



THE IMPORTANCE OF BIOLOGICAL METHODS IN LINKING SOCIAL EXPERIENCE WITH SOCIAL AND EMOTIONAL DEVELOPMENT

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The ability to decode and express emotions allows the developing child to assess and change many aspects of the environment. When emotional development is unfolding in a normative manner, the child's early experience within his or her family context promotes increasing abilities to successfully adapt to environmental demands. This is a critical developmental process as difficulties in emotional functioning can lead to problems in social adaptation and health. The issue of how adverse social experiences alter and shape children's social and emotional development has become a center stage for the exploration of the relative contributions of nature and nurture in child development. Our research has examined the ways in which children's developing biology is shaped in a manner that may be adaptive to their early environment but confers risk for a host of negative developmental outcomes. Here, we discuss some of the challenges that we have encountered in trying to address issues related to the influence of early social context on the development of biological processes underlying emotional development. When used thoughtfully, biological methods can enrich our understanding of emotional development by moving beyond a descriptive "biomaker" approach and excavating the mechanisms underlying developmental changes in these systems.

RESEARCH WITH AT-RISK SAMPLES OF CHILDREN

One way to understand how a system emerges is to examine perturbations in those processes. In this manner, we have studied children who have had adverse early social experiences that distinguish them from children raised in a normative family context. Specifically, we have studied children who have

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been physically abused and children who were reared in understaffed international orphanages. Physically abused children are reared in an environment in which anger is an extremely salient cue. Anger is highly predictive of danger, and as such, it is adaptive for the child to be sensitized to this signal. Indeed, we have demonstrated that children who experience physical abuse are quicker than typically developing children to identify anger (Pollak, Cicchetti, Hornung, & Reed, 2000). In contrast to physically abused children, who are prominently exposed to expressions of anger, children from international orphanages have received impoverished emotional input. Children from international orphanages experienced extreme neglect. In the orphanage, a prominent lack of emotional and physical contact from caregivers is a consistent adverse feature of the environment (Human Rights Watch, 1998). Later in life, subsequent to removal from the orphanages, and adoption into typical families, many of these children experience problems in establishing social bonds and regulating social behavior. This includes a lack of developmentally appropriate wariness of strangers, atypical and disinhibited patterns of attachment, and difficulties developing close friendships (Fisher, Ames, Chrisholm, & Savoie 1997; O'Connor et al., 2003; O'Connor & Rutter, 2000). Our initial investigations underscored how these groups of children develop sets of behavioral problems that are related to specific features of their early social environment (Pollak, 2005, 2008). More recent research from our group, employing neurobiological metrics such as electrophysiological, neuroimaging, and neuroendocrine indices, has assayed potential neurobiological mediators of these apparent behavioral difficulties.

Electrophysiological Measures

Behavioral studies have indicated that physically abused children have an enhanced perceptual ability for anger detection (Pollak et al., 2000); however, the behavioral studies alone do not provide any evidence indicating how this may serve as a risk factor. We hypothesized that these behavioral features reflected that physically abused children were devoting disproportionate cognitive resources to signals of anger. Such privileged processing of anger might deflect resources from other important cognitive and emotional processes necessary for healthy social functioning. To test this hypothesis, we used an electrophysiological approach called the event-related potential (ERP). An ERP is an averaged electroencephalogram (EEG) time-locked to specific stimuli. ERPs have exquisite temporal resolution (on the order of milliseconds) but relatively poor spatial resolution. As such, ERPs can be used as an index of various cognitive processes including attention (Luck, 2005). A specific aspect of the ERP, the P3b component, is thought to reflect selective attention toward task-relevant information and is also influenced

by the context and salience of attended stimuli (Isreal, Chesney, Wickens, & Donchin, 1980). As we expected, physically abused children showed an enhanced P3b in response to angry faces compared to other emotions (Pollak, Cicchetti, Klorman, & Brumaghim, 1997; Pollak, Klorman, Thatcher, & Cicchetti, 2001). Importantly, again using the P3b as an index of attention, we demonstrated that the severity of physical maltreatment was associated with the amount of attention devoted to anger (Shackman, Shackman, & Pollak, 2007).

