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ABSTRACT

In the field of communication studies the preeminent forms of explanation of human behavior have been the social and psychological, but biological origins may be as important to understanding human communication as are social origins. Communication research suggests a biological basis for certain patterns of adult interaction. Although these patterns of interaction do not exhaust all or even the most important aspects of human interaction, there is ample evidence that they are functionally important to the adult and to the infant-adult relationship. The patterns of interaction may even be the mechanism for defining caretaker-infant bonding. An appreciation of the intricate relationship between social and biological behavior and the common biological bases of human communication is one result of looking for the biological sources of ultimate causation for patterns of human communication. The emphasis on learning, culture, and socialization, the emphasis on higher-level cognitive processes and on highly deliberate linguistic exchanges have had a central place in the study of human communication. But it is time to recognize that part of what makes communication human is its biological commonness across peoples and even species. (One hundred-and-two references are attached.) (RS)

The Origins of Human Interaction

by Joseph N. Cappella

The Van Zelst Lecture
in Communication

May 1988

Northwestern University
School of Speech

Evanston, Illinois

Foreword

The Van Zelst Research Chair in Communication was established at Northwestern University's School of Speech in 1981 with an endowment from Mr. and Mrs. Theodore W. Van Zelst. The rotating fund permits a professor to devote a year to research on an important issue in communication. The gift also provides for an annual lecture. This lecture, the dissemination of research findings, and the interaction of students and faculty with the visiting professor are designed to increase understanding of significant trends in the field of communication.

Joseph N. Cappella, professor in and chair of the Department of Communication Arts at the University of Wisconsin-Madison, was visiting professor of communication studies at Northwestern during the winter and spring quarters of the 1987-88 academic year.

Professor Cappella received his bachelor's degree from LeMoyne College and his master's and doctorate from Michigan State University. His numerous publications focus on face-to-face interactions and quantitative methods for representing these interactions. Professor Cappella is coeditor of *Sequence and Pattern Communication Behavior* and *Multivariate Techniques in Human Communication Research.* He is editor of the journal *Human Communication Research* and serves on the review boards of *Communication Monographs,* the *Journal of Personal and Social Relationships,* and the *Journal of Nonverbal Behavior.* In 1979, 1981, 1984, and 1985 he received the Top Three Paper Award from the International Communication Association.

The Origins of Human Interaction

by Joseph N. Cappella

Delivered at Northwestern University May 9, 1988

Consider what one can mean by the origins of a set of human behaviors. Origins can be located in learning, through the social, cultural, and environmental forces impinging on the organism. They can be located in the set of causal forces that produce the immediate behaviors under scrutiny (e.g., what is causing a speaker's hesitations in presentation). Origins can also be found in the set of logical operators that give rise to the set of all possible behaviors of a given domain, as Chomsky's (1957) grammatical operators did for language. Finally, the origins of a set of behaviors can be located in the biological, genetic, and evolutionary forces that are ultimately responsible for the behavior set. These four domains may be labeled nurture, proximate causality, logical generation, and nature.

A student of human behavior interested in understanding behavior in its fullest would be unwise to neglect any of these aspects of a behavior's origins. To do so would be like trying to understand the volume of a complex geometric figure (like a duodecahedron) by measuring its height. It just won't work. That caveat offered, I will nevertheless limit my focus to the biological origins of human interaction, locating myself on nature's side of the nature-nurture debate.

Why should one focus on the biological origins of human interaction? Forgetting about the human interaction component for the moment, three reasons recommend a consideration of the biological. First, in the field of communication studies the preeminent forms of explanation of human behavior have been the social and psychological, that is nature and immediate causality. The reasons for this are as much accidents of history, linked to the roots of communication studies in social psychology, as they are due to rational consideration of the set of explanatory forces operative in human conduct. Recent trends indicate that social forces are being given an even larger role in explaining human communication (witness the recent set of volumes, *Rethinking Communication,* by Dervin, Grossberg, O'Keefe, and Wartella). Although I have no bone to pick with proponents of these trends, I think it wise that a balancing of this historical trend be undertaken. I hope to show that biological origins are as important to understanding human communication as are social origins.

Second, a swing toward the biological is necessary because we are, after all, biological organisms. This is not to hold for some sort of naive biological determinism but to reflect the simple observation that in addition to existing within societies, to harboring abstract knowledge, and to requiring cultural rituals both grandiose and mundane, we also possess brains, genetic material, psychopharmacological chemicals, and animal relatives, near and far. To pay homage exclusively to the social while ignoring that which we can touch at any moment, our physical and biological reality, can promote an ignorance and myopia that will be costly to any science of human behavior in the long run.

Third, the field of communication studies, like other fields in the behavioral and social sciences, is trying to establish itself as a science. A science is not coincident with its methods, and scientists can and should use various methods to establish their knowledge claims. A true science is evaluated in terms of the type of knowledge it generates. Scientific knowledge is knowledge that is stable, knowledge that is pancultural and ahistorical. Whether such knowledge is achievable in the social and behavioral sciences is anything but a settled issue. I believe that scientific knowledge claims in human communication will, at a minimum, be constrained knowledge claims. The nature of these constraints will be found in the location of scientific knowledge claims. I believe that such claims, if they are to meet the criteria of being pancultural and ahistorical, must be either at very high levels of abstraction (e.g., equity principles but not what counts as equitable) or very low levels of abstraction. It is these latter, low levels of abstraction that lead me as a third reason to the study of biological forces shaping human interaction. Simply put, the emphasis on biological origins is one potentially rich location for the discovery of truly scientific knowledge about human interaction.

Please note that the above three reasons for focusing upon the biological origins of human interaction do not include payoff. There is no reason to believe *a priori* that scrutiny of biological origins will produce more understanding or greater explanatory power than one of the other sources. What is certain is that ignoring the biological origins of human behavior will produce a less complete and more skewed understanding than giving it serious consideration.

What is Meant by Human Interaction?

I will spare the reader an exegesis on what it means to be human rather than nonhuman (since that would no doubt take most of the rest of the paper and leave me in the embarrassing position of having written a paper on the words that make up the paper's title). Instead I want to focus briefly on what is meant by interaction. Basically I want to distinguish behavior that is generated *within* interaction from the patterning of behavior between persons that constitutes interaction. It is this latter sense of interaction, as patterning, that will be my focus.

Interaction is not simply the generation of social symbols or social signals, neither is it reducible solely to the reception or interpretation of such symbols or signals. Nor can interaction be understood to be the interleaved monologues of two schizophrenics unresponsive to the other's words (which one might call, with apologies to Luigi Pirandello, *Two Monologues in Search of a Dialogue*). Although interactions are made up of components identifiable as production and comprehension, and although interactions may include long monologues by one or the other party, interactions are not reducible to these parts without losing the essence of interaction: regular patterning of exchange.

When I talk about interaction in this paper I mean the regularized patterns of messages from one person that influence the messages sent in turn by the other over and above what they would otherwise be (Cappella 1985, 1987). Please be careful to note that this definition emphasizes the pattern of exchange between two persons and not the behavior of one or the other person even though that behavior occurred in the context of an interaction with another. For example, on my definition, your rude remark during cocktails is not an interaction; in itself it is merely a rude remark. But your rude remark followed by my sarcastic reply and your insult in turn *is* an interaction representing a fairly common and regular pattern of escalating hostility. These patterns constitute the essence of interactions and are the focus of discussion here.

