CHILD DEVELOPMENT PERSPECTIVES

Individual Differences in Environmental Sensitivity

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ABSTRACT—***A fundamental trait found in most organisms is the ability to register, process, and respond to external factors. Although such environmental sensitivity is critical for adapting successfully to contextual conditions, individuals tend to differ in their sensitivity to the environment, with some more sensitive than others. Such differences in environmental sensitivity can be seen across many species, including humans. Although the notion of variability in environmental sensitivity is reflected indirectly in many traditional concepts of human psychology, several new frameworks address individual differences in environmental sensitivity more directly and from a perspective of developmental and evolutionary theory. In this article, I integrate these perspectives into a broad meta-framework before proposing ideas for research on individual differences in environmental sensitivity. I also emphasize that inter-individual variability in environmental sensitivity be considered in both theoretical and applied work.***

KEYWORDS—*environmental sensitivity; developmental plasticity; diathesis-stress; vulnerability; resilience; differential susceptibility; vantage sensitivity*

Human development is fundamentally contextual. Without the specific and active support of a nurturing environment, no child would thrive or even survive. Given this dependence on external environmental resources, it is not surprising that humans register, process, and respond to many different aspects of their social and physical environment. However, individuals differ substantially in such sensitivity and responsivity, with some being more and others less responsive to the same environmental conditions.

In this article, I look at individual differences in environmental sensitivity, drawing from several theoretical perspectives and emerging empirical evidence. Rather than discussing in detail conceptual differences between the various frameworks, I present an integrated view across concepts and perspectives. Finally, I propose research on individual differences in environmental sensitivity and suggest that we consider inter-individual variability in environmental sensitivity in both theoretical and applied work.

VARIABILITY IN ENVIRONMENTAL SENSITIVITY

Individual differences in the behavioral response to environmental factors can be seen across many species from pumpkinseed fish, zebra finches, mice, and nonhuman primates to humans (for review, see 1). The pattern that seems to emerge consistently is that some of the members of each of these species tend to be bold, aggressive, and impulsive when approaching new or threatening situations, whereas others appear to avoid such situations, behaving less aggressively and more cautiously and fearfully. These two prototypical behavioral types have been described as *hawks* and *doves*, reflecting two different behavioral strategies—*proactive* versus *reactive* coping (2)—that evolved over time, each characterized by specific advantages and disadvantages for health and reproductive fitness (3). Similar behavioral differences have been described in humans in many psychological frameworks, including extra- and introversion, behavioral activation and inhibition, high and low reactive temperament, physiological stress reactivity, sensory sensitivity, resilience and vulnerability, reaction norms, and developmental plasticity (4–6). Although these established psychological concepts differ from one another, they all seem to describe how people vary in their response to contextual factors, with some more affected than others, manifested in qualitatively different psychological or behavioral response patterns. The notion that *individuals differ in how they perceive and process environmental*

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features, with some being generally more and some generally less sensitive, may represent the underlying common denominator linking these diverse concepts (4). This interpretation suggests that environmental sensitivity—and the variability thereof—is an important higher-order personality dimension whose different aspects are reflected, captured, and described in many existing psychological concepts.

At least two important distinctions are worth considering when discussing matters related to environmental sensitivity from such a broad perspective. First, we should differentiate *sensitivity* from *responsivity*. Whereas *sensitivity* refers to aspects of perception and internal processing of external influences (i.e., the input), *responsivity* refers to the resulting behavioral consequences (i.e., the output). Although differences in environmental sensitivity are largely responsible for the manifestation of differences in responsivity (7), sensitivity does not equate with responsivity. Given that behavioral responses are generally influenced by many factors, depending on the specific circumstances, heightened sensitivity may not always be associated with the same behavioral response. For example, while a highly sensitive child may behave in a more introverted and shy manner in a novel and unfamiliar social environment, the same child may behave like less sensitive children in a well-known and familiar setting.

