn activate an affect program, although it may not. Thus the awareness of a feeling of sadness via central imagery may in turn activate a program which will in turn produce a facial response of oblique eyebrows and down-turned mouth which will, as feedback reaching awareness, continue and amplify the imagined sadness. On the other hand the face may continue to be impassive but the individual continue to feel sad.

Eleventh, we will use the term innate affect to transformed retrieved memory images to refer to those responses activated by innate programs, in response to centrally retrieved memory images, where the affect produced was not part of the memory. This may happen when the memory image is itself without stored affective information, or when the memory image would have been accompanied by retrieved affect imagery, but for the interference from the activation of a different affect as a result of some transformation of the retrieved memory images. As an example, upon remembering a joke which originally seemed very funny and which had provoked much laughter, the retrieval of this information is in part faithful to the original information except that

the "build-up," the "punch-line" and the laughter are retrieved as simultaneous data, whereas they were originally experienced sequentially. Because of this cognitive transformation upon the memory trace, the original affects of excitement, surprise and laughter are not retrieved from memory, but instead the present affect is usually a smile, which is triggered by a specific innate program, but distinct from the affect program of excitement, surprise and laughter.

Twelfth, innate affect to transformed percepts refers to the same dynamic except that the transformation is upon the perceptual interpretation of afferent sensory information. Thus if someone retells the same joke in rapid succession, the cognitive transformation on the central assembly which includes this incoming information will sufficiently attenuate its novelty so that the affect which is evoked is at best a smile rather than the original affect.

Thirteenth, affect accretions refer to the learned accompaniments or substitute responses which come to accompany the activation of innate affect programs. Thus if every time a person cries in distress he clenches his fist, this is an affect accretion and usually comes to be experienced as part of the affect of distress. If the cry should be inhibited but the clenched fist continue to be activated every time the innate affect is activated, then we will also consider that this remains an affect accretion, despite the interference with the innately programmed affect motor and glandular responses by competing motor messages.

THE DETERMINANTS OF AFFECT

The affect system is a multi-function one. It can in fact be activated by drives, by special releasers, by other affects and by memory, imagination and by thinking. We will argue for a radical dichotomy between the "real" causes of affect and the individual's own interpretations of these causes and that it is the latter which ultimately are responsible for transforming motives into governing Images.

Although there are affect activators which are quite independent of any learning or interpretive

activity, no sooner do memory and analysis come in to play than they too become activators of affect as potent as any of the inherited mechanisms. Indeed, it is the inheritance of a flexible, varying central assembly structure capable of activating and combining affect with varying components of this assembly that, we propose, guarantees the basic freedom of the human being. This is to be distinguished from the doctrine of association and of mediation. We are here arguing for an inherited capacity for evoking affects directly by memory or idea. What is produced as a consequence of storage or analysis or both is capable of “really” evoking distress as directly as stubbing one’s toe, or as directly as any “releaser” evokes affect. Some of the determinants of affect are innate, some are learned. The capacity for learning to activate affects however is itself an innate one. Similarly, we learn our native tongue, but the capacity to learn speech depends on inherited structures which are not found in animals other than men. This capacity to learn new objects of affect combines with drive activation, specific releasers and activation by other affects to produce the graded freedom of the affect system.

Drives Make It So

How drives activate affects we have already examined in some detail. In Chapter 2 we stressed the dependence of the drive system on the affect system, since this direction of the interdependency is greater than has been realized. Here, however, we wish to stress the dependence in the other direction. If one pinches the skin of the neonate, the pain will produce immediate distress and crying and so will numerous other drive stimuli. To the extent to which the drive system is in a continuing state of activation the infant enjoys relatively little freedom with respect to his affects or the behavior which combined drive and affect urge on him. This restriction of freedom is in the “best interests” of the helpless organism, guaranteeing attention, by him and his parents, to his vital needs. Nonetheless, compared with special releasers, other affects and cognition as determinants of affect, drive determination

represents the low point in choice. A life spent in pain or in hunger is almost certainly a life spent in distress.

Releasers Make It So

How special “releasers” evoke affect we are beginning to learn from the work of Tinbergen, Lorenz, Hess and the ethologists. Paradoxically, we know more of the special stimuli which evoke animal affect than we know of the innate stimuli to human affect.

Numerous instances of innate releasers of affects have been reported by the ethologists. Thus a gosling will emit fear to a model of flying birds if the model has a short neck like a hawk. It emits no fear to a model of a flying goose with a long neck out in front. If the same model goes backwards over the heads of the geese, they emit the same fear reaction as to the model like the hawk. Specific releasers have also been reported for the affect of aggression and its behavioral consequence, fighting. The spring fighting of male sticklebacks is especially directed against other male sticklebacks in nuptial markings. Since the males have intensely red throat and belly, Tinbergen presented models which were very crude imitations of sticklebacks lacking many of the characteristics of the species or even fish in general, but which did possess a red belly. Other models were accurate imitations of sticklebacks but had no red coloring. Thus, the red color was put into competition against all other morphological characteristics. The males attacked the unsticklebackish red-colored model more than the uncolorful imitation. This specificity of reaction, Tinbergen claims, is not because the eyes are unable to see these other details, but because the other aspects are neglected under the pressure of the releaser stimulus.

