

Behavioral and Physiological Correlates of Ostracism

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A model of social interaction is outlined and used to interpret behavioral and physiological correlates of ostracism. Reported findings suggest that several physiological systems contribute to behaviors that are associated with ostracism and that these as well as other systems are involved in responses to being ostracized. The ideas discussed in this article suggest that future research should (1) identify persons whomay be genetically predisposed to engage in behaviors associated with ostracism, and (2) identify persons who are physiologically vulnerable to being ostracized.

INTRODUCTION

For this article, ostracism is defined as forced exit from desired social groups. The definition assumes that persons are predisposed to interact socially and that only under special circumstances (e.g., prospecting) do they voluntarily discontinue social interactions.

The article is divided into two parts. The first part outlines a model of social interaction. The model is influenced by ideas from evolutionary and behavioral biology. Within the context of the model the second part of the article focuses on selected behavioral and physiological correlates of ostracism.

A MODEL OF HUMAN SOCIAL INTERACTION

Two ideas are central to the model: (1) humans are predisposed to socially interact, and (2) social interactions alter physiological states which, in turn, alter behavior. A representation of the model is presented in Figure 1.

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FIGURE 1.

(See associated.pdf file)

Characteristics of a human social interaction model. Person and social characteristics included in a social interaction model. The model is discussed in text .

The model contains both internal and external elements. The internal (or person) elements include motives, cognitive-emotional attributes, and physiological processes. The term motive refers to a desire, consciously or unconsciously originated, that causes a person to act. Cognitive-emotional attribute refers to thoughts and affects that correlate with behavior. Physiological process refers to biological functions that correlate with behavior. The external components of the model include social group composition, social options, and social demands. Social group composition refers to the age, sex, and social-economic status of those with whom one interacts. Social options are the opportunities for social relationships available to a person. Social demands are the communicated expectations of others with respect to a person's behavior.

In Figure 1, vertical and horizontal interactions are postulated between all elements. For example, one may be motivated to achieve a particular goal, such as assuming leadership of a group. The social option of becoming a leader may not be available, however, e.g., a group may be satisfied with its leader. Persistent attempts to replace an existing leader may result in increased social demands for the aspiring leader to change his or her behavior. As a consequence, the aspiring leader may undergo physiological

change (e.g., increased adrenal or norepinephrine activity) and these changes may be associated with an increase in aggressive behavior and an increased probability of ostracism.

Because people differ in their internal elements, an understanding of individual differences is critical to identifying possible factors and responses that contribute to being ostracized. Two biological concepts provide convenient frameworks in which to discuss such differences. The first is developmental conversion: gene-environment interactions result in the activation of "open" and "semi-open" genetic programs that influence development; e.g., if the same child is highly stimulated compared to minimally stimulated, different genetic programs will be activated. These programs will influence a person's physiology, learning potential, temperament, etc. The second concept is phenotypic modulation: phenotypic variation is a consequence of a person's environmental interactions. These influences (e.g., culture, language, neighborhood characteristics, parents' values) affect the degree of refinement of developmental programs (e.g., the use of associated behaviors and cognitive-emotional attributes in social interactions). Phenotypic modulation is not thought to alter genetic programs controlling development (Smith-Gill 1983) although the reverse is true: developmental programs (e.g., intelligence) influence phenotypic modulation. Because people differ in their genetic composition, their activated genetic programs, and in the experiences which influence modulation, cross-person behavioral and physiological differences are expected.

Activation (or failure of activation) of certain genetic programs can have ~ behavioral consequences which extend across a lifetime. For example, infant rhesus monkeys (assumed to be genetically "normal") may be separated from their mothers and raised in isolation. Such animals are physiologically different compared with normally raised peers. These animals may then be introduced into groups of normally raised age-matched peers. After approximately 1 year, and under non-stressful social conditions, the once separated animals are behaviorally indistinguishable from normally raised peers. However, when ambiguous or stressful situations are created, the initially separated animals are more frightened, more aggressive, and less socially active (Kraemer, unpublished data). In these studies, similarity in social behavior across the two types of animals may be interpreted as an example of phenotypic modulation; persistence of atypical responses to stressful events among the initially separated animals may be interpreted as an example of activation of (or failure to activate) specific genetic programs. (A clear implication of these findings is that cross-person differences in genetic programs can be "masked" in certain contexts.)