Second, environmental sensitivity features at least two different perspectives, the first describing developmental processes (i.e., change over time in response to past experience) and the second, immediate reactivity (i.e., response to current experience). The developmental perspective refers to developmental or phenotypic plasticity, the ability of an organism to adapt its phenotype over time to the conditions of the particular environment. For example, children characterized with a more reactive temperament in infancy develop into children with consistently more or less aggression, depending on whether their early care environment was less or more supportive (8–10). Developmental plasticity is conceptually restricted to early developmental periods during which the direction of development is most likely to be environmentally programmed, with additional adaptation in response to environmental changes less likely (though not impossible) in later periods. In contrast, the perspective of immediate reactivity refers to environmental sensitivity as a relatively stable trait, and implies continuity of environmental sensitivity across life and across different contexts. For example, in a study in which young adults rated perceived stress during examination and nonexamination days, those with the short version of the serotonin transporter gene (5-HTTLPR), a gene variant consistently associated with heightened developmental plasticity (11), reported both higher and lower stress, respectively, than those carrying other versions of the same gene (12), suggesting that the gene version associated with developmental plasticity in early childhood may also predict immediate reactivity in early adulthood. However, we need more research on the potential overlap between developmental plasticity and immediate reactivity to clarify the relationship between these different aspects of environmental sensitivity (for a detailed review and discussion of the various forms of behavioral plasticity, see 13).

The notion of individual differences in environmental sensitivity as implied in traditional psychological concepts has typically been framed within a *diathesis-stress* model, with sensitivity seen primarily as vulnerability for developing problematic outcomes when faced with adversity (14, 15). As a consequence, most research on environmental sensitivity is biased toward psychopathology, often failing to consider the possibility that environmental sensitivity may extend to positive environments and adaptive outcomes (16). However, over the last two decades, several frameworks emerged that describe environmental sensitivity in a less biased manner—drawing on evolutionary and developmental theory rather than a perspective of psychopathology.

CONCEPTS FOR INDIVIDUAL DIFFERENCES IN ENVIRONMENTAL SENSITIVITY

Since the late 1990s, researchers have proposed at least three theoretical frameworks related to variability in environmental sensitivity. The first is sensory processing sensitivity (SPS) by Aron (5, 17). SPS is based on a personality perspective, suggesting that about 20% of people have a high-sensitive personality trait defined by greater awareness of sensory stimulation, behavioral inhibition, deeper cognitive processing of environmental stimuli, and higher emotional and physiological reactivity (4). Differences in SPS are evolutionarily adaptive, influenced by genes, and associated with a more sensitive central nervous system. Researchers also propose that SPS is a stable personality trait that emerges in infancy and is shaped further by the environmental conditions children experience while growing up (18).

The second concept is Belsky's differential susceptibility theory (DST; 19–24). According to DST, individuals differ in their environmental sensitivity, with some being generally more and some generally less susceptible to both negative and positive environmental influences. DST posits that such fundamental differences in susceptibility represent two alternative developmental strategies that have been maintained by natural selection as a form of bet-hedging, given that the future is inherently unpredictable: The plastic strategy is characterized by adaptation to the environment (i.e., high susceptibility), whereas the fixed strategy reflects relative inertia in response to environmental factors (i.e., low susceptibility). Originally, DST adopted the view that differences in susceptibility are genetically determined and manifested in the sensitivity of the central nervous system. More recently, researchers suggest that high susceptibility may also develop in response to prenatal and early postnatal factors (25, 26).

Finally, Boyce and Ellis (6) concluded in their biological sensitivity to context (BSC) theory that individuals differ in *bio-behavioral reactivity* to the environment, inspired by the sur-

prising observation that both negative and positive aspects of the environment affected children who were physiologically highly reactive (27). In contrast to SPS and DST, BSC emphasizes the role of environmental influences in shaping differences in environmental sensitivity over time (i.e., conditional adaptation), with individuals exposed to especially adverse or supportive environments developing higher physiological reactivity and consequently, higher sensitivity to both cost-inflicting and benefit-conferring features of the environment than those growing up in more moderate environments. Given that both BSC and DST are rooted in evolutionary theory and describe similar developmental dynamics, researchers have tried to integrate these two frameworks (24).

