

Experience-Dependent Affective Learning and Risk for Psychopathology in Children

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ABSTRACT: The influence of childhood affective experiences across development may be understood in terms of preparedness to learn about emotion, combined with general immaturity and neuro-plasticity of perceptual systems. Early in development, processing resources are relatively immature and limited in capacity, thereby constraining how much information the young child can absorb. But it is clear that learning about emotions proceeds swiftly in nearly all children, suggesting biological preparedness to track associations between certain stimuli and outcomes. It is proposed here that limited processing capacity, in tandem with dispositions to filter or select key privileged stimuli in the environment, facilitates adaptive, rapid, affective learning. The developmental organization of affective systems is contingent upon those features of input that are most learnable, such as signals that are particularly salient, frequent, or predictable. Therefore, plasticity confers risk for maladaptation in that children's learning will be based upon these prominent features of the environment, however aberrant.

KEYWORDS: child abuse; genes; psychopathology; affective learning; maltreatment; experience; plasticity

INTRODUCTION

The recent publication of several scientific papers^{1,2} and popular press books, such as *The Nurture Assumption*,³ *The Blank Slate*,⁴ and *Enough*,⁵ suggest that the age-old nature–nurture debate is over. One might gather from the theses advanced in these expositions that there is little question about the degree to which parents and early rearing environments influence rudimentary aspects of children's development beyond providing children's genetic make-up. Rather than being resolved, however, the issue about biology and experience is undergoing a reformulation that suggests the topic is just getting started—again. In the past few months, compelling and sophisticated examples of nature–nurture (or gene–environment) interactions have appeared in the literature.^{6–9} These reports highlight the complex, dynamic interplay between biology and experience in shaping children's behavior. As scientists advance our understanding how biological factors (including genetic polymorphisms, variations in neurophysiological processes, and neuroanatomical lesions) are associated with mental health problems, compelling questions emerge about the processes

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through which experience shapes biology, necessitating a more fine-grained approach to explaining mechanisms of change and development.

GENES AS A MECHANISM OF EXPERIENCE

The phenomenon of child maltreatment is at the center of debates about the relative roles of children's early learning environments, parents' genetically influenced characteristics, children's genetically influenced characteristics, and risk for the development of maladaptive behaviors. My students and I examine the effects of child maltreatment from a developmental perspective, viewing child abuse as a manipulation of species-typical experience that may shed light on the role of experience-dependent processes in the emergence of psychopathology. While emphasizing the role of affective learning in the development of psychopathology, we also recognize that even powerful learners are not blank slates. Ultimately, affective learning (like learning in other complex systems) must be explained by a combination of biological predisposition and experiential input. Our hypothesis is that a predisposition for learning about emotions, achieved through general perceptual learning mechanisms, may explain the development of behavior problems in maltreated children.

Genes and anatomical structures, in and of themselves, strike us as very important but not very profound. From a developmental perspective on psychopathology, genes become important when taken together with the context in which they are expressed; anatomy becomes important in terms of how and under what circumstances it is (or is not) used. To fully understand the ontogenesis of mental health problems in children, it is important for psychopathologists to focus not only on what is in children's heads, but on what their heads are in: the give-and-take with the wide welter of signals and sensory input received by the developing brain from the outside world during both fetal and postnatal development. Surprisingly, little research has focused on the *mechanisms* underlying the emergence of emotional processes in children, and the neurodevelopmental processes involved in the organization of affective systems remain largely unknown. This dearth of knowledge is an exigent problem in developmental psychopathology, in which the creation of effective, tailored interventions for children suffering from emotional difficulties requires a clear understanding of the regulatory processes that have gone awry.

Our perspective is not in conflict with, but complementary to, psychiatric molecular genetics. Conceptual problems abound in attempts to disentangle genetic and environmental influences in studies of biologically related parents and children. For example, even if some heritable association between child maltreatment and the development of psychopathology exists, it is not clear what is being genetically transmitted. Might abused children be bound to develop problems even if they were not abused? Have these children inherited characteristics that make them likely to be abused in the first place? Both of these alternatives seem unlikely. Behavioral genetic analyses have ruled out the possibility that heritable characteristics of the child evoke physical maltreatment.¹⁰ To the degree that the sequelae of child abuse are genetically determined, it appears that what are heritable are the characteristics of the parent that are transmitted to children via family environment.^{10,11} What children inherit are toxic environments, which highlights the need for better understanding of how children are influenced by such early aversive experiences.