With the exception of research in mental illness, there are very few; well-controlled studies of humans that examine behaviors associated with or in response to ostracism. One exception is a study of predispositions to petty criminality among Swedish adoptees which includes 862 Swedish men

and 913 Swedish women adopted by relatives at an early age (Bohman et al. 1982; Cloninger et al. 1982; Sigvardsson et al. 1982). Critical findings include the following: (1) criminality was heterogeneous and largely non-familial - however, some genetic subtypes could be identified; (2) low social status, when combined with genetic predisposition (limited to selected subjects in the sample population), increased the probability of criminality; (3) specific postnatal experiences (e.g., unstable pre-adoptive placement) increased the chances of criminality in men but not in women; and (4) compared to men, predispositions to criminality had to be more severe for women to be affected. Petty criminality thus appears to be in part a consequence of genetic predisposition, in part the result of developmental program activation, and in part a result of phenotypic modulation. Similar findings have been reported by Mednick et al. (1984) in a study of adoptees in Denmark.

The preceding points may be integrated into a discussion of ostracism in the following ways. First, there is the issue of taxonomy. Potential difficulties in developing a rigorous taxonomy of ostracism are implied in Figure I: both the person and social characteristics applicable to any two individuals will differ. As the variance of a population increases, the probability of developing a meaningful taxonomy decreases. Second, the studies of initially isolated and later socialized monkeys underscore the importance of early experiences on subsequent history, particularly physiological vulnerability. Third, the Swedish adoptee study illustrates the importance of additive variables: heritability and environmental influences together are better predictors of criminal behavior than either is alone.

Although individual differences in part explain behaviors associated with ostracism, as Figure 2 suggests, such differences are not the only explanations of cross-person behavioral and physiological differences.

Figure 2 shows the concentration of the chemical serotonin in the blood of adult males from three different primate species. Serotonin is found in both the blood and the central nervous system (CNS). Under many conditions there is a close correlation between blood serotonin levels and CNS serotonin function. In the discussion below, unless otherwise stated, a close correlation is either known to exist or is strongly implied by the data. Although serotonin serves a number of functions, we shall limit our discussion to its role as a neurotransmitter. It is one of many neurochemicals that are known to influence nerve transmission (see Cooper et al. 1982 for a review) and both inhibitory and facilitatory functions have been reported: for example, among adult male vervet monkeys (*Cercopithecus aethiops*), pharmacologically induced increases in CNS serotonin function are associated with an increased frequency of grooming, resting, eating, and environmental surveillance; conversely, pharmacologically induced decreases in CNS serotonin function are associated with a reduced frequency of the preceding behaviors and an increased frequency of aggression and solitariness (Raleigh et al. 1984).

FIGURE 2.

(See associated.pdf file)

Social status and whole blood serotonin in three species. Whole blood serotonin (WBS) concentrations (ng/ml) in adult males from three primate species: squirrel monkeys, vervet monkeys, and humans. Four groups of squirrel monkeys each containing three adult males were observed. Each group had a linear dominance hierarchy. WBS showed little intra-animal variability. The four dominant, or alpha, males had WBS concentrations about 40% higher than the four second ranking, or beta, males. In turn the beta males had WBS concentrations that were about 20% higher than the lowest ranking, or gamma, males. Nineteen groups of vervet monkeys, each containing two or more adult males, were observed and WBS concentrations were stable within individuals. The 19 dominant males WBS concentrations that were about 80% higher than those of the 37 subordinate males. Four all-male fraternities were also studied. From each fraternity, WBS was determined in two officers (e.g., president and vice president) and two recently initiated members. The officers and initiates did not differ in age, race, or grade point average but the officers were rated by other fraternity members as having higher status than the initiates. The eight officers had WBS levels about 25% higher than the initiates. Within a species, all differences (e.g., between officers and initiates) are statistically significant ($p < 0.05$).

Among male vervet monkeys, squirrel monkeys (*Simiurus samii*), and humans, socially dominant or high-status individuals have high levels of whole blood serotonin (WBS) compared to subordinate monkeys or lower status persons (McGuire et al. 1983a,b; Raleigh et al. 1984). When a dominant male vervet becomes subordinate (or vice versa), the animal takes on the physiological and behavioral characteristics of his newly acquired social status, a finding strongly implicating behavior-physiology interaction. When all subordinate males are removed from a multi-male, mixed-sex group, WBS levels will decline in the remaining dominant male to levels normally seen in subordinate animals. Thus, high blood serotonin levels appear to be a function of male-male interactions (McGuire et al. 1983b).

When a dominant vervet male is removed from a multi-male, mixed-sex group, which of the remaining adult males will become dominant appears to be less a function of a given male's competitive (e.g., fighting) ability than that of the behavior of female vervets. Females "ally" themselves with one of the remaining males and assist him in fights with other males. (The reasons why specific males are selected by females are not known.) Animals that

become dominant have a characteristic physiological profile (e.g., high WBS and high CNS serotonin function); animals that remain subordinate have another.

