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BIOLOGY, CONTEXT, AND DEVELOPMENTAL INQUIRY

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■ **Abstract** This chapter summarizes some of the conceptual changes in developmental research over the last half-century. These advances include an acknowledgment of the role of maturation; also recognized have been the need for positing distinct psychological structures, the influence of temperament, the malleability of the infant, the role of the local context, and the dynamic nature of the categories describing human psychological types.

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INTRODUCTION

Scholarship in developmental psychology during the last half-century, the era that brackets my graduate years and this moment, has reformulated old questions and rejected premises that failed empirical challenge. Four obvious changes are evident in a comparison of papers in the journal *Child Development* during the 1950s with last year's titles. Most of the early work ignored the contributions of biology, the specificity and variety of cognitive processes, and the cumulative effects of identification with ethnic and social class groups because the discipline was shackled by a commitment to the exclusive power of external rewards to shape habit. In the 1950s Yale's department faculty was confident that a satisfying, essentially behavioristic explanation of behavior, both the ontogeny of universal qualities as well as individual variation, was attainable. John Dollard and Neal Miller declared in *Personality and Psychotherapy* that most human qualities were learned responses to drive conditions. "Human behavior is learned; precisely that behavior which is widely felt to characterize man as a rational being" (1950, p. 25). Although contemporary investigators acknowledge the relevance of conditioning mechanisms to certain domains, they appreciate that the spontaneous reorganization of concepts, rules, and beliefs that accompany brain growth and new experiences are of equal (and for some human qualities, of far greater) potency.

Although developmental psychologists, then and now, celebrate rational, pragmatic, material, and experimental analyses of functional components, only the current cohort legitimizes the symbolic representations, combined in emotions, identifications, and intentions, that need not have an obvious referent in action. Psychologists of the 1950s were constrained by the demands of operational theory, absence of measurements of brain function, and a habit of quantifying limited samples of behavior in austere laboratory settings. As a result, the evidence revealed surface phenomena rather than a deeper psychological architecture. For example, the phenomena of object permanence and stranger anxiety, which usually appear at 7–10 months of age, were treated as independent events. When psychologists learned that the brain growth that occurs at this age is accompanied by an enhanced ability to retrieve the immediate past and to compare it with the present, they recognized that both phenomena were derivatives of changes in brain function in infants living with people and objects to manipulate. The advantages of new methods enable the current cohort of investigators to peer beyond the behavioral display to infer more fundamental processes, as the student of musical composition perceives the theme hiding in the surface improvisations.

Two premises remain unchallenged. The first holds that psychological freedom is the hidden telos in development. This belief, explicit in the writings of Locke and Watson, is implicit in research reports on play, independence, and autonomy. The supposition that all children should grow toward freedom from external restraints on the perfection of self is a derivative of a political philosophy that enjoys special favor in the West, but, unfortunately, has a weak foundation in historical scholarship or ethnographies. Social scientists have permitted their ethical preferences to influence their theories.

The second favored premise that resists critique is that parental love, especially the affection from the biological mother, is necessary if children are to attain the prize of psychological freedom. The observed signs of this resource a half-century earlier were adult actions that regularly relieved the infant drive states of hunger, thirst, cold, and pain. The contemporary referents are not a well-defined set of adult behaviors but the vaguer notion of continued sensitivity to the young child's need to feel secure. Parental sensitivity and security are harder to infer than hunger or pain.

Although these two premises still penetrate much research, a number of conceptual advances have accompanied the replacement of conditioned responses with cognitive and affective processes. Six such advances are recognition of (*a*) the influence of brain maturation, (*b*) distinct psychological structures, (*c*) the role of temperament, (*d*) flaws in the assumption of infant determinism, (*e*) the importance of the contexts in which agents act, and (*f*) the dynamic nature of the categories for psychological types.

THE CONTRIBUTION OF BIOLOGICAL MATURATION

Most contemporary investigators accept the fact that brain maturation sets constraints on behavior, feeling, and cognition in the opening years. As noted earlier, the appearance of object permanence and stranger and separation fear requires an enhanced ability to retrieve schemata related to the present and to hold both structures in working memory while trying to assimilate the new event. This competence is made possible by predictable changes in brain organization. The second half of the first year is marked by accelerated growth and differentiation of pyramidal neurons, especially lengthening of dendritic terminal segments and dendritic bifurcations in layers III and V of the cortex (Koenderink et al. 1994), and sharp increases in the number of spines and extra large excrescences on the proximal dendrites of pyramidal cells in the CA3 region of Ammons horn (Seress & Mrzljak 1992). These anatomical changes are accompanied by increased glucose uptake in the lateral frontal cortex at 6–8 months, and in the dorso-lateral prefrontal cortex at 8–12 months (Chugani et al. 1987). All of these classes of growth permit retrieval of past events and a comparison of the retrieved representations with the present (KA Pelphrey, JS Reznick, B Goldman, N Sasson, J Morrow, unpublished). Hence, 8-month-old infants living in a typical social environment will cry in response to strangers and separation and will search for a toy hidden under a cover by an adult several seconds earlier. Piaget would have written a different theory to account for his acute observations if he had been born a century later. I blush as I recall telling my first undergraduate class in 1954 that a rejecting mother could create an autistic child.

The quartet of talents that emerges in the second year includes initial understanding of, and the ability to express, language; an appreciation that some actions are punishable; the capacity to infer some intentions and feelings in others; and an early form of awareness of self's feelings, intentions, and abilities. The actualization of these competences is aided by a different set of maturational events.

The accelerated elongation of the dendrites on pyramidal neurons in layer III of Wernicke's area should help the child understand spoken language, and because the axons of these neurons connect the right and left hemispheres this growth should aid not only language but other functions as well (Goldman-Rakic & Porrino 1986, Jacobson & Trojamowski 1977). Children should now show more efficient coordination of lexical categories (stored primarily in the left hemisphere) with schematic structures (stored primarily in the right) and as a result, begin to describe an event that has alerted them.