Our knowledge of the specific activators of human affects is rudimentary but nonetheless important. It is restricted, as we have noted, to some of the conditions activating startle, the smiling response and the shame response.

Nonetheless the general proposition that affects in some organisms may be activated by specific

releasers other than through drive stimuli seems beyond dispute.

A Theory of the Innate Activators of Affects

Inasmuch as we have argued that the affect system is the primary motivational system, it becomes critical to provide a theory of the innate activators of the affect system. We do not believe that the "specific releaser" theory provides an adequate account of the innate basis of affect activation in human beings, despite its persuasiveness in accounting for imprinting phenomena among birds and fishes. The affect system in man is activated by a variety of innate activators, such as drive signals and other affects as well as external activators. The most economical assumption upon which to proceed is to look for communalities among these varieties of innate alternative activators of each affect. We have done this and we believe it is possible to account for the major phenomena with a few relatively simple assumptions about the general characteristics of the innate, unlearned activators of affect.

In Figure 3 we have graphically represented this theory.

We would account for the differences in affect activation by three general variants of a single principle—the density of neural firing or stimulation. By density we mean the product of the intensity times the number of neural firings per unit time. Our theory posits three discrete classes of activators of affect each of which further amplifies the sources which activate them. These are stimulation increase, stimulation level, and stimulation decrease. Thus there are guaranteed three distinct classes of motives—affects about stimulation which is on the increase, stimulation which maintains a steady level of density, and stimulation which is on the decrease.

With respect to density of neural firing or stimulation, then, the human being is equipped for affective arousal for every major contingency. If internal or external sources of neural firing suddenly increase, he will startle, or become afraid or become interested, depending on the suddenness of increase

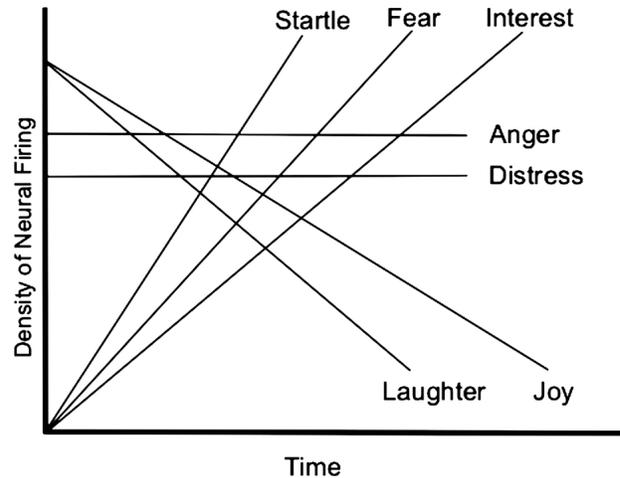


FIGURE 3 Graphical representation of a theory of innate activators of affect.

of stimulation. If internal or external sources of neural firing reach and maintain a high constant level of stimulation, he will respond with anger or distress, depending on the level of stimulation. If internal or external sources of neural firing suddenly decrease, he will laugh or smile with enjoyment, depending on the suddenness of decrease of stimulation.

The general advantage of affective arousal to such a broad spectrum of levels and changes of level of neural firing is to make the individual care about quite different states of affairs in different ways. It should be noted that according to our views there are both positive and negative affects (interest, fear, startle) activated by stimulation increase, but that only negative affects are activated by a continuing unrelieved level of stimulation (distress, anger) and only positive affects are activated by stimulation decrease (laughter, joy). This latter in our theory is the only remnant of the tension reduction theory of reinforcement. Stimulation increase may, in our view, be punishing or rewarding depending on whether it is a more or less steep gradient and therefore activates fear or interest. A constantly maintained high level of neural stimulation is invariably punishing inasmuch as it activates the cry of distress or anger depending on how high above optimal levels of stimulation the particular density of neural firing is. A suddenly reduced density of stimulation is invariably rewarding, whether, it should be noted,

the stimulation which is reduced is itself positive or negative in quality. Stated another way, such a set of mechanisms guarantees sensitivity to whatever is new, to whatever continues for any extended period of time and to whatever is ceasing to happen, in that order.

Let us first consider startle, fear and interest. These differ with respect to activation only in the rate at which stimulation, or neural firing, increases.

Startle appears to be activated by a critical rate of increase in the density of neural firing. The difference between startle (or surprise in its weaker form) and interest is a difference in the steepness of the gradient of stimulation. The same stimulus therefore may evoke surprise or interest, depending on the steepness of the rise of stimulation (which in turn depends on numerous factors prominent among which is the degree of unexpectedness) or it may evoke first surprise, then interest, or it may evoke interest and then surprise, or surprise and then some affect other than interest. Let us consider each of these possibilities.

Whether a stimulus activates surprise or interest will depend on just how rapidly density of stimulation increases. Thus a gunshot will evoke startle rather than interest. An unexpected tap on the back of the shoulder by someone who is not seen will also evoke startle rather than interest. In the case of the gunshot the suddenness of increase of stimulation was primarily in the auditory stimulus itself. In the tap on the shoulder the suddenness of this stimulus might have been sufficient but the over-all density of stimulation was so low as to have been insufficient to become conscious, in the competition between messages for transformation into reports. We assume that such a weak stimulus must recruit information from memory which has a steep rate of increase of neural firing to activate a sequence of further more rapid retrievals which summate to activate startle. If the same person is somewhat less unexpected and seen gradually approaching, such stimulation may be just steep enough in increased density of stimulation which it recruits to activate interest or even excitement (the more intense form of interest) without preliminary startle or surprise.