Classifying Interactions

The domain of possible types of interaction is incredibly broad ranging, from the ritualistic insults of young teenagers (Labov 1972) through the hostile exchanges of spouses in conflict (Gottman 1979) to the studied politeness of requests and refusals in class conscious societies (Brown and Levinson 1987). Such a domain is rich enough to be studied for a lifetime by a phalanx of scholars.

My aims in this paper are somewhat (but not much) more modest. I will restrict the set of interactions scrutinized here as follows. One way of separating types of interaction is in terms of how *deliberate* or *automatic* the enacted pattern is. At one pole of this dimension, some interactions are deliberate in the sense that how one responds is for the most part purposeful, conscious, and voluntary—involving the allocation of one's cognitive resources to the choices that are being made. The decision to share secrets about oneself with another, to reciprocate or withdraw from a deliberate touch, to minimize another's compliment, to offer excuses in response to an accusation or transgression, and to stare back at an impolite stare are all examples of deliberate interactions. As interesting and important as these interactions are, they are excluded from consideration in what follows. My reasons for excluding them will, I hope, become clear as we progress. However, these interaction patterns are more likely to have strong components of learning and to be culturally and historically bound than the more automatic patterns.

At the other pole of this dimension, some interactions are automatic in the sense that how one responds is without reflection on the behavior itself so that few cognitive resources are being allocated to the behavioral choices being made. It is not that these patterns cannot be brought to consciousness or made to operate under voluntary control, for indeed they can, but rather that, for the most part, they are not. The hostile tone of voice that develops as conflict intensifies, picking up an accent when talking to a business associate from London, the increasing loudness after just 15 minutes with your boisterous sisters, and the contagious pace of conversation with an exuberant colleague are all examples of automatic interactions. Despite their apparent triviality and seemingly innocuous role in human affairs, these interactions will be my focus.

The deliberate-automatic distinction is a common one in the study of cognition (Kahneman 1973) but the same distinction arises in the study of brain sidedness. A great deal of research on brain-damaged and normal individuals has shown that the left side of the brain (in right-handed individuals) has primary responsibility for the processing of language and verbal content. For some time it was thought that the right side of the brain had primary responsibility for processing nonverbal behavior (Buck 1982).[1] However, patients with damage to the left side of the brain also exhibit deficits in verbal-like nonverbal behaviors such as finger spelling, pantomime, and so on. The resolution of the apparent inconsistency was made by Buck and Duffy (1980), who found that patients with right hemisphere damage had much more difficulty spontaneously posing emotions than did subjects with left brain damage. Coupled with other evidence on normals who are right hemisphere dominant (more accurate senders of emotion and left faced in the posing of emotion), it would be fair to claim that the right side of the brain has greater responsibility for the recognition and generation of spontaneous expression while the left has greater responsibility for voluntary and deliberate expression. Evidence from dichotic listening tasks, presentation to the left vs. right visual field experiments, and other data on right hemisphere damaged patients make a clear case for this claim (Davidson 1984). Thus, not only is the distinction between deliberate and automatic interactions conceptually useful, it is also based upon a clear distinction in brain hemisphere functioning.

I recognize fully that realistic interactions weave the deliberately enacted and automatically produced signs of human conversation together, sometimes creating a masterful tapestry and at other times a knotted jumble. My focus here is on the automatic features of interaction both because they are assumed to be less susceptible to cultural and historical variations and because, as I hope to show, they are central to human communication, human development, and human affairs.

To summarize, I will focus upon the biological origins of human interaction, considering only those interactions that are spontaneous and automatic rather than deliberate and voluntary. Within these limits, I will try to argue that there are definitive patterns of adult interaction that have parallels in the early social life of the infant and neonate. These patterns in both adult and infant groups will be seen to have significant consequences for the quality of life of the organism. To explain such parallels will require appealing (at least in part) to selection forces in evolution, to ethological parallels, and to innate physiological mechanisms.

Patterns of Adult Interaction

I have been involved in the study of adult (automatic) interaction for over a dozen years now. During that time I have contributed to the basic research in the area and written several reviews summarizing the available literature (Cappella 1981, 1983, 1985, 1987; Cappella and Greene 1982). On the basis of those reviews I can point out three broad patterns of adult interaction, which I will call turn taking, stimulation regulation, and emotional responsiveness. Turn taking refers to the processes by which people allocate speaker and hearer roles during ordinary processes of interaction. Though the parallelism with infant development is fascinating, turn taking will not be considered further, since evidence of other biological origins is not available.[2] Stimulation regulation refers to those processes by which persons control one another's expressed levels of activation (as measured by intensity and rate of behavior). Emotional

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[1] For a summary of this work, see Buck, *The communication of emotion* (1984)

[2] This feature of interaction would seem to be a likely candidate for slow acquisition by the infant,

responsiveness refers to the tendency to approach or withdraw from, to mimic or mismatch, the expressed emotional state of another.

In both these broad patterns of interaction, an important aspect of the psychological and social life of the actors is controlled. In the case of stimulation regulation, intensity and excitation are transmitted and accepted or rejected. In the case of emotional responsiveness, particular emotional states (including especially anger, sadness, joy, fear, disgust, surprise, interest, and distress) are communicated; more generally, the hedonic tone (positive or negative) of the sender leads to either approach or withdrawal by the receiver.

Supportive Research

The amount of research relevant to these broad patterns of interaction is, for the most part, quite extensive. In this section some specific findings will be discussed.

Stimulation regulation represents a type of interaction that is close to my own research interests. One indicator of stimulation is the tempo of the conversation as measured by the rate of speech of the partners and their quickness (or latency) to respond. Research with adults (Cappella and Planalp 1981) and probably three dozen other supportive studies all suggest that partners converge partially toward one another's conversational tempos. A recent study (Street and Cappella 1988) on three- to six-year-old children with an adult partner obtained a similar effect for speech rate, especially for children who were skilled enough to be responsive to the topic. Thus the regulation

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especially after he or she has begun to exercise linguistic skills. However, some evidence suggests that turn taking develops earlier Rutter and Durkin (1987) studied the turn-taking activity of two groups of children ranging in age from 9 to 36 months. "Overlapping of speech" segments began to drop by the second year and "gaze at the end of one's turn" segments (an adult cue) developed by 18 months. Mayer and Tronick (1985) studied whether adult turn-taking cues produced responses (such as vocalizations and smiles) in infants They found that the usual set of turn-taking cues, namely, intonation, drawl, hand movements, and head movements regularly predicted infants' responses Kaye (1977) reasoned that alternation, which is the basis of turn taking, may be developed very early in the learned alternation required in other contexts between mother and infant. He studied infants in their second day and second week of life, observing the feeding rhythms of infants with their mothers during breast or bottle feeding Although infants have a regular rhythm of sucking and then pausing, mothers tend to jiggle them (or the bottle or the breast) to encourage additional sucking Infants do not tend to start sucking again until the jiggling stops, whereupon another burst of sucking begins. By the second week some accommodation has been reached, with the jiggle-stop sequences of the mother shortened What is fascinating about this sequence is that it is driven by primal forces (feeding routines), which result in nonoverlapping patterns of action.