The coordination of schemata for bodily feelings with the initial corpus of semantic categories should make empathy possible, for the semantic labeling of another as "in pain" will be integrated with the retrieval of the representations that were created when the child had been distressed in the past. The coordination of representations of uncertainty or fear with semantic categories for punishable acts should cause the child to suppress behaviors that violate the family's standards. Finally, the coordination of the representations of bodily feelings with the new semantic categories for self should make consciousness possible. The fact that the number of neurons per unit volume decreases rapidly until birth and slows toward the middle of the second year led one scientist to assert that the period between 15 and 24 months was a significant moment in brain growth, when almost all layers of the cortex reached, for the first time, a similar state of maturation (Rabinowicz 1979). It is likely that equally specific anatomical and chemical changes to be discovered in the coming decades will help to explain the victories of concrete and formal operations.

THE NEED FOR VARIED PSYCHOLOGICAL FORMS

The diverse categories of behavior, cognition, and emotion require positing distinctly different psychological structures. Biologists appreciate that form is the fundamental riddle in nature, where form—or structure—is defined as a pattern of relations among a set of constituent features. Every mature natural science combines an understanding of each of its many forms with their correlated functions. Psychologists have been slower to recognize this truth because they typically study functions—actions, memories, feelings, and perceptions—and have been less interested in the psychological structures that permit those functions to be actualized. Unfortunately, function does not reveal form. It is not possible to infer the anatomy of the retina from the adult's perception of a soaring hawk, nor the form of the psychological structures that permit a two-year-old to ask about the name of an unfamiliar animal.

Although discovery of the patterns of activated neuronal ensembles that accompany a psychological reaction may illuminate the nature of the relevant psychological forms, the biological knowledge cannot be a substitute for a description of the psychological structures. The latter are an emergent property of the entire system of brain activity. The concept of robustness in systems biology provides an analogy. The ability to cope with an intrusion is a property of the entire system

of biological networks and is not a property of any single constituent. That is, melancholy is a property of a mind, not of the neuronal circuits that participate in that emotional state. Although the psychological processes, and the psychological structures on which they rest, emerge from brain activity, the former cannot be reduced to or explained by a description of the latter. This means that the words used to describe the psychological events cannot be replaced with sentences that contain only biological words. Roald Hoffmann, an eminent chemist, used the example of the oxidative state of a molecule to remind us that the same conclusion holds for chemistry: "The life giving ideas of chemistry are not reducible to physics . . .. If one tries to reduce them, they wilt at the edges, lose not only their meaning, but their interest too" (Hoffmann 2001, p. 311).

Thus, the social scientist who acknowledges that thought, feeling, and action arise from cascades of brain events, but insists, nonetheless, that these events must be described in a language different from the one that describes the underlying neural processes, is not a metaphysical dualist. All of nature cannot be described with one vocabulary.

Below I discuss three distinct psychological forms: schemata, sensory motor structures, and semantic networks.

Schemata

A schema is a representation of an event, often combined with features of the context, which retains to varying degrees the patterned features of the original event (Gibson 1969, Paivio 1986, Vernon 1954). The representation of a friend's face is a prototypic example. There are at least two different schematic forms. Visceral schemata, which originate in the activity of sensory receptors in body organs, including skin, nose, tongue, muscles, and inner ear, represent states of the body. A visceral schema is activated when a person retrieves the pain of a stomach cramp or the sweetness of ice cream.

Perceptual schemata, on the other hand, are representations of external events. Infants can create some schemata with minimal experience because they are biologically prepared to perceive whole objects and do not have to connect separate features to create a representation of a face, cup, or hand. Newborns, for example, can discriminate between recordings of their own cry and the cry of another infant; two-week-olds can discriminate the breast odor of a nursing woman from many other odors (Morrongiello et al. 1998, Dondi et al. 1999, Makin & Porter 1989). Young infants attend longer to circular over linear patterns, moving over stationary objects, and contoured over homogeneous fields (Haith 1980). It is not surprising, therefore, that they quickly create schemata for human faces, which are circular, often in motion, and contain contour at the hair line, sclera, and mouth (de Haan & Nelson 1999).

Infants also create prototypic schemata that are psychological averages of a number of similar events. This phenomenon is clearest for the schemata that represent the phonemes of the child's local language (Doupe & Kuhl 1999) and for

familiar objects like toy animals (Arterberry & Bornstein 2001). Infants can also construct schematic concepts for temporal patterns of meaningless vocal sounds. In a test of this idea, 7-month-olds first heard a 2-minute speech sample containing 3 representations of each of 16 different 3-syllable utterances of the form a-b-a. For example, on the first trial the infant might hear "ga-ti-ga," on the second trial, "li-no-li," and on the third trial, "bo-gu-bo." The feature shared by all utterances was that the first and third syllables were identical. After being familiarized with this pattern they heard on test trials either an utterance of the same form—a-b-a—or a new set of syllables with a new form; for example, a-b-b, as in "wo-fe-fe." The infants displayed greater attention to the unfamiliar a-b-b pattern, indicating they had created a schematic concept for the a-b-a pattern of sounds (Marcus et al. 1999).

The representations of features shared by events in two different modalities, called cross-modal processing, are also schematic concepts. Three-year-olds will point to a sad over a happy face after listening to a 20-second excerpt from a Mozart symphony in a minor key but will point to the happy face after listening to a segment in a major key (Droller 2000). Three-year-olds usually select the color red, rather than brown, as most fitting a smiling face (Zentner 2001). The ability to create cross-modal representations matures in a major way after six months, in part because the prefrontal cortex links symbolic information from different modalities, and anatomical links among sensory association areas and medial-temporal and prefrontal cortex are immature during the first six months. Cross-modal schemata are possible, but very fragile, during the first half-year.