If the stimulation rises in density so steeply that startle is evoked, the further exploration of this object may recruit, from the combined sensory and memory sources, perceptual messages of sufficient acceleration of stimulation density to evoke interest in the continued exploration of the object. The affect of interest may itself also activate startle rather than the converse. As we have noted before, the "double take" is such a case. Here the individual first responds with interest in looking at an object, which is weak and very brief, but sufficient to activate further retrieval from memory which produces a sudden enough change in stimulation to evoke interest, which, combined with the ongoing retrieval of further information now provides a sufficiently steeper increase of stimulation to startle the individual and then to support further interest and a second look at the object. Startle need not of course be followed necessarily by interest.

There are at least two other possibilities. One is that as soon as the startling object is identified and it proves to be a very familiar object interest can be sustained only momentarily. The other possibility is that the object evokes some affect other than interest or excitement. Thus the identified person may turn out to be a familiar person who evokes the smiling response, since as we will see, one of the activators of the smile is the relatively sudden reduction of negative stimulation, or the relatively sudden reduction of startle or interest. The individual who appears unexpectedly may also activate fear rather than interest immediately after the startle. Our theory of the mechanism of fear activation is that it lies midway between startle and interest among the density of stimulation gradients. If a stimulus or set of stimuli, internal, external, or both, increase with maximum acceleration, the startle is activated. If the density of stimulation increase is less steep, fear is activated, and if it is still less steep, interest or excitement is activated. The intensity of each of these affects, whether it is surprise or startle, whether it is fear or terror, whether it is interest or excitement, depends, we think, on the absolute level of density of stimulation rather than the gradient of the rate of change. Thus a change from one loudness to another

might startle, frighten or interest, depending on the gradient of change of stimulation, but whether it evoked surprise or startle, or interest or excitement, or fear or terror would depend on the absolute density of stimulation involved. A gunshot would startle, whereas a toy cap pistol would surprise, though both involve the same gradient of sudden stimulation.

If startle, fear and interest differ with respect to activation essentially only in the rate at which stimulation or neural firing increases, then we can account for the unstable equilibrium which there seems to be between them. First, it would illuminate the familiar sequence of startle, fear, interest. The same object which first startles quickly passes over into fear and this somewhat less quickly is transformed into interest or excitement. Lorenz has reported the characteristic lability of fear and excitement in the raven who, on first encountering anything new, flies away, up to an elevated perch and stares at the object for hours, after which he gradually approaches the object, still showing considerable fear. As he comes closer, he hops sideways with wings poised for immediate flight. Finally he strikes one blow at the object and flies right back to his perch. This sequence is repeated until eventually he loses interest in it. Harlow and Zimmerman have also noted the alternation between escape from and exploration of the feared object when the model mother is present. The infant monkey alternates between clinging to the mother and, when the fear has somewhat abated, going forth to explore the object and then returning to the mother.

This lability, which is based on a similarity of activators, would also account for the paradoxical conversion of electric shock into an activator of interest rather than fear. Pavlov reported that by appropriate gradualness of training procedure he could produce in dogs conditioned salivation to an electric shock which preceded the presentation of food. It could further account for the self-conscious titillation of excitement in human beings through the confrontation of danger which is sufficiently threatening to arouse a delicately balanced ultra-labile compound of excitement and fear. Sexual excite-

ment may also be intensified through the pursuit of the tabooed, feared object if the fear can be kept within bounds.

In comparison with startle and fear, the affect of distress appears to be based not on an increase of density of stimulation, but rather on an absolute level of density of stimulation or neural firing. Thus pain characteristically produces crying in the infant. The suddenness of pain is not the critical feature of the activation of distress. Thus a sudden stab of pain elicits an equally sudden scream of distress, but prolonged pain ordinarily produces prolonged crying. In contrast to fear, it is the total quantity or density of stimulation over time which further increases the density of stimulation through crying. It is the quantity rather than the quality of stimulation which appears to be critical. The cry and moan of excessive sexual pleasure in intercourse is an example of stimulation which is predominantly pleasurable, nonetheless evoking a cry of distress. If distress is activated by a general continuing level of non-optimal neural stimulation, then we can account for the fact that such a variety of stimuli from both internal and external sources can produce the cry of distress in the infant and the muted distress response in the adult. These range from the low-level pain of fatigue, hunger, cold, wetness, loud sounds, overly bright lights to the cry itself as a further stimulus.

This theory would also account for some of the observed differences in types of affect which specific drives recruit as amplifiers. Thus according to our view the sudden interruption of the air supply activates fear, whereas hunger drive characteristically first activates interest, because the former produces a more dense and steeper gradient of stimulation. As the hunger drive signals gradually increases to a higher and higher level of neural stimulation, interest changes to distress, but not to fear. We should expect, on the basis of our theory, that variations in metabolic rate between different animals should be accompanied by similar variations in the hunger drive between an extreme of steepness of gradient of stimulation in the case of animals with very high metabolic rate, who must eat often to survive, to an

extreme of low-level stimulation from the hunger drive signal, with a very gradual gradient of neural firing. For some animals, hunger would have effects similar to interruption of the air supply and activate fear, and for others, with a very low metabolic rate, hunger would rarely activate any affect and then only distress, as the level of neural stimulation gradually rose with deprivation.