The maltreatment of children is a horrific psychosocial phenomenon in which young infants and children do not receive the protection, care, nurturance, and interactions that are typical of how humans (and many other species) care for the young. More than 2 million children a year are victims of child maltreatment in the United States.¹² Perhaps because it is both obvious and has been demonstrated that children who experience such severe perturbations in care are at very high risk for the emergence of behavioral problems later in life,¹³ the precise mechanisms linking the experience of maltreatment with the development of psychopathology are infrequently examined and largely unknown. But this is a critical question: How is it that such adversity early in life can lead to a range of problems including depression, aggression, substance abuse, health problems, and general unhappiness years after abuse has ended? The emotional development of maltreated children provides a compelling clue of where to begin looking. Maltreated children often evince unusual patterns in their abilities to recognize, express, and regulate emotional states.^{14–16} Physically abused children often display both withdrawal and aggression,^{17–19} readily assimilate and remember cues related to aggression,^{20,21} and tend to attribute hostility to others.²² These processes lead to poorly regulated and situationally inappropriate affect and behavior.^{23,24} Our research program has been motivated by the scarcity of investigations targeting specific physiological, perceptual, or cognitive processes that may act as proximal determinants of such affective regulatory problems.

LEARNING FROM AND SENSITIVITY TO EMOTIONAL EXPERIENCE

We propose that exposure to maltreating environments affects children's processing of emotional information, and that these effects may explain children's interpersonal difficulties across situational contexts and developmental epochs. This influence of early experiences may be understood in terms of the general immaturity and neuroplasticity of sensory and perceptual systems.^{25,26} On this view, maturational limitations on processing resources aid children's learning about emotion by requiring the child to filter information from the environment. This leaves the development of emotion systems contingent on the most salient aspects of the child's experience, however aberrant. One possible experience-dependent mechanism for these developmental effects is that infants' biological preparedness for emotion includes a general perceptual mechanism that becomes tuned to combinations of signals, which, through experience, combine to form affective neural circuitry and categories. Such a learning mechanism might include the ability to parse sensory inputs into meaningful units and to track the regularity, predictiveness, and temporal synchrony of emotional information. Similar learning mechanisms have been proposed for other cognitive abilities such as cross-modal matching, phonetic discrimination, and word segmentation.^{27–29}

Developmental affective learning problems may arise because the emotional signals the maltreated child receives can be disproportionately complicated, inconsistent, poorly conveyed, distressing, limited, threatening, or excessive. Or processing differences may arise simply because abused children learn, first and foremost, to track signs of threat, reflecting an adaptive ability to effectively pair a signal with a

meaningful outcome.³⁰ In abusive environments, displays of anger are likely to be a particularly salient cue with a learned association to threat or harm for abused children, disproportionately recruiting these children's attentional resources. Neurobehavioral plasticity of developing cognitive and perceptual systems figures prominently in this account. Mature, adult computational networks can ignore or effectively filter noise, but, in a developing network, such noise becomes part of the basis of development. For example, a traumatic reaction may occur when an adult is assaulted, because the individual's expectations have been violated. But for a child exposed to chronic maltreatment, violent experiences may form the basis of the child's expectations of others. Irrespective of the initial state of the organism, emotional development is contingent on the nature of the input or experiences which confront the child. Experience matters.

To test and refine our hypothesis, we focus on the problem of emotion recognition: how do signals received from the environment acquire the salience that makes them "emotional" and how do children process such salient cues? We highlight two candidate developmental mechanisms that may be affected by early experience: perceptual sensitivity and attentional control. In one of our earliest studies, we found that physically abused children perceived angry faces as highly salient relative to other emotions.¹⁶ A significant aspect of this study was that we were able to contrast children with different types of maltreatment experience. Physically abused children had experienced abuse by commission—they were directly injured by a parent. In contrast, neglected children experienced abuse by omission—lack of care and responsiveness from parents. Neglected children, who purportedly did not receive adequate scaffolding to master decoding of communicative signals, had difficulty differentiating facial expressions of emotion. Rather than showing global deficits in performance, physically abused children performed well, especially when differentiating angry facial expressions. These data suggest that specific kinds of emotional experiences, rather than simply the presence of stress or maltreatment, differentially affect children's emotional functioning.¹⁶