Two important behavioral differences distinguish dominant and subordinate males. In group living situations, dominant males have priority access to preferred perches, nutrients, and sleeping sites. In addition, they copulate more frequently and copulation is not interrupted by subordinate males although the reverse frequently is the case. Thus, social options differ among dominant and subordinate animals and these options are in part influenced by female preference, which has physiological consequences. In addition, dominant and subordinate males behaved differently in individual behavior tests (McGuire et al. 1984). These tests involve temporarily removing animals from their social groups in order to control for social inhibition or facilitation effects which are known to significantly influence behavior in group settings. Such tests demonstrate that dominant males are more likely to attack predators whereas subordinate males are more likely to touch unknown objects; dominant males systematically and calmly explore novel environments whereas subordinate males are both hyperactive and unsystematic in their exploration of such environments. The physiological-behavioral consequences of group living thus remain in effect during periods in which animals are temporarily separated from their groups.

The behavior of selected group members can have a significant influence on the behavior of other members. This point is illustrated in Figure 3, which documents the behavior of untreated group members following treatment of individual animals with the drug parachlorophenylalanine (PCPA). PCPA reduces CNS serotonin function and both dominant and subordinate animals respond in a similar way to PCPA treatment—they become irritable, hyperactive, aggressive, and relatively unpredictable in their social interactions. Despite cross-status similarities in the behavioral effects of PCPA, the social consequences for untreated animals differ significantly. When a subordinate animal is treated with PCPA, his behavior does not noticeably reduce the grooming behavior of other untreated subordinate animals in his group. However, when a dominant animal is treated with PCPA, the grooming behavior of untreated subordinate animals significantly decreases in frequency (Raleigh and McGuire 1980). If hyperactive and aggressive behavior among dominant males is equated with increased social demands (i.e., subordinate males must attend to such behavior), behavioral options among subordinate males are decreased as a result of the dominant male's behavior.

To summarize, we have outlined a social interaction model in which there are bidirectional effects. Persons are motivated to seek particular goals. Many of these goals (e.g., gaining the attention of others, becoming dominant, sharing) will not be achieved without the cooperation of others. Depending on group composition, social options, and social demands, one's physiological processes and behavior will be affected. Much behavior that

FIGURE 3.

(See associated.pdf file)

Interrelationships between social status, grooming, and PCPA treatment, in vervet monkeys. The effects on untreated group members when PCPA (an inhibitor of serotonin synthesis) is given to animals of different social status. Among male vervets, chronic treatment with DL PCPA (parachlorophenylalanine, 80 mg/kg/day for 14 days) resulted in irritable, aggressive, and hypermobile behaviors. Animals of different social status show similar responses to PCPA. PCPA-induced behavioral changes in dominant males significantly altered the behavior of nontreated group members. When the dominant male was treated, the frequency of grooming among other group members decreased significantly more than when a single subordinate group member was similarly treated with the same dose of PCPA. See text for further discussion.

results in ostracism thus may be best understood as a product of bidirectional effects between person and social group during a preostracism period.

BEHAVIORAL, PHYSIOLOGICAL, AND NEUROCHEMICAL CORRELATES OF OSTRACISM

Behavioral Correlates of Ostracism

The average adult U.S. citizen is reported to spend 6.75 hours per day interacting socially. There appears to be relatively little day-to-day variance in this figure except under special circumstances (e.g., hiking alone), and such circumstances are usually temporary. It is through social interactions that many goals are achieved, social options exercised, social demands made and responded to, and physiological status altered.

Forced or voluntary disruptions of social interactions have profound consequences, which are illustrated in sensory deprivation studies: memory becomes disorganized; learning and thinking performance decline; and the probability of panic, body temperature reduction, hallucinations, touch distortions, and smell aberrations significantly increases (see Shultz 1965; Solari &

omon 1961 for reviews). The possibly severe consequences of social isolation are demonstrated in a recent set of studies by Volkart and colleagues, who examined the effects of solitary confinement among prisoners. Compared to both nonprisoner and prisoner control subjects (the latter group being guilty of the same offenses and incarcerated for similar periods but not socially isolated), the frequency of psychotic behavior was approximately 50% higher among prisoners who were placed in solitary confinement. In addition, depression and suicide attempts significantly increased among the isolated prisoners (Volkart et al. 1983 *a,b*; Volkart 1983). From the perspective of Figure 1, solitary confinement can be viewed as a dramatic discontinuation of social options (e.g., reduction of the option to achieve certain goals that require others' participation) and social feedback. These data also illustrate a point about individual differences: not every prisoner placed in solitary confinement developed psychotic symptoms or attempted suicide. Because Volkart's research design balanced and corrected for confinement type and type of offense, individual differences are implicated in his findings: prisoners who became psychotic or who attempted suicide are likely to have had different genetic programs and/or developmental experiences compared to persons who did not become psychotic, depressed, or suicidal.