Further, the characteristic differences between hunger and air on the one hand and the sex drive on the other would also be a consequence of differences in gradients and levels of neural firing. In man, sexual stimulation is often enough sudden and peaked in arousal to activate excitement, but not so steep a gradient as to activate fear as in the interruption of the air supply. In the lower forms, as Olds has shown, each subcortical site of affective stimulation appears to have its own associated site of affective stimulation (in the joy and aversive centers). In man this may also be true, but it seems more likely that the drive signals may activate fear, excitement or distress in the same manner as any other set of messages in the nervous system, i.e., on the basis of gradients and levels of neural stimulation.

Another affect which is activated by the absolute density level of stimulation is anger. It is our assumption that anger is activated by a higher density level of stimulation than is distress. Hence, if a source of stimulation, say pain, is adequate to activate distress and both of these continue unrelieved for any period of time, the combination of stimulation from pain and distress may reach the level necessary to activate anger. This is also why frustration may lead to anger. Further, either distress alone or pain alone might be sufficiently dense to activate anger. Thus a slap on the face is likely to arouse anger because of the very high density of receptors on the surface of the face. In contrast a stab of pain elsewhere in the body may lack both the requisite density and the duration to activate more than a cry of distress. This principle would also account for the irritability produced by continuous loud noise which would tend to recruit widespread muscle contraction, which, added to the distress affect, could raise the density of stimulation to that necessary for anger. We will examine further consequences when

we discuss anger as a separate affect. We wish at this point only to contrast such a mechanism of activation with that which we have postulated for interest.

Finally, in contrast to stimulation increase and stimulation level, there are also affects which operate on the principle of stimulation reduction. The smile of joy and laughter are the primary examples of such a mechanism. The relatively steep reduction of pain or excitement or distress or anger will produce the smile of joy which represents relief in the case of pain and distress, the smile of triumph in the case of anger and the smile of familiarity in the case of the sudden reduction of excitement.

The smile of joy to the sudden reduction of stimulation accounts for several very disparate phenomena. On the one hand it would account for the incremental reward of the sudden cessation of any negative stimulation, such as pain, distress, fear, shame or aggression. On the other hand it would account for the very different phenomenon of the enjoyment of the familiar. If we assume that any unknown but familiar stimulus will first produce interest, with a sudden increase in neural firing from the feedback of this affective response, and then an equally sudden reduction of this stimulation when the familiar stimulus, e.g., the face, is recognized as familiar, then this latter will in our theory activate the smile of joy and so reward the individual for re-establishing contact with a familiar object, personal or impersonal.

The same type of mechanism, we believe, operates in the affect of shame, except that stimulation reduction is incomplete compared with joy, and appears to be restricted to the reduction of positive affects themselves rather than any kind of stimulation. Hence any barrier to exploration, whether because one is suddenly looked at by one who is strange, or because one wishes to look at or commune with another person, but suddenly cannot because he is strange, or one expected him to be familiar but he suddenly appears unfamiliar, or one started to smile but found one was smiling at a stranger—any of these which involve an interruption and incomplete reduction of interest or smiling will activate the lowering of the head and eyes in shame and thereby

reduce further exploration powered either by excitement or joy.

Some Evidence on the Imprinting Mechanism

A complex instance of a specific releaser of affect is the phenomenon Lorenz called *imprinting*, in which the first object to elicit a social response continued later to elicit that response and also related responses such as sexual behavior. The failure to appreciate the importance of the affective system has led to much of the difficulty in understanding this phenomenon. Hess has reported an example of a jungle fowl cock which he imprinted and isolated from his own species for the first month of its life. This animal, though he spent much of the next five years with his own species, sexually courts human beings rather than his own species.

Lorenz has suggested that it is the motor pattern which is inherited and not the recognition of the stimulus which will release it. He conceives of it as an endogenous activity directed towards members of the species, for which no innate releasing stimulus exists. Hess has shown, however, that stimuli *do* vary in effectiveness of imprinting and that they therefore should be conceived of as releasers with wide variations in stimulus characteristics—but essentially similar to instinctive releaser phenomena. Hess further suggests that although there are wide variations in the characteristics of imprintable objects, once the animal reacts to the releaser, the *specific* characteristics of that particular releaser are learned and later become the only stimuli capable of eliciting this response.

Hess has presented several lines of argument and evidence to support the hypothesis that imprinting involves different mechanisms than the typical associative learning which results from food reward.

First, in contrast to associative learning, massed practice is more effective than distributed practice. Second, primacy is more important than recency in contrast again to learning. Thus two groups of ducklings, one imprinted on a male mallard model and then on a female model, the other in

reverse order, each preferred the model to which they had first been imprinted. Third, punishment rather than decreasing imprinting increases its effectiveness in contrast to associative learning.