Perceptual schemata of external events differ from visceral schemata in three important ways. First, perceptual schemata are more easily retrieved from memory. Most individuals can retrieve a rich visual representation of the Statue of Liberty visited 20 years ago but have difficulty recreating the taste of yesterday's chocolate mousse. Second, the ability to attend to, or ignore, most external events is seriously compromised for bodily sensations. Finally, visceral schemata have a weaker link to semantic structures because information from the body synapses primarily on the corticomedial and central areas of the amygdala, while visual and auditory stimuli synapse first on the lateral area. Reciprocal connections with cortical association areas are richer for the lateral than the corticomedial and central areas. One reason why questionnaires and interviews are relatively insensitive indexes of human emotional states, and why scientists code changes in face, posture, and physiology to aid inferences about an individual's emotions, is that language has a limited number of words to describe the visceral representations of bodily sensations that are the essential components of every emotion.

Sensory Motor Schemes

Representations of coordinated motor sequences permit the skilled performances of violinists and athletes, as well as implementation of each morning's automatic routines. The behaviors of seven-month-old infants illustrate the ease with which sensory motor representations are implemented. Infants first saw either a small or a large hoop while simultaneously hearing a distinctive sound accompanying

each hoop. After a number of familiarization trials, the room was darkened and the infants heard one of the two sounds but could not see whether the hoop was small or large. Remarkably, the infants adjusted their hands and arms to fit the sound, for they reached with both hands to the sound that had accompanied the large hoop, but with one hand to the sound that had accompanied the small object (Clifton et al. 1991). Presumably, the schema for each hoop evoked a distinct sensory motor scheme when its particular sound was heard.

Semantic Networks

Semantic representations combine the representations of words, called lexical structures, with schemata and sensory motor structures to form networks that are logically constrained, occasionally hierarchical, and exploited to communicate information and to facilitate thought (Bickerton 1995). The distinction between schemata and semantic structures is critical. The relations among the features of my schema for a terrier who barks early in the morning (the color, size, gait, sound of bark, and spatial relations among head, ears, eyes, limbs, and tail) are different from the relations among my semantic representations of this animal, which include links among the semantic concepts dog, pet, mammal, domesticated, and annoying.

The distinctive qualities of schemata, sensory motor structures, and semantic networks have implications for current discussions of consciousness, especially whether minds experience a number of qualitatively different conscious states on the one hand, or one unified state with different features on the other (Searle 2000). Humans can be conscious of very different events, including sensations, thoughts, intentions, and symbolic categories for self. Imagining a pink cloud at dusk can be mediated by schemata with minimal contributions from semantic or motor structures. Recalling the taste of chocolate, the feeling of ice on the skin, or the pain of a cut finger differs in both brain profile and subjective state from the awareness that accompanies remembering one's childhood home, deciding whether to have a second glass of wine, brooding about one's ethnic category, or trying to solve a difficult mathematical problem. We celebrate Marcel Proust's rich descriptions of the childhood visceral schemata he retrieved when he tasted a madeleine cookie he had dipped into his tea. Most writers have been less able to capture as evocatively the feelings of a child who wakes up to find no one at home or the visceral schemata that pierce consciousness on a Christmas morning with fresh snow on the lawn and cinnamon biscuits in the oven.

TEMPERAMENT

The ancient concept of human temperaments, ignored by almost all investigators during the first half of the twentieth century, was reintroduced to psychology by Alexander Thomas and Stella Chess (1977) and gained acceptability because neuroscientists provided an empirical scaffolding for explanations of consistency in certain behaviors. Most psychologists regard this term as referring to stable

profiles of mood and behavior with a biological foundation that emerge early in development, although not always in the opening weeks or months. Each temperamental category implies the possession of a particular physiology and an envelope of potential behavioral phenotypes whose final form depends on the rearing environment. A child with a temperament that protects him from excessive fear or anxiety over challenge or reprimand is likely to become a popular, accomplished ten-year-old if reared in an economically secure home with consistent socialization of aggressive behavior, but he is more likely to become a delinquent if raised by economically disadvantaged parents who are inconsistent in punishing disobedience and aggression. The varied forms that condensed water vapor can assume supply an analogy for, depending upon circumstances, the vapor can be a distinct cloud, a mackerel sky, or a dense fog. Although the cloud and fog are distinctly different in appearance, the constituents of both are identical.

Current discussions of temperament refer primarily to behavioral features because psychologists do not yet understand the relation between the inherited physiological profiles and the behavioral phenotypes. In the future, however, temperamental categories will include biological measures as part of their definition. Research on voles (a small rodent resembling a mouse) provides an example. Prairie voles pair-bond but montane voles do not. Insel and colleagues have discovered that this dramatic behavioral difference is due, in part, to a small segment of DNA in the promoter region of the gene responsible for the distribution of receptors for vasopressin (Insel & Hulihan 1995, Insel & Winslow 1999). Some human temperament types—extremely irritable infants, for example—may result in part from another genetic profile.

Mary Rothbart's synthetic writings appropriately dominate discussions of infant temperament (Rothbart 1989). Temperament, for Rothbart, refers to constitutionally based differences in reactivity and self-regulation. "Constitution" refers to relatively enduring biological processes influenced in part by heredity and in part by experience. "Reactivity" refers to the ease of arousal of motor, affective, autonomic, and endocrine responses. "Self-regulation" refers to processes that modulate reactivity, including attention, approach, withdrawal, attack, inhibition, and self-soothing.