This evidence certainly suggests that infants develop adult cues rather early, are sensitive to adult cues even earlier, and from birth seem attuned to the need for interleaved action. They also seem to be sensitive to the rhythms of activity from birth. Miller and Byrne (1984) summarize research indicating that rhythmic audio and visual stimuli are soothing for infants whereas arrhythmic ones are not and tend to be arousing. Research summarized by Miller and Byrne indicates that infants are born with a "central pacemaker" that beats in the range of 1-1.2 Hz (hertz) and is based in the hippocampus His evidence is that natural sucking rhythms are in the range of 1 Hz and that consoling rhythms are in this same range. (Later the frequency of this central pacemaker increases to about 6 Hz.) Rhythmic activity also plays a role in stimulation regulation between infant and mother, especially during play.

In short it seems that one of the fundamental aspects of human conversation, the alternation of turns, occurs early in the social life of infants and may in some naive form be present even from birth.

of conversational tempo exists in children just beginning their linguistic careers.

If speech rate and latency were the only behaviors indicative of stimulation regulation, then this pattern would be a weak one indeed. Instead, a wide variety of behaviors are involved. Cappella and Palmer (1988) recently reported convergence between partners in speech-related gestures even for partners who knew each other well but didn't like each other. Buder (1985) has reported matching in fundamental frequency of voice during periods of simultaneous speech. Fundamental frequency, technically known as f_0, is commonly associated with arousal; the higher the f_0, the higher the arousal (Scherer 1986). Convergence in vocal amplitude has been carefully studied by Natale (1975a; 1975b). He found that people tended to converge over the course of time to the loudness levels of their partners, especially if their need for approval was high.

Perhaps one of the most fascinating findings in this domain is that of dialect matching. Trudgill (1986) presents considerable data confirming our own experiences of picking up certain (but not just any) features of the dialect of the linguistic community with which we have recently interacted. Less obvious is the observation that dialect matching does not occur by watching the television, but only through face-to-face contact in which response is required.

All of the above findings indicate that in adults stimulation is contagious, and there is no indication that stimulation is rejected through some form of withdrawal. Indeed, adults seem to find others' social stimulation arousing for the most part and respond with an increase in their own expressed activity or an imitation of the others' behaviors. But the same cannot be said for the stimulation caused by close interpersonal distance. Such distances are experienced, for the most part, as anxiety producing in neutral or negative social settings (Cappella 1983) and lead to withdrawal primarily in the form of reduced gaze, more indirect orientation, and quicker responses. Cappella and Greene (1984) found this same effect in one study but also found that persons who viewed arousal as rewarding, or high sensation-seekers (Zuckerman, 1979), exhibited less withdrawal than those who viewed arousal as punishing, or low sensation-seekers. These findings suggest that the control of arousal mediates the proximity-withdrawal effect.

Emotional responsiveness studies would normally be concerned with the matching or mismatching of particular emotional states as revealed though pancultural facial displays of subjectively experienced emotion (Ekman 1972; Ekman et al., *Universals and cultural differences*, 1987). To my knowledge no study of facial displays of emotion between adults in natural social interaction has been conducted. Part of the reason for this may be the concern that displayed facial emotions will be confounded by cultural display rules and facial emblems, so that displayed facial configurations will represent voluntary and controlled reactions rather than spontaneous subjective states. Despite a lack of research on matching and mismatching of specific emotions, the more general hedonic tone of the interaction has been studied.

Gottman's (1979) work is central and exemplary here. His work with interactions among married couples has found that hostile affect tends to be matched in both well-adjusted and less well adjusted couples (Gottman 1979). This finding has been replicated by Pike and Sillars (1985), Margolin and Wampold (1981), and others Noller's (1984) studies of married couples revealed convergence for eye gaze patterns between husbands and wives, again for both satisfied and dissatisfied couples.

In an experimental context with a different group of subjects, Bavelas (1986, 1988) observed that when subjects were exposed to a target who was about to be injured, observers leaned with or grimaced with the victim, especially when the victim could see the observer's reaction. Apparently the communicative value of the expressed emotional response was significant in encouraging its elicitation.

As with stimulation regulation, matching seems to be the rule for which exceptions exist. The clearest example is found in the work of Kaplan, Firestone, Kline, and Sodikoff (1983). Kaplan et al. manipulated a confederate's hedonic tone so that it appeared to be increasingly affiliative and observed the approach and withdrawal reactions of persons exposed to the confederate. For those persons who had been led to believe beforehand that the confederate was very similar to them, approach resulted; for those who were led to believe that the confederate was very different from them, strong avoidance resulted. These findings were clear and decisive; not only did the subjects take into account the hedonic tone of the confederate's actions but weighed those actions relative to their expectations about the confederate's attitude toward them.

The only studies that come close to the matching and mismatching in specific emotions that should be characteristic of emotional responsiveness are those of Buck (1975, 1976, 1979). In his slide-viewing paradigm, Buck had subjects watch certain types of slides chosen for their ability to elicit facial reactions from the particular subject group. The watchers were surreptitiously videotaped and their facial displays shown to another group of dissimilar or similar judges whose task was to guess what emotion was being displayed. In the paradigm, accuracy of judges is determined by comparing the judges' guesses to the slides' emotional content and comparing the judges' ratings of emotion of the sender to the emotion reported by the sender. With college students and three- to six-year-old children, communication accuracy was above chance levels for both types of comparison. Also, those who were more accurate senders of facial emotion showed less skin conductance when responding than those who were less accurate senders. Overall, emotional states, spontaneously generated, did communicate accurately both the subjective state and the eliciting condition of the emotion, at least for subjects who were "externalizers" of their subjective states and did not hold in their emotional reactions. This paradigm is as close as the adult research comes to a study of discriminative emotional responsiveness.

Significance of Adult Interaction Patterns

The stimulation of and emotional patterns in adult social interaction are certainly interesting to communication scientists but then, South American tree frogs are interesting to zoologists. Before asking complicated questions about the origins of certain adult patterns of interaction we should also raise questions about the social value of studying these patterns.

Patterns of interaction and their disruption can be the symptoms of some underlying personal or relational disability or can be associated with some positive or negative interpersonal outcome. Street (1982) found that when interviewees' speech patterns had converged to those of an interviewer, judges evaluated the interviewees more positively than those whose speech had not converged. Feldstein, Konstantareas, Oxman, and Webster (1982) studied the speech convergence of autistic teenagers and found that they failed to show convergence with either parents or therapists, while the parents and therapists exhibited convergence with one another. A similar finding was obtained with adult schizophrenics (Glaister, Feldstein, Pollock 1980) and depressives.[3] Thus, convergence seems to be recognized as interpersonally positive, and its absence seems to be characteristic of abnormal adult interactions.