If the human experimenter steps on the toes of the young mallard while he is being imprinted, during the critical period, he does not run away in fear, but rather stays closer to the punitive experimenter. Fourth, the tranquilizer meprobamate does not interfere with learning a color discrimination problem, but reduces imprintability to almost zero.

Finally, Hess cites the following experiment:

In one condition young chicks were exposed to triangles or circles which they could look at but with no food reward. In a second situation, young chicks were fed in boxes lined with small circles or triangles. In the third situation the chicks were rewarded with food for responding to triangles several thousand times. These latter chicks under non-reinforcement conditions pecked at these triangles about the same as the controls. They dropped from 85 percent pecking to about 25 percent. The chicks that had been fed in the presence of circular or triangular forms later showed a depressed pecking preference for the familiar stimulus. The chicks who had been exposed to the triangle or circle without food reward spent more of their time near the familiar stimulus than near the strange stimulus. During the first few hours of their life food reinforcement is not as critical as a social response made to an attractive object.

Hess has contributed much to our understanding of why certain young animals later show a preference for being with the object they had been exposed to during the first few hours of their life. Let us examine some of his experimental evidence before we return again to the question of the nature of this phenomenon.

Hess used newly hatched wild mallards on a circular runway around which a model decoy duck was moved. The decoy was fitted internally with a loud speaker and a heating element. It was suspended two inches above the center of the circular runway and could be rotated on arms connected to a motor. As the mallard duckling was released on the runway the sound was turned on in the decoy model

and it began to move. The sound used was an arbitrarily chosen one of a human voice saying “gock, gock, gock.” This was emitted continuously during the imprinting procedure. The duckling remained in the apparatus about an hour and then returned to its incubator. The test for imprinting was to release the duckling halfway between two duck models, four feet apart. One model was the decoy which had been used to imprint, the other was a female model which differed only in coloration. The male model emitted the same “gock” sound, the female emitted the call of a real mallard female calling her young.

There were four test conditions: 1) both models stationary and silent; 2) both stationary and calling; 3) the male stationary and the female calling; 4) the male stationary and silent and the female moving and calling.

If the duckling gave a positive response to the imprinting object in all four tests, imprinting was regarded as complete, or 100 percent. One minute was allowed for the duckling to make a decisive response to the silent models. At the end of a minute the sound was turned on, regardless of the duckling's response.

The ducklings were imprinted at various ages after hatching. Although some imprinting occurred immediately after hatching, 100 percent imprinting occurs only in those ducklings imprinted when 13 to 16 hours old. Thirty-two hours after birth imprinting is all but impossible and even after 24 hours of age imprinting scores average less than 20 percent. Age is still a potent factor however. Comparing the average scores for the animals between 24 and 32 hours old with those 36 to 52 hours old, the former scores average 60 percent against the latter score average of 43 percent.

In field tests, in which laboratory imprinted animals were put in a duck pond with the decoy model pitted against a real mallard duck, they followed the laboratory mother and avoided the real mallard. Mallards hatched in the laboratory but not imprinted followed the live mallard.

Color and form preferences in the imprinting objects were investigated and reliable differences in the effectiveness of different colors and forms were found.

Hess has presented evidence that the strength of imprinting varies logarithmically with the effort of the animal to get to the imprinting object during the period ($I_s = \log E$). In one series the distance the animal had to travel to keep up with the decoy varied but the time in which he had to travel this distance was kept constant (ten minutes). Increasing the distance when the time was held constant increased the strength of imprinting, up to fifty feet, after which there is a leveling of this effect. Then the distance traveled was held constant but the time during which this distance was traversed was varied. This made no difference in the strength of imprinting. From these two experiments Hess concludes that it is not the duration of the imprinting experience but the effort exerted in following the imprinting object. In further test of this interpretation he placed 4-inch hurdles on the runway which had to be cleared by the duckling in pursuit of the decoy. These animals made higher imprinting scores than those which had traveled the same distance without the hurdles. In another experiment the duckling had to follow the decoy up an inclined plane and this also increased the strength of imprinting.

Then an experiment was designed to prove that it was the distance walked by the duckling, whether or not the decoy followed a moving object. This was done by using two identical decoys three feet apart. One was lit and quacking. When the duckling reached this illuminated quacking decoy, light and sound were turned off and turned on at the other decoy. The duckling in this way was shuttled back and forth between what appeared to be the same decoy (albeit somewhat mysteriously displaced in space and time). Again the strength of imprinting varied with the amount of walking, and, presumably, effort.

Hess next turned his attention to the nature of the critical period—why imprinting did not appear full blown at birth and why it disappeared so rapidly after 16 hours. He found two factors responsible for the time shape of the imprinting curve: one the increasing ability of the animal to walk, the other the increasing incidence of fear which interferes with further imprinting to new objects.

Immediately following birth, Hess found, chicks show no fear until 13 or 16 hours after

hatching. Beginning at this time more and more animals show fear until 33 to 36 hours by which time all of them show fear.

The ability to walk increases from birth to hours, as measured by the average speed of each age group. If the percentage of animals showing fear and the percentage of animals able to move three feet a minute or more are plotted together, this curve resembles the empirically derived imprinting curve, although somewhat lower than this hypothetical curve.