Although each of these three concepts provides unique and important theoretical insights into environmental sensitivity, perhaps the most significant contribution shared across all three frameworks is the notion that sensitive individuals differ not only in their response to environmental adversity but also in response to positive, supportive aspects of the environment. This positive end of environmental sensitivity is summarized in the vantage sensitivity (VS) framework (16). According to VS, people differ in their response to positive influences as a function of inherent characteristics, with some more sensitive and some more resistant to the beneficial effects of positive experiences and exposures.

AN INTEGRATED MODEL OF ENVIRONMENTAL SENSITIVITY

Although diathesis-stress, SPS, DST, BSC, and VS provide unique perspectives on variability in environmental sensitivity, integrating the different concepts into a single overarching meta-framework of *environmental sensitivity* may prove valuable for both research and practical application (e.g., 24). In this section, I propose such an integrated perspective regarding the determinants of environmental sensitivity, the hypothesized existence of different sensitivity types, the basic mechanism of sensitivity, and evolutionary considerations pertaining to differences in environmental sensitivity.

Determinants of Environmental Sensitivity

To what degree are individual differences in environmental sensitivity determined by genetic factors versus shaped by environmental influences? Many gene–environment interaction studies suggest that differences in environmental sensitivity are associated with genetic differences between individuals (22, 23, 28). However, the observation that physiological and psychological characteristics reflecting environmental sensitivity are also shaped by the developmental context (6, 25) suggests that both genetic and environmental forces contribute to individual differences in environmental sensitivity (for a general discussion of the role of genes and environment in development, see 29). In more detail, whether, to what degree, and in what way a genetic potential for high sensitivity is actualized may depend on the environmental conditions an individual experiences, particularly in early development. For example, the quality of the prenatal environment predicts increased environmental sensitivity, but only in children who carry sensitivity genes (25, 30). Similar findings related to genetic moderation emerged in relation to the effects of the postnatal environment on environmental sensitivity (31). Such interplay between genetic and environmental factors most likely involves the regulation of gene expression through environmentally induced epigenetic changes (32, 33).

Sensitivity Types

Are there distinct types of environmental sensitivity (e.g., general susceptibility, vulnerability, and VS), or are all these manifestations of the same basic propensity for environmental sensitivity? The observation that increased vulnerability is often associated with the same individual characteristics (e.g., gene variants, infant temperament, and cortisol stress reactivity) that predict sensitivity to positive features of the environment suggests that both diathesis-stress and VS reflect the same general propensity for environmental sensitivity (16, 22; see Figure 1). However, given the significant role of environmental factors in the development of environmental sensitivity, individuals with a genetic predisposition for environmental sensitivity may get sensitized to specific aspects of environmental quality. That is, an initial *neutral* genetically based propensity for sensitivity may develop into a *biased* sensitivity toward contextual adversity (i.e., vulnerability) or contextual support (i.e., VS) depending on the specific environmental conditions encountered in early development (see Figure 2). Some studies suggest that early adversity increases sensitivity toward adversity in those carrying sensitivity genes. For example, adolescents carrying the 5-HTTLPR short allele were more likely to respond with emotional problems to recent stressful life events than others, but only if they had a history of

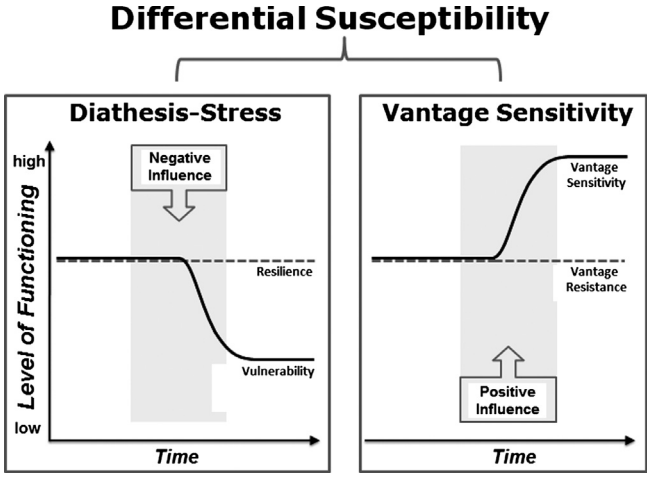

Figure 1. Illustration of three patterns of environmental sensitivity. *Diathesis-stress* describes individual differences in response to exclusively negative influences, whereas *vantage sensitivity* (VS) refers to variability regarding positive influences only. *Differential susceptibility* represents the combination of diathesis-stress and VS as a function of the same sensitivity factor.