However, it is the findings on matching in negative affect that are most striking. Although reciprocal negative affect is common in studies of married couples, Pike and Sillars (1985), Gottman (1979), and others have found that less well adjusted and less satisfied couples exhibit greater reciprocity in hostile affect. While it is not clear whether the similarity in hostile affect is a symptom of marital discord or results in marital discord, its replicable relationship to marital unhappiness is a promising, if unhappy, result. In a recent update and extension of these findings, Levenson and Gottman (1983) found once again that negative affect reciprocity continued to distinguish distressed from nondistressed marriages. In addition, the linkage between husbands and wives on four physiological measures of arousal taken during the interaction very strongly predicted distress, with the more strongly linked couples also the more distressed. These findings are especially important because the physiological measures of arousal paralleled the findings for the interactional measures of negative affect in predicting marital distress. When these results are coupled with the controversial findings of Ekman, Levenson, and Friesen (1983) reported in *Science*, that heart rate acceleration accompanies the negative emotions of fear, sadness, and anger, we have the exciting possibility that coupled emotional states, measured physiologically and behaviorally, distinguish distressed from nondistressed couples.

The story would not be complete without mention of Levenson and Gottman's (1985) follow-up to their 1983 study. They recontacted the couples studied earlier to determine the state of their marital relationship after three years. Once again, the decline in marital satisfaction *three years* after the initial lab interactions and physiological measurements was strongly predicted by negative affect reciprocity and by the couples' physiological arousal. (In this case, it was the mean level of couples' arousal and not their temporally linked arousal.) What is remarkable, of course, is the strength of the findings and their persistence over such a long time span.

In Sum

Two patterns of interaction characterize the spontaneous aspects of adult conversations. In all cases, matching and approach responses are the typical modes of reaction. Under certain circumstances mismatching and withdrawal can and does occur. These interactions are also important indicators of relational state and possibly indicative of individual or relational distress.

Given the pervasiveness and significance of these interaction patterns, the curious cannot help but speculate as to their origin. Have they been learned in particularistic cultural and social settings? Are they the remnants of some primitive biological and genetic dispositions? Numbering myself among the curious, I plunge ahead.

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[3] A study of speech rates in patients with major depressive disorders conducted by Jaffe and Anderson is included in *Speech sounds and silences. A sociological approach to clinical concerns*, ed. C. Crown and J. Welkowitz (Hillsdale, New Jersey: Lawrence Erlbaum, in press).

Searching for Evidence about Origins

What kinds of evidence about origins is possible? Discussions about origins inevitably come down to questions about biology and society, nature and nurture. If creating a complete explanation of origins is one's goal, the answer to these dichotomous queries must include both influences. Direct comparison between the two is not ethically possible, in any case, since one cannot seriously control human learning environments. Therefore, the case must inevitably be circumstantial; this does not mean that we are guessing, only that a complex web of interlocking facts and evidence must be used to piece together an explanation that is no less complete and compelling than if we had a definitive set of studies.

What evidence could plausibly distinguish the two sources of influence on human interaction?

Evidence from the study of neonates and infants. The influences of culture and socialization have had little opportunity to affect infants; if adult patterns are present in the interactions of infants and their primary caretakers it suggests some type of biological disposition for the pattern (or at least for the mechanisms that give rise to the pattern). The earlier the pattern emerges, the more likely the pattern is the result of some genetic heritage rather than some learned association. Of course, the neonate differs from the adult in terms of brain structure (Buck 1982) and facial muscle control, among many other things, so that the infant's patterns of interaction must be studied within the bounds of these physical limitations.

Evolutionary adaptiveness. Here the argument is made that a particular pattern of behavior has adaptive value, not in general but specifically, in terms of the survival of members of the species. If a particular behavior pattern has adaptive value for the species, then presumably that pattern is the result of some individual difference in genetic composition that enables the individual to survive while others fail. It is this genetic difference, and its associated behavioral manifestation, that accounts for the biological origin of the behavioral pattern. The argument for biological origin based on evolutionary adaptiveness and selection is, by itself, not very strong, since learning, like evolution, may be biased in the direction of learning what is socially advantageous. One could argue that societies and groups adopt social norms for future behavior that have been successful in the past in producing effective and viable members of the society. However, in combination with evidence from neonatal and infant development, physiological structures, and ethological parallels, the arguments for adaptive selection and genetic endowments are bathed in a different light.

Evidence from physiological structures responsible for the observed patterns. If physiological structures and processes can be identified that are linked to the behavioral patterns under scrutiny, then, while social conditions may *elicit* the behavioral patterns, biological factors are the necessary causal mechanisms without which socialization could not occur.

Cross-cultural similarities. To the extent that a given behavior pattern is observed across cultures, that behavior pattern is more likely to have a biological or panhuman basis, with cultural influences playing a smaller role. Given the difficulty of conducting cross-cultural research and the ethnocentrism of much social and behavioral research, only a little cross-cultural evidence is available to make this portion of the case.

Ethological analogies. Parallels between human and other animal species may be of two general types: analogies and homologies. A homology traces similarities in behavior between two or more species to a common ancestor responsible for the existence of the trait or behavioral pattern. An analogy merely notes that similar behavior patterns are analogous to one another and may be the result of a homologous relationship, although the origin is indeed unknown and certainly unverified. The former is clearly more difficult to establish but also is a stronger argument for the biological basis of a given behavior pattern. On the other hand, the complete absence of analogous information allows no inference to biological origins, no matter how weak that inference might be. In short, analogies between humans and other species are better than nothing.

What is clear in the above discussion is that no single source of evidence can be definitive in establishing a case for the biological origins of a particular behavior pattern. However, the pattern of evidence can lead to the construction of a circumstantial case permitting reasoned, if tentative, speculation. Evidence in each of the above areas will be introduced.

Interaction in Neonates and Infants

Stimulation regulation. The typical pattern of mother-infant playful interaction (for normal mothers and infants) during the first nine to twelve months of infancy can be characterized as follows: 1)the mother is passive while the infant gazes away; 2)the mother engages the infant through modifying facial, vocal, intonational, and movement behaviors; 3)the mother and infant remain in visual contact, vocalizing, gesturing, moving, smiling, and being facially animated; 4)the infant terminates the interchange with gaze averted from the mother (after Cohn and Tronick 1987).

The evidence for this pattern of normal play is quite extensive (Field 1987), and only a few recent works will be summarized here. Jasnow and Feldstein (1987) found matching in speech latencies for mothers and their nine-month-old infants (although latencies from infant to mother were negative). Berneri, Resnick, and Rosenthal (1988) had judges rate the tempo or synchrony of mother-infant play sessions (age fourteen to eighteen months) and found that those of mothers with their own infants were rated as more synchronous than those of mothers with a different infant. Stern, Hofer, Haft, and Dore (1985) studied matching in intensity, timing, and shape between mothers and their eleven-month-olds, finding matching across modalities (e.g., gestural rhythm of infant matched by vocal rhythm of mother).

The stimulation matching observed with older infants also occurs earlier. Cohn and Tronick (1987) studied 54 mother-infant pairs at three, six, and nine months of age. From a rather extensive set of analyses, one of their central conclusions is that across all three ages it is the infant who breaks the stimulation interchange; the mother remains engaged throughout. Symons and Moran (1987) observed vocalization, gaze, and smiling in each one-second unit for the attention-getting sessions. They found that infants were responsive to their mother and mothers to their infant in the next one-second unit in the play and imitation sessions only. Similar findings have been obtained in studies of noncontent speech in four-month-old infants (Beebe, Alson, Jaffe, Feldstein, and Crown 1988) and of affective behavior in three-, six-, and nine-month-old infants (Cohen and Tronick 1988). Thus, the infant is not merely being molded by the mother but is, in fact, regulating the interaction, as well.