Hess believes that all animals that are imprintable will have a critical period which ends with the onset of fear. For the human being, he therefore derives a theoretical end to imprinting at about five and one half months—the time at which the onset of fear has been reported in children. Indeed, Hess believes it would be possible to predict the critical period of imprintability knowing only the time of onset of fear.

Hess pursued the nature of the following response further by analyzing the relationship between its “distress notes,” “contentment tones” and orienting behavior. Distress notes have high intensity, medium pitch, one-fourth second duration—emitted with little modulation in bursts of five to ten notes. They are easily distinguished, according to Hess, from contentment tones, which are high-pitch, low-intensity notes, each lasting about one-twelfth second, emitted with much pitch modulation in bursts of three to eight notes. During distress notes the head is usually held high whereas it is held down during the emission of contentment tones.

In an experiment similar to the first few minutes of the imprinting procedure, naive broiler chicks that had never experienced light before were observed as they approached a stationary model. The younger the animals, beginning immediately after hatching, the more they oriented toward and tried to move under the cover of the nearby model. Although it was more difficult for the younger chicks to reach the model because of poorer locomotor development, they nonetheless covered the distance in less time than the older chicks. Indeed they covered the distance not by walking but by what Hess de-

scribes as a kind of tumbling, using both feet and wings as supports, which left them exhausted on covering the few inches between themselves and the warm, illuminated model mother. These animals tended to emit contentment tones to the model. As the animals got older the proportion of animals orienting toward and approaching the model steadily declined, as did the contentment tones. This decline in orientation toward the source of warmth and shelter was paralleled by a decrease in contentment tones and an increase in emission of distress notes, even in the presence of the lit, warm, sheltering model.

The critical effect of fear or distress was further investigated with tranquilizing drugs—meprobamate and chlorpromazine. The former drug does not interfere either with locomotor or perceptual performance in these animals. The learning of a color-discrimination problem was not at all depressed by meprobamate. The effect of the drug on the ducklings was to markedly reduce the fear of strange objects or persons. Contrary to expectation it also reduced imprintability, though the other tranquilizer, chlorpromazine, did not.

Finally, it proved possible to breed ducklings who were highly imprintable by using parents who had shown high imprintability. Hess reports reliable differences even in the first generation in the imprinting behavior of the separated groups. Different breeds of birds are known to show different degrees of imprintability and animals who are domesticated, such as the Leghorns, are not easily imprintable.

An Affect Theory of the Imprinting Mechanism

How are we to interpret these results? The critical problems are why does it occur at all, why does it occur when it occurs, why does it continue to occur to the same object, why does it not continue to occur to the other objects?

It occurs in the first place, we believe, because the animal is born with an innate perceptual sensitivity to “objects” with certain general characteristics ordinarily possessed by adult members of his own species—size, warmth, color, shape and so on. Although there is a broad spectrum of variation for

all of these characteristics, nonetheless as Hess has shown, the animal does not imprint equally well to every variation of these characteristics. Harlow has shown that the pneumatic quality of the terrycloth-covered model mother is more rewarding to the young monkey than any wire mother who offers food without such comfort.

Secondly, these qualities innately release intensely rewarding positive affective responses in addition to the pleasure and creature comfort of contact with the protective, feeding mother. In laboratory experimentation these latter effects of contact are minimized and the imprinting still takes place, so we must suppose the positive affective responses are sufficiently rewarding to produce the imprinting response without auxiliary drive reinforcement.

That imprinting is in large part the consequence of the differential threshold of two affects—one positive and rewarding, indicated by so-called “contentment tones,” the other negative, indicated by “distress notes”—seems reasonably clear. Hess has noted the correlation between these indices of affect and the consequent approach and avoidance behavior toward the same model, paralleling the strength of the imprinting.

Hess’s argument that it is the effort of the following response which is the primary factor in imprinting is problematical. To some extent this is an artifact of the criterion which is employed to evaluate the phenomenon. If it is the *preference* based on the positive affect which the object evokes, which is the heart of the matter as we are proposing, then even by the evidence Hess has presented the effort per se need not be very great to guarantee this preference. In the experiment cited before in which chicks were exposed to a triangle or a circle, one at one end of a box, the other at the opposite end, some distance away, they could *not* follow the object for any distance but they could orient to it or sit near it, but remained separated from the object by a Plexiglas wall which was six inches away from the circle and six inches away from the triangle. This preference for the object was revealed on subsequent test in that they spent more of their time near this familiar stimulus than a strange one when offered the choice.

Another limitation to the effort of walking hypothesis is that it is not a strictly linear function. It appears to level off between 50 and 100 feet of walking. Increases in walking and effort beyond this distance do not increase the strength of imprinting beyond 80 percent.

Yet the evidence of logarithmic linearity which holds for the most part is impressive and any alternative to the maximum effort theory must account for it.

We would account for it in the following way: Any stimulus or response by the young animal which increases the intensity and awareness of the excitement or joy response, or both, increases the strength of imprinting. Requiring the animal to exert itself more is one way of heightening the positive affective response and Hess has presented evidence that contentment vocalization is emitted by just those young animals who have the greatest difficulty getting to the mother, but who nonetheless do it in the shortest time, supporting themselves on legs and wings because they cannot yet walk very well and arrive exhausted but “content.” In contrast, the older animals easily negotiate the distance, emit distress notes in the presence of the mother and increasingly fail to approach her.