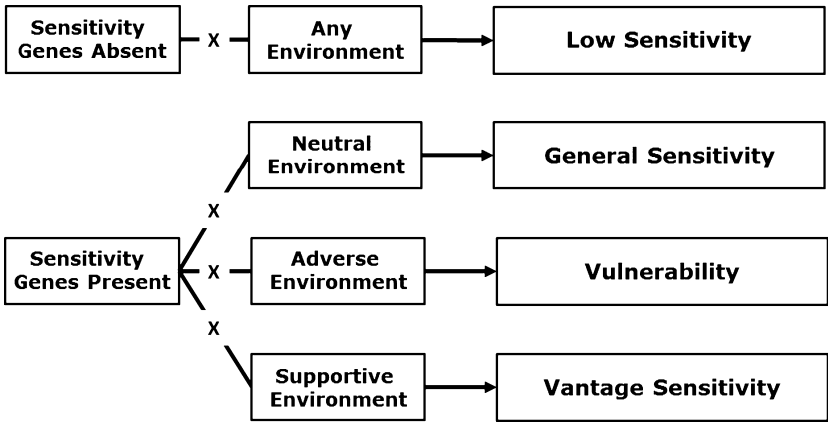

Figure 2. Graphical illustration of the development of *sensitivity types*. In the absence of sensitivity genes, environmental sensitivity will be low regardless of environmental quality. If sensitivity genes are present, the quality of the early environment shapes the sensitivity type: In response to a neutral environment, sensitivity will reflect heightened susceptibility to both negative and positive influences. However, a predominately adverse environment increases sensitivity toward threats, whereas a predominately supportive environment increases vantage sensitivity.

early institutional care (34). In the absence of early adversity, 5-HTTLPR did not moderate the effects of stressful life events. Similarly, men homozygous for the 5-HTTLPR short allele showed elevated cortisol reactivity in a psychosocial stress condition, but only if they also reported many stressful life events (35). However, researchers have not yet tested whether growing up in very supportive conditions also leads to the development of pronounced VS in those carrying sensitivity genes.

The notion of sensitivity types is not unrelated to predictions made by the *adaptive calibration model* (36), according to which differences in the quality of the developmental context shape an individual's pattern of stress responsivity: A safe environment produces heightened general sensitivity (i.e., DST), moderate stress leads to a more buffered general sensitivity (i.e., moderate susceptibility), a dangerous environment results in a high sensitive vigilant pattern (i.e., vulnerability), and traumatic stress in a general lack of responsivity.

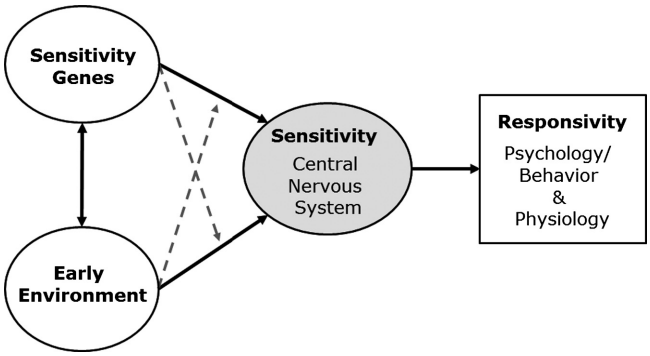

Figure 3. Illustration of the *neurosensitivity* hypothesis. Direct and interactive effects between sensitivity genes and environmental factors shape the sensitivity of the central nervous system. Heightened central nervous system sensitivity is then manifested in psychological/behavioral and physiological responsivity.