Most investigators agree that stable displays of high or low degrees of irritability, smiling, and activity, as well as distinct profiles of attention are likely to have a temperamental contribution. Two temperamental categories, observed in the second year in response to unfamiliar events, are excessive shyness/sociability and timidity/boldness. Nancy Snidman and I, along with Mark McManis, Susan Woodward, Doreen Arcus, and many others, believe there is a relationship between these two categories and two infant profiles observable at four months of age.

Reactivity in Infants

Healthy middle-class Caucasian four-month-old infants who show vigorous motor activity and distress in response to unfamiliar visual, auditory, and olfactory stimuli

are called high-reactive and comprise about 20% of similar samples. High-reactive infants tend to become shy, timid, and fearful in response to unfamiliar events in the second year (Kagan 1994). One third of the high-reactive infants become very fearful and are called inhibited. By contrast, infants who display low levels of motor activity and minimal irritability in response to the same stimuli (about 40% of most samples and called low-reactive) are biased to become sociable, relatively fearless children. One third of the low-reactive infants become minimally fearful and are called uninhibited. We believe that each temperamental type inherits a distinct neurochemistry that affects the excitability of the amygdala and/or the bed nucleus of the stria terminalis and their projections. The neurochemical profiles might involve variation in the concentration of, or distribution of receptors for, dopamine, norepinephrine, corticotropin-releasing hormone, opioids, or gamma-amino butyric acid (GABA). The potential role of the latter molecule is seen in a collaborative, and as yet unpublished, study with Kevin Nugent which revealed that the small number of newborn infants who displayed great difficulty controlling excessive distress during an examination were likely to be categorized as high-reactive when they were four months old. Because one function of GABA is to inhibit neural activation, newborns who cannot regulate their distress may possess compromised GABA function.

Longitudinal evaluations of children through age 11, from these two temperamental categories, indicate that although the specific behavioral reactions to unfamiliar events change with age—11-year-olds do not cry in response to adult strangers—a larger proportion of high- than of low-reactive children remained shy and subdued in the face of unfamiliarity, while a larger proportion of low-than of high-reactive children were sociable and affectively spontaneous in the same unfamiliar situations.

Because not all high-reactive infants become avoidant, and not all low-reactives become bold, we confront the question of how to classify high-reactive infants who did not become timid and low-reactive infants who did not become sociable. We have two choices, and which one is favored depends on the scientist's theoretical interests. On the one hand, we can emphasize the infant's temperament and continue to place sociable, spontaneous children who had been high-reactive infants in the same category with high-reactives who became inhibited. However, it is reasonable to acknowledge the obvious changes in behavioral phenotype and to classify the children in accord with both their infant temperamental category and their current behavior.

The 11-year-olds who had been classified as high- or low-reactive at 4 months were administered a 3-hour battery that included measurements of autonomic and brain functions. The pre-adolescents who had been classified as high-reactive infants showed greater electroencephalogram (EEG) activation (loss of alpha band power) on the right than on the left parietal area (McManis et al. 2002), and, if classified as fearful in the second year, greater activation in the right frontal area (see Fox 1991). The high-reactives also showed larger brain stem-evoked potentials from the inferior colliculus in response to a series of clicks (Woodward

et al. 2001), and a larger negative wave form between 400 and 1000 msec in the event-related potential in response to discrepant visual stimuli. The possession of a more excitable amygdala among the high-reactives could desynchronize alpha frequencies in the cortex, potentiate the evoked potential from the inferior colliculus, and contribute to an enhanced event-related potential to unfamiliar events. However, a small number of 11-year-olds who had been high-reactives and in addition displayed this biological profile were not especially shy or subdued—that is, the biology presumed to be the foundation of the infant category was preserved to some degree, even though the behavioral phenotype of these children had changed over time. Thus, in some theoretical contexts it is useful to distinguish, within a group of high-reactives, the shy children from the sociable ones. However, on other occasions, it is theoretically more fruitful to distinguish between children who had been high- or low-reactive at four months and to ignore their current social behavior.

The genes that contribute to high and low reactivity may be pleiotropic and contribute to body size and eye color as well. One of every four 11-year-olds who had been a high-reactive infant was small in size and had blue eyes, compared with only one of 20 low-reactive infants. The tame silver foxes that were the product of 20 generations of interbreeding tame with tame animals on a Siberian farm showed more flexible ears and tails and a unique distribution of melanin in the fur than the less tame foxes. These facts suggest that the genes contributing to the tame behavior may influence physical features that, on the surface, seem unrelated to the behavioral phenotype (Trut 1999).

The Ambiguity of Measures

Many scientists assume that the relationships among variables presumed to reflect a psychological or biological process are essentially the same across all individuals, especially if the sample consists of volunteers free of pathology. A typical report notes the age and gender distribution of the sample and occasionally mentions social class, but rarely do authors describe some biological features of their subjects. Psychologists are reluctant to acknowledge that individuals with different physiological profiles might display different relations among the same set of variables. For example, investigators will report correlations between biological and psychological measures in a volunteer sample but fail to parse the sample into those who are high or low on some other relevant biological variable, like body size or sympathetic reactivity in the cardiovascular system. Psychological and biological processes occur together within a person, and the individual's particular biology often affects the nature of the relations among the variables of interest.

Our research on temperament is illustrative. About 5% of our large sample of Caucasian children showed a combination of high reactivity at four months, high levels of fear in response to unfamiliar events in the second year, and extreme shyness with strangers during the school years. If we add to the above three features a small body size, blue eyes, right hemisphere activation in the EEG, and a large

evoked potential from the inferior colliculus, this category represents about 3% of middle-class Caucasian children. This small group is a meaningful psychological category. That is, rather than regard small size and blue eyes as correlates of a high reactivity, it might be theoretically useful for some arguments to claim that 3% of middle-class Caucasian children combine high reactivity in infancy, high fear in the second year, childhood shyness, a small body size, and blue eyes.