A reasonable inference from the studies cited in the paragraph above is that normal functioning of many physiological processes is dependent on social interactions. In the absence of these interactions physiological drift or deregulation occurs. Under normal social living conditions deregulation can be controlled: when physiological processes begin to become deregulated, people initiate social interactions in order to reregulate and if others respond to the initiator in positive ways, reregulation generally occurs. On the other hand, if others respond in negative ways, or not at all, deregulation continues and may be exacerbated. This sequence of events facilitates explanations of the already cited social isolation data as well as events such as frustration when kin or friends do not respond as expected. It also suggests that subtle forms of ostracism, such as not responding as expected or refusing to see another, may have physiological consequences upon the one ostracized.

Physiological and Neurochemical Correlates of Ostracism

In shifting the discussion to physiological data associated with ostracism, several introductory points should be emphasized. First, many physiological and neurochemical processes cannot be meaningfully discussed because of conflicting or incomplete evidence. Second, the material presented below does not consider many potentially important processes. For example, we do not deal with the fact that certain neurotransmitters have biological variations (e.g., circadian) relatively independent of situationally induced changes (Walter -Van Cauter et al. 1981; McGuire et al. 1982; Purifoy 1981). Third, behaviors that result in ostracism (e.g., child abuse, adult aggression, and

theft) are seen among a number of primate species (see, for example, Noll, et al. 1982; Walker et al. 1983; Troisi and D'Amato 1984; de Waal, this issue). Thus, biological mechanisms that contribute to ostracism may be widespread.

Interactions between the limbic system, hypothalamus, pituitary body, and the adrenal gland influence a multitude of physiological and behavioral measures. In non-dangerous situations, a principal function of these systems is to mediate physiological changes associated with emotions such as fear, flight, anger, hunger, thirst, sex, and pleasure. These systems respond to both external and internal events. In situations perceived as dangerous (and within limits) these systems are considered adaptive: they alter metabolic functions, blood-clotting mechanisms, and alertness, all of which may enhance self defense. Chronic alterations in these systems (e.g., prolonged response to fear) reduce physiological and behavioral adaptiveness in that they are associated with increased fatigue, restricted behavior (behavioral rigidity), a decrease in immunological competence, elevated blood pressure, altered lipid metabolism, and an increased probability of illness.

A number of biological processes, including those associated with hypothalamic-pituitary-adrenal, serotonin, and catecholamine function appear to be particularly responsive to forced isolation from social settings. For example, short-term increases in levels of circulating plasma cortisol (a product of the adrenal gland) are observed in squirrel monkey infants when they are separated from their mothers (Coe et al. 1978 *a, b*). Rhesus monkeys forcibly separated from their peers have elevated levels of serotonin in the hypothalamus as well as higher levels of all the major enzymes involved in catecholamine synthesis in the adrenal gland (Breese et al. 1973). Reite and Short (1978) and Reite et al (1978, 1981, 1982) have shown that forced separation of macaque monkey infants from their mothers alters heart rate and rhythm, body temperature, sleep patterns, circadian rhythms, and immunological function. These changes are thought to be primarily hypothalamic in origin. The hypothalamus is believed to have intimate connections with the limbic system, which is involved in memory, pleasure, emotional excitability, and activity level. In addition, there are known limbic influences on hypothalamic function (Dreyfus et al. 1968) and limbic function may subservise attachment and affiliative behavior (Kling and Steklis 1976). Reducing normal social interaction options thus may alter limbic system activity; in turn, hypothalamic activity may be compromised and, indirectly, so too may adrenal activity. Although adequate human data are not available, a reasonable working hypothesis is that many of the behavioral consequences associated with ostracism can be related to pathological changes in one or more systems described above.