Maltreated children also have difficulty disengaging attention from angry faces (Pollak & Tolley-Schell, 2003) and show impaired regulation of goal-directed attention (Shackman et al., 2007). Research using the N2 ERP component, an index of conflict processing (Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003), has revealed that physically abused children attend to facial signals of anger, even when instructed to ignore them (Shackman et al., 2007), and that the degree of cognitive conflict experienced in response to task-irrelevant angry faces predicts poorer task performance (i.e., slower reaction times; Shackman, Shackman, Jenness, & Pollak, 2010). In this series of investigations, ERPs provided us with insight into an aspect of maltreated children's social development—attention to anger—something that could not have been observed by behavioral methods alone. The severity of the maltreatment predicted attention to anger, and the more attention devoted to anger, the worse the children performed on the task.

Hormonal Measures

Hormonal systems play an important role in social behavior, and animal studies have provided a great deal of evidence that they can be altered through early experience (Sanchez et al., 2005). In our lab we have investigated the effects of early adverse experience on the neuropeptide oxytocin (OT) and the stress-related hormone cortisol. OT is produced in the hypothalamus and released centrally and peripherally into the blood stream via axon terminals in the posterior pituitary (Kendrick, Keverne, Baldwin, & Sharman, 1986) and appears to be part of the neural system of reward circuitry that includes the nucleus accumbens (Lovic & Fleming, 2004). For example, in nonhuman animals and humans alike, higher levels of OT are associated with decreases in stress hormones, such as cortisol, and increases in positive social interactions and attachment behaviors (Kosfeld, Heinrichs, Zak, Fischbacher, & Fehr, 2005; Witt, Carter, & Walton, 1990; for review see Carter, 1998). Cortisol, the end product of the hypothalamic–pituitary axis (HPA), modulates a wide range of biological responses such as energy release, cardiovascular function, immune activity, growth, emotion, and cognition (Diorio, Viau, & Meaney, 1993; Sapolsky, Romero, & Munck, 2000; Takahashi et al., 2004).

These hormonal changes allow the organism to adapt and cope effectively with current stressors. However, chronic elevation of cortisol impairs behavioral adaptation and has been associated with emotion regulation difficulties and psychopathology (Goodyer, Park, Netherton, & Herbert, 2001; Gunnar & Vazquez, 2001; Heim, Owens, Plotsky, & Nemeroff, 1997; Sapolsky et al., 2000).

The behavioral problems of postinstitutionalized children are consistent with dysregulation in the OT system and the HPA. To examine these questions, we investigated the response of OT and cortisol to a social game with their mother and a stranger. Our investigation demonstrated that, unlike typically developing children, postinstitutionalized children have an abnormally muted OT response after interacting with their mother (Fries, Ziegler, Kurian, Jacoris, & Pollak, 2005). Furthermore, postinstitutionalized children showed prolonged elevations in cortisol levels following the interaction with their mother, but not the stranger. More severe neglect was associated with the highest basal cortisol levels and the most impaired cortisol regulation following the mother interaction (Fries, Shirtcliff, & Pollak, 2008). These results suggest that early social deprivation may disrupt the function of the OT system and the HPA. The use of hormonal measures provided us with insight into postinstitutionalized children's experience of a social interaction with their mother. The disrupted response of the OT system and the HPA suggests that for postinstitutionalized children, interactions with their mother may be stressful, rather than calming and comforting. If this is the case, it is easy to infer how such experiences could interfere with the development of adaptive social relationships.

Structural MRI Methodology

Evidence from our ERP studies suggests that physically abused and typically developing children have differences in their neural responses to anger. To investigate whether maltreatment was related to structural brain changes, we employed structural magnetic resonance imaging (sMRI), which provides detailed anatomical images. Considering maltreated children's difficulties with social and emotional functioning, we investigated brain regions that have previously been implicated in these processes. The orbitofrontal cortex (oFC) has important implications for socioemotional development and behavioral regulation (Bachevalier & Loveland, 2006; Schore, 1996). Furthermore, longitudinal neuroimaging research in child, adolescent, and adult populations implicates the oFC as one of the last regions in the brain to fully develop (Gogtay et al., 2004), with changes in the oFC seen well into the third decade of life. The protracted development of the oFC suggests that it may be particularly vulnerable to postnatal experience. Our data revealed that maltreated

children had smaller oFC volumes compared to nonmaltreated children and that the size of the child's oFC region predicted the amount of stress that children reported experiencing (Hanson et al., 2010).