A second illustration involves several variables quantified on our 11-year-old longitudinal subjects: a stable profile of shy or sociable behavior at both 7 and 11 years, lateral asymmetry of alpha power in the EEG, and resting heart rate. Boys who were low-reactive as infants and who had right frontal activation in the EEG at age 11 were sociable and spontaneous; high-reactive boys with right frontal activation were not sociable. High-reactive girls who were shy had high resting heart rates; low-reactive girls who were shy did not. Finally, the relation between the number of comments the child made to the examiner and resting heart rate was low across all 237 children ($r = 0.03$). But high-reactive boys showed a significant positive correlation between spontaneous comments and heart rate. Thus, the relations among behavioral and biological variables can vary with temperament and gender. These facts imply that the meaning of a behavioral or biological variable can be ambiguous until additional qualities of the subjects are specified.

DOUBTS ABOUT INFANT DETERMINISM

The attractiveness of human development to college seniors planning graduate study is based, in part, on the popular assumption that early experiences create psychological structures that persist for an indefinite time. The two beliefs hiding in this Platonic conception are, first, that the dispositions established in early childhood persist and, second, that they will be actualized in different contexts because, like skin color, they are stable features that belong to the child. These assumptions form the basis for the belief held by many European and American commentators that some habits wrought by the events of infancy cannot be abrogated. This premise has deep historical roots. One commentator wrote nearly 80 years ago, "the powerful significance of the intellectual processes—perception, fantasy, thinking, and their social results in science, art, and philosophy in the human being—have their first roots in the specifically human mental structures of the three month old child . . . Historically, all phenomena of adult mental life must be traceable to birth" (Bernfeld 1929).

Why have many social scientists been persuaded of the permanent power of the early years, especially when evolutionary biologists have demonstrated that the persistence of a feature over generations depends on its adaptive value in a particular ecological niche? One clue lies with the social conditions in eighteenth-century Europe. A growing number of wives of merchants and skilled artisans, freed of the responsibility of gathering wood, tending animals, and weeding vegetable plots, were assigned the task of socializing their infants. A well-nurtured

child who married the proper partner and mastered the skills that led to positions of prestige in the community would enhance the family's status. As the children of the bourgeoisie lost their economic value, they became investments in the family's future pride, and middle-class parents began to view them as objects of sentiment and pleasure rather than as a source of labor needed for family survival.

Second, because eighteenth-century European society had become socially more mobile, it was possible for the son of a blacksmith to rise in the social hierarchy and for the son of a squire to fall. Change in social class position became simultaneously a hope and a fear and, therefore, a source of uncertainty for families located in the middle, most vulnerable, rungs of the class ladder. When a source of uncertainty permeates the consciousness of a large segment of a society, an explanation will be invented that is reasonable and, more important, implies actions that, if taken, will reduce the number of sleepless nights filled with worry. The suggestion that certain maternal behaviors guarantee the development of character traits necessary for a successful future and, as a result, protect the family against a descent in status, rationalized ritual practices that swept some of the anxiety away. But if mothers did not nurture their infants properly, their children would become vulnerable to a dull mind, a wild spirit, and a downward spiral.

It has proven difficult, however, to demonstrate that experiences of the infant years determine profiles during childhood or adolescence. The orphans produced by World War II and the Korean conflict, who had fragile bonds to any caretaker, developed reasonably well after adoption by nurturing foster parents (Rathbun et al. 1958; Winick et al. 1975). One group of frightened, quiet two- to four-year-olds, who had been raised in an overcrowded institution with few caretakers, were subsequently enrolled in regular play sessions with adults and children. The restrained affect apparently caused by the indifference of caretakers lifted after less than two years and the emotional vitality seen in most four-year-olds emerged (Flint 1966).

The Influence of Social Class

A longitudinal study of children born and reared on the Hawaiian isle of Kauai revealed that about 15% had serious academic or conduct problems during adolescence. The best predictor of these problems was the social class of the family. Over 80% of those with problems came from the poorest segment of the sample; only one upper-middle-class child developed a psychological problem. But the conditions that define social class have a continuing influence on the child; they are not limited to the first year or two of life (Werner & Smith 1982). Social class also has a far more profound influence on children's development than the fact of surrogate care. Regular attendance in a day-care center, or in another form of surrogate care, does not produce children who are very different from those raised at home, as long as the children come from the same social class and ethnic background (NICHD Early Child Care Research Network 2001).

No scientist has been able to demonstrate that a particular set of experiences during the first two years in children growing up in typical American or European homes produces a particular adolescent or adult outcome in even one-tenth of those exposed to those experiences. An extreme level of deprivation, such as existed in the Romanian day-care centers a decade ago, does produce an undesirable outcome (O'Connor et al. 2000). But this degree of deprivation is rare in most families, even poor ones; and, as noted above, some of the severely deprived children become resilient after adoption by nurturing parents.

One reason why long-term preservation of early qualities, and of the representations on which they are based, is unlikely is that the brain is immature during the first two years. The frontal lobes, which evaluate information from the environment and the body, are not fully connected to the rest of the brain during the first year. As a result, emotional experiences are not evaluated, and it is likely that many early memories are lost. Few adults can remember episodes that occurred before their third birthday.

The most important argument against the doctrine of infant determinism flows from the hypothesis that infants, like adults, are influenced primarily by events that are discrepant from their usual experience, rather than by a particular experience qua experience. The most formative discrepancies are those that violate the child's symbolic interpretations, and children do not regularly interpret experience symbolically until their third birthday. These symbolic constructions are more critical determinants of future anxiety, depression, apathy, or anger than the events of the first year. Palestinian youths throw stones at Israeli soldiers because they believe that the Israeli government has unjustly oppressed their ethnic group. Their violent behavior is not traceable to the parental treatment they received as infants. No smiling African-American infant knows of the history of oppression of blacks or the remaining pockets of racism in American society. The realization that there is prejudice will not form until these children are five or six years old.