Neurotransmitter systems are a major focus of current biological research, primarily because of their reestablished importance in the transmission of information and the initiation or suppression of behavior. Understanding their function would appear to be essential to understanding ostracism. Neu -

rotransmitters are neurochemicals that (generally) are synthesized, stored, and then released from a presynaptic neuron into the synaptic patch. They carry out their "transmitter" function by "attaching" to pre- and postsynaptic receptors specific for different neurotransmitters. The number and sensitivity of receptors for a given transmitter are known to differ across brain region although the functional importance of such differences is not as yet clear. Neurotransmitters are generally characterized as either inhibitory or excitatory, but for any specific transmitter it is not known if function is constant across regions of the brain. In addition, different physiological states result in alterations in receptor parameters.

The serotonin system(s) has been briefly discussed above and will be further elaborated in an accompanying article (see Raleigh and McGuire, this issue). Only the results of one social isolation study are discussed here. When adult male vervets are removed from stable social groups and socially isolated, WBS levels initially stabilize at about 600 ng/ml, the usual level for group-living subordinate adult males. By the 70th day of isolation serotonin levels begin to rise and by the 100th day they are elevated to 1200 - 1400 ng/ml, a value comparable to that seen among dominant males living in social groups (Brammer et al., unpublished data). The behavior of these animals in individual behavior tests resembles that of subordinate males, however. Isolated animals become increasingly aggressive as their WBS levels rise. Moreover, they do not show an elevated WBS response to tryptophan (a serotonin precursor) treatment whereas group-living animals with similar high levels of blood serotonin show a significant increase in WBS 60 minutes following tryptophan administration. These findings suggest that there may be a reverse of the blood-CNS serotonin relationship seen in socially living animals (i.e., animals isolated for more than 100 days are "peripherally dominant" and "CNS subordinate").

Data from studies of serotonin in humans are less clear, although findings strongly implicate this system in ostracism-related behavior. Increases in aggressive-impulsive and suicidal behavior are associated with decreased levels of WBS and CSF 5-HIAA (5-hydroxyindoleacetic acid), a metabolite of serotonin (see Brown et al. 1982; Davis et al. 1983; Pucilowski and Kostowski 1983). Low peripheral serotonin levels and low cerebral spinal fluid 5-HIAA levels are found among a subgroup of clinically depressed patients (Rydin et al. 1982). When treated with drugs that elevate serotonin levels, the symptoms of depression often lessen and patients increase the frequency with which they socialize (Singhal and Telner 1979). Further, brain serotonin receptor sites are reduced among a significant number of persons who commit suicide when compared to persons who die from other causes (e.g., accidents) (Stanley et al. 1982). CNS serotonin function thus is likely to be altered in many situations in which persons behave in ways associated with ostracism as well as in response to being ostracized.

Norepinephrine is usually considered an excitatory neurotransmitter. There is evidence suggesting that changes in norepinephrine levels are associated with

sociated with altered mood and behavior. Elevated levels are associated with excessive excitability, excessive but brief social contacts, rapid speech, excessive movement, an exaggerated increase in the sense of well-being (within limits), as well as an increase in the frequency of aggressive behavior (see Brown et al. 1982, for a review, as well as standard psychiatric textbooks under the heading of mania). Such behavior is correlated with an increased probability of ostracism (e.g., social avoidance, mental hospitalization). On the other hand, when norepinephrine levels are reduced, depression, social withdrawal, and suicide are more likely (see Brown et al. 1982 for a review).

Evidence primarily from studies of pharmacological treatment of non-human primates separated from their social group clarify some of the preceding points. For example, alpha-methyl-para-tyrosine (AMPT) inhibits the production of tyrosine hydroxylase and blocks norepinephrine and dopamine synthesis, i.e., there is a reduction in the levels of these neurotransmitters. When AMPT is given to animals who have been forcibly separated, who show signs of despair, and who are known to have low norepinephrine levels, these animals exhibit a significant increase in despair symptoms compared to normal peers treated with the same drug. Norepinephrine, therefore, is an important determinant of social behavior.

DISCUSSION

Several themes wind their way through this article. One is that certain types of social interactions contribute to our sanity, to a low probability of deviant behavior, and to the regulation of a variety of physiological systems. Another is that other types of social situations do just the opposite, but more so in some persons than others. Identifying which persons are affected by particular social environments could be one goal for research in ostracism. Another could be identifying the physiological events that occur as a result of particular persons being in particular environments. There is evidence that the probability of enacting behaviors that lead to ostracism is influenced by past history (via atypical physiological systems) and that current environmental situations further alter the probability of such behaviors being enacted (also via physiological systems). Evidence is compelling that there are physiological and biochemical consequences of ostracism. These effects appear in part to be examples of physiological deregulation. Finally, neurotransmitter systems are clearly implicated in ostracism. Their contribution remains to be determined, however.

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