Again, this would account for another of Hess’s findings which he has not integrated into the maximum effort theory, namely that if the human experimenter steps on the toes of the young mallard while he is being imprinted during the critical period, he does not run away in fear but stays closer to the punitive experimenter. It is well known that a stimulus which might ordinarily evoke one affective response will summate with a dominant ongoing affective response. It is similar to the effect of pain in heightening rather than diminishing ongoing sexual excitement.

On the other hand, this theory would also account for the effect of increasing intensity of fear (with age) reducing the strength of new imprinting since fear and positive affect are capable of the greatest interferences by virtue of antagonistic utilization of the same organ systems.

Hess interpreted the failure of meprobamate to permit imprinting as due to its characteristic as a

muscle relaxant which interfered with muscular effort and its feedback. We would argue against this interpretation, first, that chicks who orient toward triangles by sitting and looking at them are probably also somewhat relaxed, but develop lasting preferences as reported by Hess. Second, Hess notes that the drug radically reduced the duck's fear responses. It is very likely that this tranquilizer also raised its positive affect threshold as well as the fear threshold. If this were the case, then it would not become afraid of potential imprinting objects, but neither would it become positively enough interested to be imprinted. The close relationship between the affects of fear and interest has been noted by many investigators. Whether it is possible to tranquilize one without the other by drug is still an open question. That this may be possible with some drugs and not with others is indicated by Hess's report that chlorpromazine did not interfere with imprinting. Given at 24 hours to ducks imprinted at 26 hours there resulted average scores of 59 percent imprinting compared with a control group average of 19 percent.

Finally the affect theory would account for some of the differences between breeds and between wild and domestic animals.

It is well known that domesticated species, such as the Leghorn, are not easily imprintable and that domestic fowl in general, though somewhat imprintable, are less so than various wild birds. It is known from Richter's study of the domestication of the Norway rat that one of the main effects of domestication is the reduction in emotionality and the reduction in size of the adrenal glands.

Since it has been possible to breed for imprintability, and it has also been possible to breed for emotionality, it would be of considerable interest to see whether in fact these turn out to be selecting the same animals.

We are saying in brief that the young animal is excited by and delighted by its mother, and will follow the mother if she is at some distance, or stay near her or look at her if she is near and stationary. Anything which increases the intensity and awareness of this rewarding affect will increase imprinting.

Some Further Evidence on the Imprinting Mechanism and Unresolved Questions

Since Hess's work, an experiment by Peterson has shown that the following response per se is not a necessary condition in imprinting motivated behavior, even though it can be a sufficient condition. He showed that when the presentation of an imprinted stimulus is too brief to permit the following response but is contingent on an arbitrarily chosen response, the rate of emission of this response increases and, contrary to what happens with food rewarded responses, does not decline after a large number of reinforcements.

After imprinting two species of duck to follow a moving yellow cylinder, the presentation of this cylinder was made contingent on responses that increasingly approximated pecking. This response requirement was then gradually increased until every eighth response produced the imprinted stimulus. This stimulus increased the rate of responding by pecking. This was then brought under the control of a discriminative stimulus, a response key that was transilluminated and which provided the reinforcing appearance of the cylinder on each completion of ten pecks. Under a second condition the key was darkened and reinforcement was contingent on at least one minute of no response. These two conditions were alternated. After four hours of such training the duck was responding by pecking when the key was transilluminated but not when the key was dark.

This response was incompatible with the response of following the imprinted stimulus—the yellow cylinder. A transparent key enabled the duck to see the imprinted stimulus while responding, but the presentation of the cylinder lasted only one second after each pecking response. Although this was too brief to permit the duck to follow it, a high rate of pecking at the key was nonetheless maintained. Controls for the effect of change of illumination showed this was not a critical factor.

Peterson argues that this evidence suggests that following is not a necessary component of the reinforcement but that the imprinted stimulus is. We would argue that he has shown that the imprinting

of a particular stimulus to a following response can be later separated so that the affect is to the stimulus rather than to the stimulus and the following response. Originally, however, imprinting produces memory traces which link together the specific imprinting stimulus with the following response and its feedback. When the imprinting stimulus is presented as a consequence of a new response which does not include the following response, this new response and its feedback produce new traces which are now combined with the older traces which activate positive affect and the following response. By preventing the following response, a new set of memory traces are deposited in which the old imprinting stimulus, the old positive affect are combined with the new learned response and its feedback and the stimulus leading to it. It is only because the reinforcement is an affective response which is capable of being assembled with new discriminative stimuli and with new instrumental responses that it is possible to teach the animal to follow the stimulus but to work for the appearance of the imprinted stimulus which will activate the rewarding positive affect.

If we are correct, it should be possible to train a duck to press a key to be able to walk, without "following" the imprinted stimulus. In order to achieve this complex, imprinting stimulus, feedback of walking and positive affect must be gradually discriminated and separated so that the positive affect can be activated by the feedback of walking without the presence of the imprinting stimulus. This could be done by activating the walking response by the imprinted stimulus and gradually reducing the time of appearance of the imprinted stimulus while the duck followed. Thus if the cylinder were to disappear and reappear with the gradually increasing ratio of non-appearance as the duck followed, this should produce a positive affect, walking complex, with less and less reliance on the imprinted stimulus. After this had been achieved, key pressing could be taught as a response instrumental to walking by restraining the animal until he pressed the key.