The significance of these periods of play and the infant's sensitivity to the mother's activity levels is demonstrated clearly when disruptions occur. Murray and Trevarthen (1985) had mothers adopt a blank face expression at one point in interacting with their six-to-twelve-week-old infants. The result of this blank expression in comparison to normal play was striking, with the infants exhibiting more signs of distress, less smiling and relaxation, and less gazing toward the mother. In a variation on this theme, the same researchers played back to the infant a videotape of the mother in a previous play session with her infant. The mother is behaving normally but her behavior is "out of sync" with that of her infant. The infant responded in a parallel way to the "out-of-sync" mother and to the "blank-faced mother," suggesting synchrony rather than affect is the regulative force.

Signs of this ability to respond to and withdraw from the mother's stimulation appear very early in the infant's development. Hoffman (1978) notes that neonates commonly engage in contagious crying in hospital nurseries, and that this crying is a quite vigorous response to external cries. In a remarkable demonstration of synchrony in stimulation, Berghout-Austin and Peery (1983) conducted a statistically reliable test of movement synchrony between neonates who were 30 to 56 hours old and an experimenter. The experimenter simply talked to each neonate at a facial distance of 19 centimeters. Movement synchrony was present in all five infants.

Together with an array of other data (Field, 1987; Street and Cappella 1988), the above studies suggest a pattern of stimulation regulation in early and later infancy parallel to the stimulation regulation described in adults. The effect is pervasive and shows signs of occurring very early in the life of the neonate. As we shall see below, disturbances of this process of stimulation regulation because of difficulties experienced by the mother or the infant can have serious consequences.

Emotional responsiveness. Like studies in the adult domain, infant studies of specific emotional responsiveness are few. Although the evidence for the pancultural and innate character of facial emotional display and its interpretation is overwhelming (Fridlund, Ekman, and Oster 1987), the ability of infants to display and recognize facial emotions is under considerable dispute (Field 1985a; Haviland and Lelwicka 1987; Izard and Malatesta 1987; Nelson, 1987). Izard and Malatesta (1987) argue that four basic emotions are present at birth and are able to be expressed by the infant in facial displays: smiling (though perhaps not the social smile), disgust, distress, and interest. The other facial emotions develop and emerge over the next seven months or so. Nelson (1987) argues that the infant's ability to recognize faces is quite limited due to lack of development of the visual system. He does not deny, however, that richly articulated faces and voices may be recognizable in certain of their features.

Some recent studies contradict aspects of the above characterizations of the infant's ability to recognize and express emotion. Field (1985b) studied 48 full-term neonates who were approximately 45 hours old. Half were exposed to their mother's versus a stranger's face and half were exposed to their mother's versus a stranger's face and voice. In terms of visual regard, 17 of 24 looked longer at their mother than at the stranger, and 21 of 24 looked longer at their vocalizing mother than at the stranger. The infants' exposure to their mothers before the study could have been no longer than four discontinuous hours. In another study Field, Woodson, Greenberg, and Cohen (1982) had a female model pose happy, sad, or surprised expressions to a group of preterm neonates (35 gestational weeks) and a group of full-term normals. Few differences were observed between the mouth expressions of the pre- and full-term infants; basically, happy faces elicited more widened lips, sad faces more pouting lips, and surprise faces, more wide-open mouths. Field's data suggest an ability at birth to recognize significant faces and to respond in a matched way (that is, imitatively) to features of the facial expressions of partners.

However, Haviland and Lelwicka (1987) discovered that infants produce adult-like affective reactions to facial displays and vocal behaviors that some others suggest should not yet exist in the infant's repertoire. Six boys and six girls who were ten weeks old were studied in an experimental situation with their mothers. The mothers randomly produced a facial and vocal expression of anger, sadness, or happiness. Facial expressions of the mothers and the infants were coded; their vocal expressions were judged, as well. There were matching facial responses by the infants to happiness and anger by the mother but not to sadness. Interestingly, the joy expressions tended to decrease over repetitions, being replaced by interest expressions, while the anger expressions increased over time with interest being generally inhibited. Although sadness did not elicit sad faces from the infant, joy, anger, and interest responses were below expectation and mouthing activities (usually associated with sucking) were above expectation. While strict imitation was not found across all sessions or all emotions, the observed patterns of interaction certainly make sense in an adult model of interpretation. Positive emotions, like joy, elicit an initially joyful response with subsequent decrease of joy but increase of interest. Anger elicits lack of interest and, when it persists, begins to elicit an angry response. Sadness elicits a lack of emotional response and an attempt to retreat into a safer, more reinforcing activity (simulated sucking).

The anger finding is particularly interesting because it parallels the findings of Gottman and others on hostile affect reciprocity. Although the data on emotional responding in adults and with infants is not as impressive as the evidence for stimulation regulation, it is still suggestive of the early manifestation of emotional responsiveness.

Significance of Infant-Mother Interaction

Common sense would suggest that the patterns of interaction between mother and infant are important to the immediate and future well-being of the infant. In this section, I want to tie some of this common sense to a base of research and to suggest how asynchronous interaction patterns might arise.

Long term effects for mother-infant interaction have been posited for language acquisition and the learning of basic concepts such as contingency. The turn-taking characteristic both of stimulation regulation and of vocalization and movement patterns in early infancy may establish the necessary proto-conversations prerequisite to the learning of language. For example, Coates and Lewis (1984) studied interactions between mothers and infants at three months and followed up the infants' cognitive and linguistic abilities six years later. They found some positive relationships between certain of the cognitive and linguistic measures at six years and mother-infant responsiveness at three months. They speculated, I think wisely, that the pattern of responsiveness at three months remained throughout infancy and early childhood, explaining the developmental success of certain of these children. The concept of contingency so central to all types of social and physical action is also embodied in the very definition of interaction; my action will affect yours and yours mine. Without the development of back-and-forth turn taking, infants may have trouble in the teaching and learning settings required for language acquisition (Bateson 1975).

Perhaps the most important effect associated with stimulation regulation and emotional responsiveness is the development of secure attachment (a positive affective bond) between infant and mother. Secure attachment by the infant is central to exploration and cognitive growth and the development of later interaction ties; it is central to the functioning of all primate species (Bowlby 1969; Ainsworth 1978). The data directly evaluating this claim are both sparse and methodologically weak. Ainsworth (1978) found that securely attached infants at 12 months (as measured via the strange situation) had more sensitive interactions with their mothers at three months. These findings were replicated in Germany, as well (Grossman, Grossman, Spangler, Suess, and Unzer 1985). While this is useful evidence one might look upon positive emotional responsiveness and synchronous stimulation regulation themselves as part of the definition of attachment, or at least as the mechanism through which attachment is achieved. We will make more of this argument later.