The psychological products created by the first two years will be preserved only if the environment sustains them. Infants living in poverty have more frequent colds and bouts of diarrhea than those in affluent homes; adults raised in poverty are more likely to have strokes, heart attacks, and sexually transmitted diseases than those raised in affluence. But the higher rates of morbidity among poor adults are not the result of having more colds and diarrhea in the first two years of life. They are due to the continuity, over years, of a poorer diet, greater life stress, and less adequate medical care. The advocates of infant determinism fail to award sufficient power to the experiences of later childhood, many of which are correlated with social class.

Other Conditions of Influence

The child's birth order, profile of identifications, cultural context, and historical era also critically influence development, but these factors are not operative during the

infant years. For example, first-, compared with later-born, children from middle-class American homes attain better grades in schools, are more often valedictorians of their high school class, and are more often listed in *Who's Who in America* (Altus 1966, Sampson & Hancock 1967, Sulloway 1996).

Identifications with class and ethnic categories affect certain aspects of development. Children, like adults, feel pride (or shame) when they learn about the experiences of another person (or group) with whom they believe they share essential features. The ethical values of most adolescents are more similar to those of their parents and other relatives whom they respect than to those of randomly selected individuals. Because identification with a family in poverty can generate shame, guilt, or anger in societies where many live in affluence, poverty can create a physiological state that contributes to the poorer physical and psychological health among those who are disadvantaged. The divergent patterns of development in children from different social classes are analogous to the developmental fates of young embryonic cells, which are determined by their spatial position. Whether a cell becomes part of the retina or a pigment cell in the skin is a function of where it is in the young embryo. Analogously, the psychological profiles of adolescents are determined in a major way by their family's place in the social class hierarchy of their society. However, identification with a class category does not emerge until after the fifth birthday.

Finally, the historical era during which the adolescent years are spent often has a profound effect on adult values. The new cognitive capacities of adolescents motivate them to probe their assumptions about self and society in an attempt to remove inconsistencies between their childhood ideas and their understanding of the present. Adolescents are unusually receptive to historical events that challenge existing premises as they synthesize the assumptions they will rely on for the rest of their lives. Youth in Kosovo have witnessed cruelties that will make deep skeptics of their generation even if they had caring parents during the first year. Samuel Beckett probably exploited his adolescent memory of the anarchy that tore through Ireland in the early decades of the last century when he had one of the tramps in *Waiting for Godot* say, "This is becoming really insignificant" and had the other tramp reply, "Not enough." The consequences of sibling order, identification, and historical era, which can produce sharp discontinuities in development, have little relevance during the first two years. As William Greenough wrote, "To focus upon the first three years and to downplay the later years is not warranted, by either human behavioral or neuroscience research" (Greenough 1997, p. 19).

CONTEXTS AND SOURCES OF EVIDENCE

The willingness to attribute power to the context of observation—i.e., to acknowledge that many conclusions must be restricted to the specific behavior displayed in a particular situation—is a fruitful product of the last few decades. Hala & Russell

(2001) provide a stunning example of the significance of the context of observation. A three-year-old watches an examiner place a piece of candy in one of two boxes. An accomplice of the examiner then enters the room and the examiner tells the child to point to the box where the piece of candy is hidden. The child had been told earlier that if the child showed the accomplice the correct box, the adult would get the treat and the child would not. But if the child pointed to the box not containing the candy, the child would enjoy the sweet. If the child is told to use his finger to point to the box, he is "honest" and points to the box containing the candy. But the child given a mechanical pointer is more likely to point to the box that does not contain the candy. That is, simply changing the way the child indicates which box contains the prize affects behavior in a serious way (Hala & Russell 2001).

The assumption that a particular behavior, or biological reaction, maintains the same meaning across different incentives and contexts is retarding theoretical progress. Consider the following two assumptions regarding a rat that has experienced several light-followed-by-shock trials: 1. that the duration of bodily immobility ("freezing") or the magnitude of potentiated startle in response to the light means that the rat is in a state of "fear"; and 2. that absence of freezing or potentiation of startle implies absence of (or minimal) "fear." The second assumption is inconsistent with the fact that a conditioned startle reaction is muted if the shock used in training is very intense. Although a rat with a lesioned amygdala shows minimal freezing, implying low fear, the same animal will defecate in the place where it was shocked, implying some form of fear state (Antoniadis & McDonald 2000). Thus, the meaning of "freezing" or startle depends on the specific context and "response in a context" should be the proper construct.

Put differently, the brain structures that must be intact in order for Pavlovian conditioning of a particular response to occur depend on the specific response. If the response is an eye blink to a puff of air applied to the cornea the cerebellum is necessary. If the response is bodily freezing the amygdala and central grey area are necessary. The assumption that an animal is in a state of fear when a stimulus produces conditioned freezing may be unwarranted. Investigators who apply an air puff to the cornea do not ascribe a fear state if the subject blinks in response to a conditioned stimulus that precedes the air puff.

Too many psychological concepts are indifferent to the species, response, and particular situation in which a behavior occurs. As a result, words like fear and aggression are often used to describe an animal's state. The authors of a recent essay in the journal *Trends in Neuroscience* on the molecular basis of aggression in animals never defined aggression; they simply assumed that a mouse biting an intruder belongs to the same psychological category as an adolescent bullying a peer (Nelson & Chiavegatto 2001). However, an intention to harm another, which is absent in mice, is an essential feature of all human acts we call aggressive. These authors would probably not regard termite destruction of a house as an instance of aggressive insect behavior; they should display the same caution when describing mice.