Because the ability to allocate attention to emotional cues in the environment is an important feature of adaptive self-regulation,³¹ we have used psychophysiological techniques to measure children's selective attentional control for emotional information. Event-related potentials (ERPs) provide an index of central nervous system (CNS) functioning thought to reflect the underlying neural processing of discrete stimuli, especially those involved in attentional resource allocation.^{32–34} Our ERP studies reveal that whereas nonmaltreated children and adults responded uniformly when attending to happy, fearful, and angry faces, physically abused children displayed relative increases in brain electrical activity only when actively searching for angry faces. Abused children performed identically to controls when attending to other emotional expressions, suggesting that attentional processes directed toward detecting angry cues distinguish maltreated children's emotion processing.^{35,36}

Although it is adaptive for salient stimuli such as emotions to elicit attention, successful behavioral regulation includes some flexibility and control over attention. Such control might include strategic filtering or timely disengagement from stimuli in the environment. Therefore, we began exploring the possibility that early experiences of abuse may affect developing perceptual systems in part by shaping the sensory threshold that anger-related stimuli must pass to recruit attentional focus. Problems with disengagement would also suggest that abused children are less able

to utilize strategic attentional control once signals of interpersonal threat have been engaged. Relatedly, problems disengaging from angry faces may also be a function of the depth of processing or strength of engagement of that cue.^{37–39} Using a selective attention paradigm, we found that abused children demonstrated an increase in brain electrical activity only when they were required to disengage their attention from angry faces, reflecting increased allocation of cognitive resources.²⁰ An additional finding from this study was that physically abused children oriented rapidly to spatial locations primed by anger. Importantly, abused and nonmaltreated children did not differ in other types of trials or in response to other emotions, consistent with the hypothesis that physically abused children have a specific problem involving processing of anger, rather than general information processing deficits.

If abused children are overattending to anger, we might expect to observe differences in how these children perceive angry cues from the environment. Therefore, we examined abused children's perception of anger. Categorical perception occurs when perceptual mechanisms enhance differences between categories at the expense of our perception of incremental changes within a category. Perceiving in terms of categories is adaptive in that it allows an observer to efficiently assess changes between categories that are environmentally important (e.g., to see that a traffic light has changed from green to yellow) at the cost of noticing subtle changes in a stimulus that are not important (e.g., such as variations in shades of greens or yellows across individual traffic lights). Children performed a facial discrimination task that required them to distinguish faces that had been morphed to produce a continuum on which each face differed by 20% in signal intensity. To create continua of facial expressions of affect, we used a two-dimensional morphing system to generate stimuli that spanned four emotional categories—happiness, anger, fear, and sadness. We found that the experience of abuse was associated with a change in children's perceptual preferences and also altered the discriminative abilities that influence how children categorize angry facial expressions.⁴⁰ Yet, abused children performed identically to controls when discriminating emotions other than anger. These findings suggest that whatever perceptual capacities infants possess when they enter the world, they need to adjust or tune these mechanisms to process specific, salient aspects of their environments. Thus, affective experiences appear to influence perceptual representations of basic emotions.

To further test the hypothesis that children exposed to high levels of threat are especially sensitive to visual cues of anger, we examined whether these children can readily relate visual cues to representations of emotions. The examination of this issue required a technique that could capture the dynamics of emotion recognition, including the sequential and content-based processes of feature detection involved in emotion recognition. To do so, we presented affective stimuli to children incrementally as sequences of emotional expressions that initially were degraded and asked participants to report what emotion they thought they were seeing. As predicted, physically abused children accurately identified facial displays of anger on the basis of less sensory input than did controls.⁴¹

DEVELOPMENT, BIOLOGY, AND EXPERIENCE

We have proposed that predispositions to attend and learn about emotionally salient events, in tandem with developmental constraints on perceptual systems, leads

children in abusive contexts to overprocess environmental signals associated with harm. Over time, such processes may lead to complex information processing atypicalities that compromise healthy, adaptive functioning. Preliminary evidence supporting this position includes findings that physically abused children perceive angry faces as more distinctive than other emotions, develop broad perceptual category boundaries for anger, require less visual information to detect the presence of angry facial expressions, devote more attentional resources to detecting anger, and display increased brain electrical activity when disengaging attention from anger. Our psychophysiological studies also reveal early (precognitive) sensory activation on the part of maltreated children to angry faces based on minimal perceptual input. In short, based on multimethod studies including electrophysiological, cognitive, and perceptual tasks, it appears that early perceptual and attentional processes directed toward angry cues distinguish maltreated children's emotion processing. Abused children seem to have become experts at anger detection. But at what cost? Whereas it is adaptive for salient environmental stimuli to elicit attention, successful self-regulation includes flexibility and control over these processes. We suspect that it is failure of regulatory capacities that lead to abused children's troubles. These studies suggest new ways of understanding the neural mechanisms through which early experience contributes to the development of psychopathology.