Mechanism of Environmental Sensitivity

Empirical studies of environmental sensitivity include those that focus on genetic, psychological, or physiological sensitivity factors (22), which seems to suggest that environmental sensitivity may be driven by many mechanisms. However, these different sensitivity factors most likely reflect different levels of analysis across various biological mechanisms that jointly influence *neurobiological susceptibility* as the underlying central mechanism of environmental sensitivity (16, 17, 20, 24, 37). In other words, heightened environmental sensitivity most likely reflects specific features of the central nervous system (e.g., amygdala and hippocampus structure and function), which cause environmental influences to register more easily and more deeply. According to this *neurosensitivity* hypothesis, sensitivity of the central nervous system is determined by both direct and interactive effects of genetic and environmental factors (16, 37). The resulting heightened central nervous sensitivity is then reflected in physiological (e.g., high stress reactivity) and psychological/behavioral outcomes (e.g., negative emotionality) elicited in response to environmental factors (see Figure 3).

Evolutionary Considerations

Do differences in environmental sensitivity reflect conditional adaptation or a bet-hedging strategy? Observations across many species suggest that high and low sensitivity types reflect different developmental strategies, each with specific advantages and disadvantages (1, 4). Given that differences in environmental sensitivity are neither exclusively based on genes nor exclusively the result of conditional adaptation processes, environmental sensitivity most likely reflects the combination of bet-hedging and conditional adaptation rather than one or the other: Environmental sensitivity facilitates conditional adaptation to the environment, but an individual's degree of adaptation depends on the presence of genetic factors that have been maintained by natural selection. Consistent with this view, most gene

variants associated with environmental sensitivity are common in the population and have been positively selected for (for DRD4, see 38). However, empirical and computer simulation studies suggest that high sensitivity is most advantageous if characterizing only a minority of the population, usually between 20 and 30% (1). In summary, differences in environmental sensitivity are beneficial from an evolutionary perspective—as long as high sensitivity is only found in a minority—and reflect variability in the propensity for conditional adaptation to the environment (6, 24, 36, 39).

LOOKING AHEAD

Much empirical evidence across many disciplines supports different components of the proposed integrated framework of environmental sensitivity (4, 40). Nevertheless, researchers should focus on the following questions to understand variability in environmental sensitivity more deeply.

First, investigators should focus on the hypothesized general neurocognitive mechanism underlying individual differences in environmental sensitivity (i.e., neurosensitivity). A promising approach is combining structural and functional brain imaging data with genetic, epigenetic, and behavioral measures (e.g., 41).

Second, it remains to be determined whether an individual's environmental sensitivity varies across different domains of functioning (e.g., cognitive, emotional, social) or whether differences in sensitivity affect all domains equally (13).

Third, researchers should illuminate developmental aspects of environmental sensitivity to understand more thoroughly how genetic and environmental factors interact in developing environmental sensitivity. Specifically, they should investigate to what extent environmentally programmed sensitivity remains malleable across life.

Fourth, researchers should test empirically the proposition that environmental factors shape an initially neutral propensity for sensitivity into specific and distinct sensitivity types (i.e., general sensitivity, vulnerability, VS). And they should investigate whether the different types of environmental sensitivity fit more effectively with a categorical or dimensional model.

Fifth, investigators should develop precise and reliable psychological and biological measures of environmental sensitivity. Although some self-report measures predict environmental sensitivity (e.g., sensory-processing sensitivity; 17, 42), we need more specific measures.

IMPLICATIONS AND CONCLUSION

The notion that people vary in the extent to which they are affected by exogenous factors has important implications for both theoretical and applied work in any discipline that deals with human functioning. Most psychological research tests hypotheses by comparing average effects across the sample, ignoring that effects may vary between people as a function of their specific degree of environmental sensitivity. Hence, such studies may underestimate effects for highly sensitive individuals and overestimate effects for less sensitive ones, particularly in intervention studies. To get more adequate and precise estimates for the effects of environmental influences, including psychological intervention, studies should consider the heterogeneity of people's environmental sensitivity. Similarly, inter-individual variability in environmental sensitivity suggests that just as some people will be affected more negatively by adverse experiences, some people will benefit more from positive, supportive ones. Such heterogeneity requires a more personalized approach in applied work, whether the focus is preventing or treating problematic outcomes or promoting competence and well-being. In short, considering individual differences in environmental sensitivity is fundamentally important for both theoretical and applied psychology.

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