So much for why it occurs. Why it occurs when it occurs, as Hess has suggested, would appear to be accounted for by the joint factors of locomotor de-

velopment and the appearance of fear, which also accounts reasonably well for imprinting to new objects stopping after the critical period.

Why it continues to occur to the same object, as it does, is somewhat less than clear and presents more of a problem than has been supposed. First of all, the role of affect appears to change when we compare the imprinting process itself with the subsequent following responses.

The radical difference in contribution of affective factors during the process of imprinting and during its evocation later is highlighted by the differential effect of the tranquilizer meproboamate. This drug, which reduced fear, and probably positive affect as well, made imprinting impossible but nonetheless did not interfere with the effects of imprinting before the drug was administered. When the animal is imprinted at 16 hours of age and tested later under the influence of meproboamate, imprinting score is no different than the control group.

If the animal is in love with its mother at first sight, when the honeymoon may be over (so far as positive affect is concerned) the animal still follows the imprinted object and later will seek it out as a sex object.

What then was learned and how does it continue to exert an influence on the animal? What was experienced we have supposed was an "unforgettable" mother bathed in the glow of the joy response. This experience plus the following response is, we presume, stored as a neurological program which, when later activated, will support a continued preference for this particular object. The first problem we encounter on such a theory is the failure of the positive affect to become attenuated and the related problem of the continuing availability of this memory, whether there is habituation or not, to support the same response. Consider the habituation problem first. Ordinarily the most rewarding positive affect responses, particularly those involving interest, habituate. What is exciting on the first sight is eventually not exciting, unless something new is seen or added to the relationship between the perceiver and the object. Ordinarily too when the affect originally underlying the approach behavior becomes habituated, the behavior ceases, although other motives

may have arisen which mask or interfere with these behavioral consequences. The honeymoon may be over but the marriage may or may not be over.

In the case of imprinting there are at least two bits of evidence that the affect changes with age. First is the change from a predominance of contentment vocalization to distress vocalization in the presence of the model, and the second is the differential effect of meprobamate on imprinting and later effect of imprinting. If fear is used to explain the cessation of further imprinting, then why does it not reduce the original imprinting as well or at the very least why does this positive affect toward the original object not suffer considerable attenuation? One possibility is that the very fact of growing fear to all objects heightens the reward value of the differentiated familiar stimulus and adds new joy experiences to seeing the now familiar mother which prevents habituation. According to such a hypothesis the marriage is nurtured by making it an escape from an increasingly punitive world. A consequence of such a view would be that limitation of post-imprinting fear experience should weaken the effects of imprinting. A second possibility is that there is in fact increasing habituation to the imprinted object, but that this is masked by increasing positive rewarding affect from new aspects of the relationship. The marriage deepens over time because the relationship between the two is never quite the same. For one thing, both are becoming older and wiser animals all the time or at least they are becoming different animals. A consequence of such a hypothesis would be that limitation of post-imprinting experience by isolation should weaken the imprinting. A third possibility is that there is increasing habituation but that the information contained in the stored memory is sufficient to constitute an Image with a sufficiently precise program of "following" that the animal continues to behave in the same way even though his heart is not in it. It is his "aim" to follow but the reward is slight. A consequence of such a theory would be that imprinting should be quite vulnerable to later punishment for following.

Finally, it is possible that there is no habituation to the early experience and that it contin-

ues in its pristine form. The lack of interference by meprobamate following imprinting might be because the "program" will instigate the behavior in the absence of supporting affect in the same way that one can drive a familiar route despite sleepiness, anxiety or pain. Since this is an experimental alteration of the normal state of affairs, it may not be altogether relevant to the question of the mechanism *in vivo*. If the original experience did not habituate we would have to account for such an unusual state of affairs. One possibility would be a general failure to analyze past experience sufficiently to reduce the element of novelty in repeated experience. This appears unlikely. Its consequence would be a general similarity of response to repeated presentation of any stimulus evoking affect.

A second possibility would be that such failure of habituation would be limited to the particular positive affect' involved in imprinting. Such a contingency is not impossible. The startle response is one affective response which even in man shows high resistance to habituation when the stimulus is at the appropriate intensity. Further, much may depend on the difference between the two varieties of positive affect, interest and joy. It may be that the interest affect habituates because the stimulus to it is a certain degree of novelty, i.e., a specific rate of change of information, whereas the joy affect may not habituate because its stimulus involves a more specific releaser. Indeed electrical stimulation of the joy center appears to be endlessly rewarding to the animal.

Finally, the preservation of this response may be a consequence of a preformed circuitry almost as complete as a reflex, or the numerous programs which silently govern the body, and which requires only the slightest exercise to consolidate the printed circuit. If such should turn out to be the case, much of the preceding argument would be wrong. The fact that specific cerebral insult prolongs the imprinting period somewhat argues for some caution in interpretation.

Whether imprinting in man is similar to imprinting in the lower forms must await further empirical work.