Of course not all interaction patterns run smoothly, and disruptions can occur as a result of several factors. For example, at-risk infants who are preterm rather than full term seem to be easily overstimulated. A study by Lester, Hoffman, and Brazelton (1985) of pre- and full-term infants at three and five months of age showed that interactions with the mother were less coherent (that is, less synchronous) for the preterm infants than for the full-term infants. Certain aspects of the synchronicity increased for the full-term infants from three to five months. Thus, the preterm infants' interactions were unlike those of their full-term counterparts. These at-risk infants also typically gaze away more, vocalize less, and have more elevated heart rates than less risky infants (Field 1977, 1982). Lester, Hoffman, and Brazelton (1982) showed that the synchronies in heart rate between infant and mother in social play were stronger than those between infant and stranger. Overall these findings suggest not only a behavioral synchrony but also a physiological synchrony early in the social interactions of infants and their mothers.[4]

Mothers, too, can be the source of interactional problems for their infants. Although there do not appear to be any studies of chronic depression in mothers and the effect of

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[4] At this point I think that I should diverge for a moment to offer a couple of caveats. First, it is difficult to say whether the Lester, Hoffman, and Brazelton study is a stimulation regulation or emotional responsiveness study They studied a variety of behaviors that were summed into an overall index that included a gross judgment of facial positiveness and one of facial distress for both mother and infant. Some behaviors do not clearly have an emotional component—for example, vocalizations—though they were given a positive or negative score.

The second point is that so called studies of positive and negative affect like the Lester et al. (1985) study usually only involve positive facial displays on the part of the mother. Malatesta and Haviland (1982) have noted that in open-ended observations of mother-infant play, mothers almost always employ positive facial displays. As developmental research turns toward the comparison between abused and nonabused children, some of these narrow emotional displays will give way to a broader set of displays. In the meantime, I think that it is fair to consider studies of positive and negative facial emotion and smiling as little more than studies of stimulation regulation skewed primarily toward the positive side of the positive-negative emotional continuum.

that chronic depression on interaction, studies in which mothers were asked to look depressed when they were not (e.g., adopt blank affect) showed that infants responded by exhibiting greater facial distress and higher activity and heart rate and attempting to engage the mother in normal interaction (Cohn and Tronick 1983). When mothers who were depressed were asked to look depressed, their infants responsiveness was no different from what it was when the mothers were asked to interact normally with their infants. These infants seemed less agitated and less active overall and also exhibited lower heart rates (Field 1984). A great deal more research is necessary before we know whether the interaction patterns of depressed mothers with their infants have negative long-term consequences for the mother-infant bond and for long-term individual development.

In Sum

So far I have tried to show that the broad patterns of adult and infant-adult interactions are parallel to one another. Clearly, rudimentary elements of adult patterns exist in the very early interactions of infants and even neonates. I have also tried to show that these patterns are important to the proper functioning of the psychological and social life of the adult and of the infant. The patterns, when they are disrupted from their normal sequences, may be symptomatic of individual or relational difficulty or, when they are operating as they should, may be indicative of relational solidarity and attachment.

I find this parallelism and its significance for what, on their surface, appear to be trivial behaviors to be both exciting and curious. If these behaviors exist in the early ontogeny of the organism and yet remain until much later in the life span of the adult organism, what would explain this continuity? One explanation could be that early learning persists throughout the developmental cycle. Another could be that physiological and genetic forces are the ultimate (though not the proximate) causes of these patterns, and that the structures behind these forces remain throughout the life span of the organism, though they are overwritten by significant cognitive and cultural demands. Although overwritten, they do not disappear, manifesting themselves within the sequences of highly verbalized and ritualized interactions.

Arguing from Evolution

In what remains, I want to argue that both emotional responsiveness and stimulation regulation increase the *inclusive fitness* of the species. By inclusive fitness, I mean the "survival value of genes stemming from reproductive success" (Petrovich and Gewirtz 1985, 280). In short, when behavior is adaptive and the genetic materials responsible for successful coping with an environmental contingency are passed on to subsequent generations, the gene pool in those subsequent generations becomes biased in the direction of the adaptive behavior (or at least the mechanisms for producing the adaptive behavior). The form of the argument is teleonomic in that "behavioral outcomes that reflect demands exerted by ecological contingencies in the history of the particular species" (ibid., 264) are selectively passed on through the gene pool. For example, cliff-nesting gulls fail to learn the identity of their young whereas ground-nesting gulls do. Young ground-nesting gulls interact with other young gulls; their parents must be able to discriminate them for feeding and caretaking. Young cliff-nesting gulls do not interact; their absence from the nest can only mean that they have fallen to their death from the narrow ledges of the nesting place.

In constructing an argument from organic evolution, several features must be specified. What are the ecological contingencies for the species? What behaviors meet these ecological contingencies? Do these behaviors increase the inclusive fitness of the species? That is, do they add to the reproductive success of the species? Even when these criteria are satisfied, evolutionary arguments are, in themselves, weak ones. As was noted earlier, adaptiveness *per se* does not exclude learning, since cultures would certainly want to develop behavioral patterns that advance the species. Second, most arguments from evolutionary adaptiveness, while rationally plausible within the context of evolutionary theory, fall far short of identifying the specific genes responsible for the adaptation. Therefore, successful arguments from evolutionary selection supplement their claims with evidence from other domains. cultural, physiological, and ethological.

I will make two arguments in the next two sections of this paper: first, that emotional responsiveness is innate and biologically adaptive and second, that mother-infant attachment is innate and biologically adaptive, and stimulation regulation is the mechanism through which that attachment is achieved.

In making these arguments, the ecological contingencies necessitating attachment and emotional responsiveness must be made clear. They are simple, and, I think, self-evident: 1) human primates are an altricial species; that is, they are helpless for extended periods after birth and 2) nonhuman primates in their natural state are subject to predatory pressures, as were human primates, presumably, in the distant past. The first of these implies that extensive caretaking of infants by their parents is necessary for survival. The second implies that proximity to the caretaker is important as is a system for warning.

The Origins of Emotional Responsiveness

It was Darwin ([1872] 1955) himself who argued for the adaptiveness of innate emotional expression, both in general and for specific emotional expressions. We only need to consider the former here, especially in the context of infant emotional displays. Izard and Malatesta (1987) maintain that in order for the caregiver to meet the needs of its dependent organism, the infant must be born with at least a rudimentary form of emotional expressiveness that carries information about its internal state to the caregiver. In turn, the caregiver must have the ability to correctly recognize the facial state of its infant in order to provide the appropriate care. The infant also must have the ability to recognize the emotional expressions of the caregiver for the information that those displays provide about danger and social attachment. In short, the organism born with an innate and rudimentary communication system that allows it to represent its own internal states to the caregiver and recognize at least some of the caregiver's internal states and allows the caregiver to know the internal states of the organism permits effective and efficient caregiving, thus making its survival more likely.

To establish the innateness of this rudimentary communication system that I have labeled emotional responsiveness requires that three features of innateness be established: 1) the production of facial emotions is innate, 2) the recognition of facial features is innate, and 3) the second leads to emotionally adaptive responses. Let us take up each of these in turn.

Production. The portrayal of each of six basic emotions, and perhaps three others, including contempt, distress, and interest is universal, having been demonstrated in a variety of western, nonwestern, and preliterate cultures (Ekman 1972; Fridlund et al. 1987). Photographs of these facial displays have been accurately decoded above chance levels by members of other cultural groups.