Based on the social and behavioral deficits demonstrated by postinstitutionalized children, we further examined the question of whether there were structural brain differences based on early care experience. In this study, we focused specifically on the cerebellum. The cerebellum is a brain region that is highly influenced by experience rather than genetic endowment (Giedd, Schmitt, & Neale, 2007). Furthermore, subregions of this structure have been implicated in cognitive and social behavior (Riva & Giorgi, 2000; Schmahmann, Weilburg, & Sherman, 2007; Tavano et al., 2007).

We found that the posterior–superior lobe of the cerebellum was smaller in the postinstitutionalized children as compared to typically developing children; this region was also associated with children's performance on a task of executive function. Children with a smaller superior–posterior lobe volume showed poor executive control (Bauer, Hanson, Pierson, Davidson, & Pollak, 2009). The results of this study suggest a mechanism by which the early experience of deprivation could exert lasting consequences on social regulation.

THINKING CLEARLY ABOUT BIOLOGICAL METHODS IN DEVELOPMENTAL SCIENCE

As detailed thus far, integration of biological methods to the study of emotional and social development can provide important evidence that enriches our understanding of the development of emotional and social processes. There are, however, important conceptual, methodological, and statistical challenges that must be considered.

Impact of Biological Measure on Emotion

Unlike simple behavioral tasks, some biological methods are invasive. A challenge in employing such a measure is that the experimenter must consider the contribution of the experimental context to the biological signal. For instance, in a large-scale sMRI study in our lab, which included 160 adolescents who ranged from 9 to 14 years of age, we found an increase in the stress hormone cortisol in response to the MRI environment (Eatough, Shirtcliff, Hanson, & Pollak, 2009). This issue is particularly salient for investigations directed at emotional and social processes, where the experimental context elicits an emotional response. As such, it is important to include measures, such as baseline samples collected prior to the experimental manipulation, to

determine the response to the experimental manipulation. It is also essential to remember that the laboratory context is itself a social context that may influence dependent variables of interest.

Group Differences in the Baseline Measure

Another important challenge to consider when employing biological methods is that there is a great deal of interindividual variation, even in typically developing populations. As a result, control conditions or regions are often included in experimental designs, and this is true of all the methods described in this review. The studies using hormonal and ERP methodologies compared a signal change between groups relative to a baseline, and the sMRI investigations compared specific regions while controlling for differences in the whole brain volume. A challenge for developmental and clinical investigations is that groups often differ in the baseline measure, which adds a level of complexity to the interpretation of any results. Consider the previously described study with OT which demonstrated a difference between postinstitutionalized and typically developing children while interacting with their caregiver (Fries et al., 2005). In order for us to suggest that social interactions with their mother were different experiences for postinstitutionalized, as compared to typically developing, children, it was important to demonstrate that their OT systems responded similarly when interacting with a stranger (control condition). Without the control condition, which demonstrated that the behavior of the OT system differed only when the children were interacting with their mother, we would not have been able to link the dysregulation to a specific social experience. If possible, it is important to determine the specificity of differences in the response of a biological system.

CONCLUSIONS

This chapter was an attempt to illustrate the rich evidence that can be gleaned from the use of biological methodologies on social and emotional development. We also strove to identify some of the challenges one must consider when using these methods. We also recommend recent papers detailing the broad limitations of employing electrophysiological (Cacioppo, Tassinary, & Berntson, 2007; Luck, 2005), hormonal (Dickerson & Kemeny, 2004), and neuroimaging measures (Aue, Lavelle, & Cacioppo, 2009; Logothetis, 2008). While use of these methodologies does require careful consideration, they also offer untold promise in unpacking the mechanisms driving developmental trajectories in social and emotional development.