The problem lies with the borrowing of predicates intended to apply to human behavior and attributing the same meaning to these words when applying them to animals. This practice tends to occur because there is a smaller number of distinct verbs than nouns for different living forms. A relatively accurate inference regarding an object is less dependent on the attached predicate. This fact is an instance of the more general principle that there are fewer functions, mathematical or empirical, than there are entities participating in those functions (e.g., physical and biological objects display curvilinear functions). The predicate "fall" can apply to a child, rock, leaf, building, or meteor. The psychological meaning of "bit" in the sentence "The boy bit his brother" is not the same as its meaning in "The mouse bit the intruder." Unfortunately, English does not have a word other than "bit" to describe the animal's behavior. Thus the behavioral biologist selects this word but assumes, incorrectly, that the act is aggressive in intent whether it occurs in humans or animals. Because the meaning of a predicate often varies with the agent—that is why the ancient Romans used different words for the act of kissing when the actor was a mother or a lover—neurobiologists should be careful when they apply to animals verbs that are intended to describe human behavior (Magnusson 2000).

Sources of Evidence

Scientists should recognize the wisdom in Bohr's insistence that the meaning of a scientific construct cannot be separated from the source of its evidence. Fear has one meaning when the referent is a rat freezing in response to a conditioned stimulus that had been paired with electric shock, but a different meaning when a child says that she is afraid of failing an examination. Similarly, "possession of a number concept" has one meaning if the evidence comes from infants looking longer at six dots after being familiarized with two dots, but a different meaning when an adolescent correctly divides 1362 by 18.5.

Consider a third example of the importance of the source of evidence. Four-month-olds facing an adult who is playing peek-a-boo with them first saw a happy face on the adult for three successive trials. On the fourth trial, some infants saw the adult display a fear face, some saw an angry face, and a third group saw a sad face. The infants looked longer at the first two expressions but did not devote longer attention to the sad face. That fact does not mean that they did not discriminate the sad from the happy face for the infants showed distinct changes in facial expression in response to the sad demeanor (Montague & Walker-Andrews 2001). Absence of increased attention does not always mean a failure of discrimination; presence of increased attention does not always mean that a child is surprised by a discrepant event.

Failure to appreciate that changing the source of evidence can alter the meaning of a construct poses a problem because contemporary students of development belong to distinct groups that are defined, in part, by method. Investigators concerned with pathology or social problems find it hard to obtain relevant information by bringing children into a laboratory and are forced to ask informants, or the child,

about behaviors and moods. These scientists assume that a parent's or a teacher's verbal descriptions of a child's aggression, restlessness, or fearfulness is almost as good as observing the child directly. This assumption is overly optimistic (Baillargeon et al. 2001).

A Critique of Self-Report

The distinction noted above between schemata and semantic structures is relevant here because the most popular personality and temperamental dimensions are based on the semantic structures activated when children or adults answer questionnaires. However, different personality and temperamental types would be inferred if the thousands of people who filled out these questionnaires had been filmed for 10 hours a month over a six-month period in different contexts and those observations had been factor-analyzed. Answers to questionnaires represent a particular type of evidence.

Several problems trail the use of questionnaires and interviews as the sole basis for inferring psychological qualities. First, each semantic representation of a trait is related to other semantic categories. A mother who affirms on a questionnaire that her child likes meeting new children is biased to respond affirmatively to all questions semantically related to that statement in order to maintain semantic consistency. Terms like sociable and shy are antonyms; the features linked to each word are inversely correlated in the semantic networks of most respondents. Because most parents treat the semantic concepts happy and sad as antonyms, parents who say their infants laugh frequently will resist describing them as irritable, even though films of infants reveal a large group who both laugh and cry frequently.

Second, if a psychological trait does not have a popular name and therefore is not part of a semantic network, questionnaires do not include relevant items. Variation in the degree of ambivalence over one's motives, energy level, intensity and quality of sexual arousal, and degree of virtue assigned to self—four qualities that influence life choices—are not easily measured with questionnaires.

Of equal importance is the fact that children and adults vary in the biological activity that contributes to conscious feelings and chronic moods. However, few individuals have conscious access to these bodily events and, therefore, children and adults cannot be asked about them on questionnaires. Two parents could report equivalent irritation with their child but differ in the degree of noradrenergic activity that occurs when the child disobeys.

Further, children described similarly by a parent can be very different biologically. For example, the mothers of our longitudinal subjects ranked 28 statements descriptive of their child. A group of boys described as having "high energy" contained two very different types of children. The low-reactive boys with this description were low in beta power in the EEG and showed greater left than right activation in the frontal and parietal areas. The high-reactive boys assigned the same trait by their parent did not display these two biological features. A second

illustration comes from the children in this sample who described themselves as "happy most of the time." The boys who described themselves this way, who had been low-reactive infants, showed left frontal activation in the EEG. The other children who described themselves as equally happy did not display this property. This fact suggests that the low-reactive boys may have based their judgment on internal feeling tone, while most of the other children used their life conditions. Even if this interpretation is incorrect, the evidence indicates that different categories of children can provide the same self-descriptions.

On some occasions, questionnaire evidence leads to conclusions that violate both biology and common sense. One team interviewed 794 pairs of adult female twins about their physical health and emotional states. The replies to the questions posed by a stranger revealed, surprisingly, that self-esteem was as heritable as physical health (Kendler et al. 2000). Had the evidence consisted of a physical examination, with blood and urine tests and direct observations of behavior, I suspect the results would have been very different. For these reasons, conclusions about a child's psychological features based only on questionnaires or interviews have a meaning that is as limited as Ptolemy's conclusions about the cosmos based on the reports of observers staring at the night sky without telescopes.