Izard and Malatesta (1987) have summarized the work on facial expressions in infants, noting the following:

1) All muscle movements of adult facial displays are present in both full- and preterm infants (Oster 1978).

2) The interest expression is present from birth and is associated with gaze fixation and the heart rate deceleration typical of information intake; this expression is associated with attention to moderate novelty, attention to the human face, and attention to movement, suggesting an adaptive value in information acquisition and social interaction.

3) The smile expression is present from birth but the social smile does not develop until about three to four weeks; the smile of the neonate seems to result from heart rate deceleration experienced during REM sleep (Sroufe and Waters 1976); it occurs for both normal and congenitally blind infants (Eibl-Eibesfeldt 1972).

4) The disgust expression is present from birth and can be produced in response to taste and smell stimuli (Steiner 1973); the adaptive value of this expression is obvious, as the caregiver is promptly informed about the infant's reaction to what it ingests.

5) Distress is also present at birth and is elicited by painful stimulation or some other form of discomfort.

The other four emotions (surprise, anger, fear, and sadness) are manifested sometime during the next seven months of the infant's life. For example, anger has been observed in response to receiving DPT injections around two months of age (Izard, Hembree, Doughtery, and Spizzirri 1983).

Although specific locations in the brain for the production of individual emotions have not been found as yet, the best current information is that emotional production is closely allied with the "old brain" regions, particularly the limbic area, rather than the higher regions of the neocortex (Buck 1984). Also, a considerable amount of evidence indicates that the right hemisphere is primarily responsible for the production of spontaneous displays of facial emotion (Buck and Duffy 1980).

Recognition. Earlier, we reviewed two studies suggesting that neonates are capable of recognizing their mothers' faces and voices within a few hours of birth and capable of imitating a model's facial displays of sadness, surprise, and happiness at least with their mouth movements. The research of Haviland and Lelwicka (also reviewed earlier) confirms that infants as young as two-and-one-half months are capable of recognizing emotions of anger, joy, and sadness. In a careful review of the facial emotion recognition literature, Nelson (1987) concluded that young infants might be capable of discriminating a single facial feature in a rich stimulus (e.g., the real mother's face) but are probably not able to distinguish a complete facial gestalt. However, when one considers the fact that mothers regularly use both facial and vocal cues. to which infants are highly sensitive (Papousek, Papousek, and Bornstein 1985), and exaggerate their facial displays considerably, then infant responsiveness to adult displays of emotion seems less problematic in reality than it is in the research context.

There is also a neurological basis for facial recognition. Parrett, Rolls, and Caan (1982) studied the reactions of rhesus macaques to photographs of monkeys and humans posing neutral facial displays. Many different photographs were used. Electrical responses from 497 cells in a certain region of the right occipital lobe were taken. Forty-eight of these cells were especially responsive to faces, with 23 of these cells responsive specifically to the eyes. This same general area of the right occipital lobe is implicated in the failure of brain-damaged adults to recognize faces (Damasio, Damasio, and Van Hosesen 1982). In adults without brain damage, the right hemisphere of the brain is also implicated in the recognition of facial emotion (Buck 1984; Buck and Duffy 1980), although the evidence is confused somewhat by the findings of Davidson and Fox (1982) that the left hemisphere is involved in the processing of positive emotions while the right is involved in the processing of negative emotions.[5] Although a complete picture of the neurological basis for the recognition of emotion is many years away, sufficiently strong evidence currently exists to hold that there are specific brain locations for emotional processing.

Understanding. The last feature of the argument about emotional responsiveness concerns whether facial recognition leads to response patterns that would suggest understanding of the facial display. The Haviland and Lelwicka study suggests that the response patterns of two-and-a-half month olds to facial and vocal displays by their mothers do indicate understanding of these displays even though the infants do not always imitate them.

Other evidence of understanding comes from studies with older infants (usually more than seven months old) in contexts such as the "visual cliff" or "unfamiliar toys" paradigms. Various researchers (Klinnert 1984; Sorce, Emde, Campos, and Klinnert 1985; Zarbatany and Lamb 1985) have shown that when mothers are trained to exhibit facial expressions of fear as opposed to happiness or neutrality, their infants use these facial cues as information about approach to or withdrawal from an unusual stimulus. Obviously, the infant's reactions to the facial displays indicate some form of understanding of the meaning of the displays; otherwise, their actions would be inappropriate in the context.

Some studies with rhesus macaques help to make the case that recognition and understanding of facial displays have an unlearned component. Sackett (1966) reared rhesus macaques in social isolation, presenting them with slides of other monkey's facial displays. Appropriate responses to the slides (e.g., in the form of vocalizations, lip smacking, and other disturbances) began to develop around two months of age. He concluded that responses to threat and to other infant monkeys have an unlearned component and that threat faces (in other monkeys) are innate releasers for fear displays.

Kenny, Mason, and Hill (1979) carried Sackett's work one step further by rearing macaques at three levels of social isolation. Beginning at 7 days of age through 129 days, these animals were presented with a mirror or with slides of a human experimenter. Responses began at around 20 days, with lip smacking (a sign of friendliness) to the mirror images and grimacing (a sign of fear) to the human faces. The rearing condition increased the intensity of the responses but even the complete isolation condition produced the same effects. These data underscore Sackett's conclusions that an unlearned

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[5] For studies on brain-damaged adults, see J.C. Borod et al., "Deficits in facial expression," 271.

component of recognition and understanding exists in the organism.

In human infants as young as four months of age, the ability to discriminate types of fearful facial expressions is quite good (Nelson and Lundeman 1987)[6] even though infants' experience with negative facial expressions is much less frequent than their experience with positive facial displays (Malatesta and Haviland 1982). It is possible that the amount of experience with a facial expression is less important than the character of the expression itself.

In Sum

The evidence for the innateness of emotional responsiveness is circumstantial but consistent across domains.

Argument for Attachment

Bowlby (1969) was the first to argue on evolutionary and ethological grounds that attachment between mother and infant had a biological rather than a psychodynamic basis. Since the young of all altricial species (which include all primate species) are relatively helpless for a considerable period after birth, they are in need of care for feeding, protection from predatory species, and other survival needs. Bowlby argued that secure attachment increases the inclusive fitness of the species by insuring a strong bond between infant and caretaker and by insuring that the protective caretaker is in close proximity when the infant is at risk or in need of care.

In fact the loss of attachment through separation and isolation is known to have serious deleterious consequences for the organism. The typical syndrome is biphasic, involving first agitation and then depression at the loss of or temporary separation from the caretaker. In humans there is evidence at every age level that significant loss or separation has psychological, physiological, and even immunological effects (Capitanio, Weissberg, and Reite 1985; Reite and Capitanio 1985). On the positive side, some evidence suggests that the existence of social attachments is associated with good health.

Since the effects of separation and loss cannot be studied ethically in experimental situations, the strongest findings come from studies of nonhuman primates and other species. Prolonged separation can lead to depression and later withdrawal from social interaction when the opportunities for it appear. Early separation from the mother can also lead to immature sexual response and inappropriate rearing behaviors (Petrovich and Gewirtz 1985). Some of Harlow's studies show that the response pattern of pigtail and rhesus monkeys separated from their mothers is exactly parallel to that of human infants during separation (Deets and Harlow 1971; Harlow 1971).