Whatever the sequential particulars of the three billion DNA subunits that make up a child's genotype, they are meaningful only in the context of phenotype, of a child's life history and experiences. Critical and unanswered questions concern what experiences turn on and off certain genes, how those genes influence our experiences, what are the mechanisms through which they act in combination with "stressful" experiences to produce psychopathological syndromes. In the latter case, the identification of a gene polymorphism in a clinical population, or even a 100% heritability estimate, cannot address what the gene is doing: how it causes or maintains disorders, how it directs or constrains an organism's interaction with the environment, whether it has the same function early in development as in adulthood, and whether the gene functions similarly across species.

In this regard, nonhuman animal studies, in which experiences can be experimentally manipulated, are essential. Although care must be taken in translating animal studies to humans (see articles by Nelson, Gunnar, and Plotsky, this volume), nonhuman animal maltreatment studies provide important information that can guide future research into the neurodevelopmental processes affected by early experience. For example, the original impetus for isolate rearing in rhesus monkeys was the desire to study learning unfettered by differences in mother-infant interaction.⁴² However, these socially deprived animals proved difficult to test in the laboratory because of their heightened emotional reactivity, leading researchers to redirect their studies to emotional processes and behavioral regulation.⁴² Early explanations for these emotional effects based on rodents first implicated the hypothalamic-pituitary-adrenocortical (HPA) axis and its limbic-cortical regulatory pathways.⁴³ Research with monkeys suggested that early experience affects development of the parietal and prefrontal cortices, as well as the limbic-cortical pathways involved in regulating neuroendocrine and behavioral responses to stress.^{44,45} Although complementary human evidence is sparse, it is known that both the HPA and sympathetic-adrenomedullary systems in humans undergo reorganization during postnatal life that are associated with the child's social relationships.⁴⁶ In addition, EEG activa-

tion, a neural correlate of social withdrawal and avoidance, and ERP activation to emotion, a correlate of attention, have been associated with early social experiences.^{36,47} As an example, infants of depressed mothers who provided unresponsive and/or intrusive care showed right frontal EEG asymmetries, reflecting increased negative affective states.⁴⁸ These data suggest that future research needs to focus on the neural substrates of children's emotional behavior to better understand the effects of experience on development.

The role of context and environment is a central problem in understanding both child mental health problems and the ways to effectively remediate those problems. One issue concerns the difficulty in precisely parametrizing the rich, complicated, "booming, buzzing, confusion" of sensory experiences to which humans are exposed within moments of birth. A related problem in the area of child psychopathology is that it is not yet clear which aspects of the environment need to be measured. Moreover, whereas we may be able to link biological similarities across species, it may be more difficult to link affective experiences between human and nonhuman animals. Maternal care in the rat involves licking and abuse in the monkey is operationalized as biting and dragging. How can we best model in nonhuman animals phenomenon such as being threatened, criticized, and beaten while being blamed, and other experiences encountered by abused children?

CONCLUSIONS

Descriptions of mental health problems observed in different populations of children cannot adequately inform us about the initial state of the organism or the developmental pathways that lead to problem behaviors. The patterns of information processing we have described suggest that children who experienced early abuse are processing certain types of emotional information atypically, while appearing to process other types of emotional information similarly to nonmaltreated children. Tracing the developmental origins of such complex behavior requires a focus on developmental mechanisms, not static lesions or deficits. Maladaptive behavioral outcomes emerge from cascading effects (and interactions) over time. To get at these interactions, we need to consider both developmental biology and context. Such a perspective must take into account anatomical constraints on the developing brain as well as an understanding of what situations the organisms has had to respond to—not only what is in the genome, but what the genome is in. Such a focus on mechanisms of adaptation and maladaptation has important implications for the development of effective prevention and treatment/intervention programs for at-risk children as well. Treatments not directed at underlying mechanisms may address distal symptoms rather than the roots of mental illness in children.

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