CLASSIFICATION OF TEMPERAMENT AND PERSONALITY

Recent essays critical of the concept of biological species may have useful implications for conceptions of temperamental and personality types (Hey 2001, Schilthuizen 2001). The new theorists argue that species are not natural objects defined by a small number of fixed features but constructs invented to serve the human addiction to categorizing experience. Animal groups vary over time on a correlated number of dimensions and features. The conditions that exist during a particular era create correlational patterns among features that include (*a*) genes, (*b*) anatomical, physiological, and behavioral properties, some derivative of the genome, and (*c*) the local ecology. Each cluster of related features can be treated as a category, but a new category may be theoretically fruitful when one or more features change. Pet beagles in American represent one cluster; wild dogs in Zaire represent another. Should the beagle and wild dog mate, the offspring belong to a new cluster.

The relevant features that define personality types include: (*a*) the individual's temperament, derivative in part from the genome, (*b*) current physiological profile, (*c*) psychological properties created by past experience, and (*d*) contexts of action. Imagine a hypothetical cluster consisting of a high-reactive infant with a low density of GABA receptors in the medulla and the limbic system, socialization by a middle-class family that promotes conformity and anxiety over error, and residence in a large metropolitan area in the United States. This cluster defines a psychological type. However, if we change the residence to an isolated village in

New Guinea but keep everything else the same, a different category is warranted. If we change only the biology, so that the child has a high density of GABA receptors, another psychological category is actualized. And if we change the historical era to second-century Gaul as the Roman empire was collapsing, still another type would be proper.

Psychiatric categories of mental illness emphasize self-descriptions of feeling and behavior and ignore the patient's biology, contexts, and historical era. Hysterical paralyses, which were prevalent in 1900, are rare today, while attention deficit disorder has become a more frequent diagnosis than it was a century earlier. John Cheever and Alice James, born only a century apart, appear to have inherited a similar temperamental bias for depression. But they differed in the interpretation of their states and in their coping strategies because they were born in different historical eras. Danish citizens who live in Copenhagen are at twice the risk for schizophrenia as Danes who live in the rural areas of Denmark (Pedersen & Mortensen 2001). A 50-year-old man in New York City who insists that he talks to God regularly would be classified as psychotic. But few psychiatrists would apply the same diagnosis to a Muslim who blows himself up in a suicide attack because he is certain that the action permits him entrance to paradise. A restless seven-year-old American child doing poorly in school who possesses a neurochemistry characterized by dopamine deficiency in the frontal lobes would be classified as having attention deficit hyperactivity disorder (ADHD), but a child with exactly the same biology would not belong to this category if he lived with a family who raised goats in an isolated Tibetan village without any school.

Ordinary citizens in their daily interactions acknowledge the significance of the context of a person's statement. Most adults would interpret the declaration "I wish I were dead" in different ways depending upon their knowledge of the speaker's mood and past events. This declaration from a friend who had committed a minor faux pas would be ignored; the same statement from a friend who has been suffering from cancer for two years would be taken seriously. I do not suggest that every context invites the invention of a new category; only that investigators should not automatically assume that the central feature of a psychological category is a particular behavior or verbal description of motive, feeling, or action free of any contextual constraints.

For many contemporary psychologists, psychological types resemble biological species as traditionally defined. That is, a psychological category is defined by a set of fundamental features (for example, a depressed mood). This position regards the context in which the individual acts as irrelevant. A reform position holds that when the context of action affects the relations among the defining features it should be included in the definition of the category. Thus, a salesman living in suburban Chicago with a spouse and two children who meets the criteria for extraversion would have to be reclassified if he lost his family in a motor vehicle accident and took a job as a forest ranger in a remote village in rural Manitoba. The earlier reference to the products of water vapor is appropriate.

The air in most locations contains some condensed water vapor, but whether that vapor is classified as fog, cloud, or neither depends on the local context. The products of a gene depend on its location in the body. Similarly, every contemporary category in personality and pathology requires specifying the contexts of its actualization.

CONCLUSIONS

The scholarship of the last 50 years invites a skeptical posture toward the simple, aesthetically pleasing perspectives that dominated psychology in the middle of the twentieth century. Contemporary scientists are more receptive to the suggestion that the meaning of most behavioral and biological reactions depends on the context; brain profiles and behavior are not always closely yoked; schemata, sensory motor structures, and semantic representations represent distinct psychological forms; and maturation of the central nervous system modulates development.

Because personal history affects each person's reactions to an event, developmental evidence should be a component in a great deal of psychological research. An agent's history is as significant for her contemporary thought, feeling, and action as the evolutionary history of a species is for its form and physiology. The challenge for psychologists is to invent methods that might reveal the early consequences of that history; the challenge for neuroscientists is to devise machines and analytic programs that can detect in brain patterns the psychological structures that originated years earlier in interpretations of childhood encounters. I am not certain that either victory is possible. That is, it is not obvious that the evidence produced by the most sophisticated examination of the brain of the writer Frank Kermode could ever reveal a childhood identification with a poor family—an identification that became a critical feature of his behaviors and moods. If this claim proves valid, prediction of the psychological reaction to an incentive from contemporary evidence alone must remain imperfect.

The deep disappointment among twentieth-century mathematicians was Gödel's formal proof that incompleteness, and therefore lack of certainty, was an inherent feature of every set of axioms. Scholars vary in the strength of their conviction that a creative mind, sitting alone in a quiet room manipulating propositions, linguistic or mathematical, can discover deep truths about nature. Biologists are more skeptical of this assumption than physicists. But the intellectual heroes celebrated in college lecture halls in Europe and America are more often Einstein, Heisenberg, Shrödinger, and Dirac than Sherrington, Cushing, Cajal, or Yalow, because formal arguments generate greater aesthetic satisfaction among members of our culture than empirical discoveries whose beauty is tainted by lists of exceptions. There is a fable of a king who asked his wisest advisors to reduce to one word the knowledge contained in all of the volumes in the palace's library. After years of work, the scholars brought the king a piece of paper on which was written the single word "maybe."

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