In short, not only is attachment of central importance to the functioning of the human and nonhuman primate infant, but its absence (at least in certain nonhuman primates) is associated with direct loss of reproductive success. Additionally, the development of attachment is observed throughout the human community, with every human society exhibiting some form of caretaking for its infants. Certainly not all societies achieve caretaking in the same way. For example, the Efe, a pygmy tribe

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[6] Also cited in Nelson, "The recognition of facial expressions," 889.

of Zaire, employ a form of communal infant caretaking and attachment, with several women responsible for the attention to and feeding of the infant (Tronick, Winn, and Morelli 1985). Finally, attachment and caretaking is observed in a widely divergent set of nonprimate species as well, including rodents, birds, canines, and so on (Petrovich and Gewirtz 1985).

The evidence for the adaptive value of attachment between mothers and their infants is strong and indeed well established over many years of research. Field (1985b; 1987) has recently argued that the concept of attachment as applied to human infants is circular in that the benefits that appear to accrue to the organism through secure attachment are only indirectly inferenced. Only by studying the negative consequences of separation are the positive consequences for attachment inferred. Indeed, there are significant negative consequences to separation and loss for the infant as well as the mother. But if we do not know what the mechanisms for the development of attachment are, then, first, we have no understanding of the attachment process (only its absence) and, second, we have no clear ideas about how to intervene to improve insecurely attached relationships.

Neither Field nor I have complete answers to this question, but a reasonable starting speculation is to treat attachment as a process whose function is to promote behavioral and physiological synchrony between mother and infant. In short, stimulation regulation in the form of synchrony in positive affect, arousal stimulation, and arousal control is hypothesized as the mechanism through which attachment is achieved. Interestingly, this notion is not far afield (no pun intended) from Bowlby's (1969) initial ideas. Bowlby held that attachment was achieved through the behavioral attachment systems, which operated as homeostatic mechanisms around a set goal of close physical proximity. The homeostatic mechanisms were never fully explicated. These mechanisms may be found in the physiological and behavioral attunements that characterize mother-infant attachment.

The above speculation is based upon several converging lines of evidence, some of which have already been reviewed. Let me summarize these lines of convergence briefly.

Attachment in animals and humans. Studies with pigtail and bonnet monkeys (Reite and Capitanio 1985) following separation from their mothers clearly indicate physiological differences during periods of agitation and depression as compared to baseline (nonseparation). If separation, which is the disruption of attachment, leads to a disruption of normal physiological processes, then the mechanism of attachment must be tied to processes that regulate physiological arousal.

Synchronous stimulation regulation is implicated in the control of arousal. Lester, Hoffman, and Brazelton (1982) found rhythmic synchrony between mother and infant in cardiac and behavioral activity that was greater than that between infant and stranger. Field (1982) found elevated heart rate more common among preterm infants in interactions with their mothers than among full-term infants. Reite and Capitanio (1985) found strong evidence of the role of arousal in attachment and separation with their study of two pigtail monkeys. These monkeys were separated from their mothers at birth and raised together for about six months. At this age they had heart rate and body temperature devices implanted surgically. These devices allowed continuous monitoring during a baseline, separation, and reunion period. The correlations between the heart rates for the twosome (controlling for obvious circadian rhythms and so on) was greater during baseline and reunion than during separation.

This was especially the case for the first five days of separation. (No comparable findings for body temperature were obtained.)

Disruptions of stimulation regulation are implicated in infant distress and in difficulty of bonding. Studies of mothers who are unresponsive (either due to experimental manipulation or temporary depression) show that their infants gaze away more, show more facial distress, and are less responsive to the mothers (after initial attempts to reengage them). At-risk infants (such as preterm, Down's Syndrome, etc.) are difficult to engage in interaction, smile less, exhibit more gaze aversion and less complete facial responses (Emde, Katz, and Thorpe 1978), and are easily overstimulated. The consequence is that the parents of these infants are sometimes disappointed in the engagement their infants exhibit in social interactions. No studies have researched the long-term implications of interaction patterns with these infants in comparison to normal controls.

Cross-cultural evidence. While the cross-cultural evidence for attachment and for the reactions to separation is abundant, I know of no cross-cultural studies of stimulation regulation and its effects. Anecdotal reports suggest that American parents use more stimulation in their interactions with infants while the Japanese, for example, use a more soothing interactional style so that arousal levels are kept low.

Brain opioids. Jaak Panksepp (1982; Panksepp, Siviy, and Normansell 1985) has carried out a fascinating program of research on the psychopharmacological basis of social affect and social attachment. Basically, he argues that social attachment is an addiction His studies with a wide variety of animals indicate, for example, that the distress cries of chicks and mouse pups upon separation from their mothers can be quieted by a variety of opioid agonists (agents). A wide variety of other psychopharmacological agents do not have the same effectiveness as the opioids in quieting distress vocalizations except one, Clonidine, which is commonly used to alleviate opium withdrawal symptoms in humans. Panksepp also points out (Panksepp et al. 1985) that if the opioids are implicated directly in social attachment and affect, then opioid receptor-site blockades (e.g., noxalone) should have the effect of increasing distress vocalizations because the receipt of the opioids at the receptor site will have been blocked. Although the effects of receptor-site blockades are not completely consistent in that the noxalone does not always increase distress vocalizations, they are sufficiently replicable to add as evidence to the theoretical claims. opioids and opioids receptor sites are strongly implicated in social attachment and separation in certain animal species.

In Sum

The arguments for the biological bases of stimulation regulation are certainly more circumstantial than those for emotional responsiveness. Yet, the evidence is sufficient to seriously entertain the hypothesis that the deleterious effects of maternal separation are not the result of some generalized stress associated with loss but rather the result of the loss of a specific regulatory process, namely the modulation of arousal through social stimulation and control of stimulation. This same argument has been made by Hofer (1984) with regard to separation and attachment in mother and infant mice. He was able to show that specific aspects of the mother-infant interaction were related to specific biological deficits when that interaction was lost. For example a depletion of the growth hormone in the pup was associated with a lack of activity provided by the mother. Providing activity to the mouse pups via another means increased the presence of the growth hormone. In human infants it may be that the attachment between mother and infant is created through synchronous stimulation regulation of both behavioral and physiological systems, perhaps mediated by the addictive responses of the brain opioids.

Conclusions

I have tried to make a case for the biological basis of certain patterns of adult interaction. I have no illusion in thinking that these patterns of interaction exhaust all or even the most important aspects of human interaction. However, there is ample evidence that they are functionally important to the adult and to the infant-adult relationship, perhaps even that they are the mechanism for defining caretaker-infant bonding.

In looking for biological sources of ultimate causation for patterns of human interaction, one is not easily brought to a position of biological determinism (especially in the face of significant variation even in the "harder" animal physiological studies). Rather, I think, one is brought to appreciate the intricate relationship between social and biological behavior and the common biological bases that we all share as human primates in that most human of activities, communication. The emphasis on learning, culture, and socialization, the emphasis on higher level cognitive processes and on highly deliberate linguistic exchanges have had a central place in the study of human communication. This place is deserved. But it is time that we recognize that part of what makes our communication human is its biological commonness across peoples and even species.

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