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In Search of the Pathways that Lead to Mentally Healthy Children

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A Dynamic Systems Approach to the Mind/Brain Debate

At the Milton and Ethel Harris Research Initiative, in York University, we are studying the processes that promote the development of a healthy mind in young children. We look at this issue at both the psychological and the neurobiological level, and the complex interactions that take place between the two. This research provides us with a unique opportunity to explore both sides in the nature/nurture debate, but given that our mandate is to benefit children in very practical ways, we can never allow ourselves to get lost in the thickets of this interminable philosophical debate. Our goal is to understand the interaction between psychological and neurobiological processes in order to identify and mitigate potential problems as early as possible, and to enhance the development of healthy minds in all children.

Whenever one encounters a protracted philosophical debate that periodically swings from one polarity to another, one can be fairly certain that the problem is not that both sides are wrong but rather, that both are partially right. The challenge is, of course, to find some way of reconciling and assimilating these competing views. But until a new framework emerges that is capable of such a feat, calls for a synthesis are doomed to remain at the level of rhetoric.

There is no end of examples of this Hegelian scenario in the human sciences, but none more telling than the mind/brain debate, which has dominated Western thinking about human functioning since the writings of Plato. To be sure, the technical details have grown considerably more sophisticated, but the fundamental issue has remained the same from the time of the ancient Greeks: either, as Plato argued, the mind shapes the brain, or, as Hippocrates insisted, the brain shapes the mind.

Such problems are the special province of philosophy, and for that reason alone, a source of unease amongst some scientists. From the very beginning the worry has been expressed—not infrequently by philosophers themselves—that the resolution of these problems will amount to little more than an "idle tea-time amusement" (Russell, 1957). But these problems can have enormously important practical as well as theoretical consequences.

For example, the mind/brain debate has profound implications for how developmental disorders are treated. Whereas those who accentuate the nurturing side of child development tend to dwell on the possibility of tailoring a child's experiences in such a way as to restore a malfunctioning neural system, those who place the emphasis on the child's biological heritage often focus on the need for medications or other prosthetics and see the role of intervention as that of recruiting some different part of the brain to perform (as best it can) an operation that has been compromised by a defective neural system. These different attitudes not only have a significant impact on the child and her family, but indeed, on the scientific view of the possibility of mitigating, and perhaps one day preventing, a broad range of developmental, psychological, and behavioral disorders.

There is a growing sense today, however, that we have finally seen the emergence of a framework that is indeed capable of synthesizing both sides in the mind/brain debate: of understanding how psychological and neurobiological processes influence each other, and how the relationship between them grows over time (Fogel, 1993). Broadly speaking, the new framework is that of dynamic systems theory, which, in place of linear models that postulate a direct relationship between cause and effect, looks at how multiple factors affect each other in mutual and simultaneous ways, looking, in particular, at

the relationship between elements in a system and how that relationship changes over time (Fogel, King, & Shanker, 2008).

How does one apply this paradigm to the mind/brain problem? Does it simply mean that mind is situated at one level in a developmental system and brain at another, alongside other levels such as family, community, and culture? If that were the case, then one would still be left with the age-old problem, so conspicuous in Descartes' famous musings about the role of the pineal gland, of explaining exactly how the two levels actually interact when they are supposed to belong to different ontological domains.

An important step forward in answering this question was taken with the advent of epigenetics: the biological theory that there is a control system of switches that turn genes on or off. The basic idea here is that early social experiences can control these switches and cause heritable effects in humans (Weaver et al., 2004). Dynamic systems theorists working in molecular biology then took this idea a critical step further with the argument that "At each level of the developmental system, the effect of any level of influence is dependent on the rest of the system, making all factors potentially interdependent and mutually constraining." Hence "The minimum unit for developmental analysis must be the developmental system, comprised of both the organism and the set of physical, biological, and social factors with which it interacts over the course of development" (Gottlieb, Wahlsten, & Lickliter, 1998).

For those working in the area of abnormal development, the most important implication of this argument is that children are not *born* with a developmental or psychological disorder: i.e., there is not an ADHD or an autism gene, in the way that generative linguists once speculated that there might be a language gene (Shanker, 2002). Nor can one trace these disorders back to a single episode or event, such as a genetic mutation, or a gene being "turned off" by adverse experiences, or an inoculation or infection. Rather, ADHD and autism are seen as complex *downstream disorders*, the result of initial neurogenetic and/or epigenetic factors that set the child on a developmental trajectory leading towards the disorder.

Herein lies the basic picture that underlies the manner in which we designed MEHRI, with half of our resources devoted to studying the effects of early intervention on a child's psychological development and half of our resources looking simultaneously at the development of the child's brain. (For a fuller description of our studies, see www.mehri.ca.) Our thinking is grounded in a *developmental pathways model*, whose basic principle, as we shall see in more detail below, is that initial neurobiological deficits—which might be the result of genetic and/or social-environmental factors—can strongly influence the kinds of interactive experiences that a child seeks out or to which she is receptive, which in turn can have a dramatic impact on the development of increasingly specialized neural systems.

What we are studying at MEHRI, therefore, is how the synthesis of social-emotional experience and neurobiology leads to a developmental trajectory that becomes ever more entrenched, so that by the time a child enters school it can be difficult to alter. The better we can identify the steps involved in these trajectories the better we can design treatment methods that promote mental health and help mitigate the disorder by addressing, and we hope reducing, the child's and/or caregiver's maladaptive strategies. Similarly, the better we can understand the pathways that lead to enhanced attention, concentration, self-regulation, social understanding, and empathy, the better we can tailor a child's individual experiences to maximize his or her development of these and related capacities.

Understanding "Healthy Mental Functioning"

As mentioned earlier, we are primarily interested in the capacities that children need in order to flourish in a modern school environment; what sorts of experiences promote the development of these capacities; what sorts of biological and/or social factors can undermine or impede these experiences; and the extent to which such deficits or constrictions can be mitigated and the child returned to a healthier developmental trajectory. But before one can begin to study these processes one first has to clarify what one understands by a healthy mind, which, to say the least, is a challenging matter.

One problem is simply that what constitutes "healthy mental functioning" might vary according to the contingencies of the environment. For example, we now know that elevated levels of cortisol early in life contribute to poor physical and mental health in adulthood (Flinn & Leone, 2006; Gunnar, 2007). Yet one can imagine situations in which elevated cortisol levels in the early years might be adaptive, given the nature of the environment into which the child is born (see Ledoux & Phelps, 2000). If one of the defining features of health is simply whatever is conducive to survival, then it might well be the case that mechanisms that promote the survival of the young with potentially negative physical and/or mental consequences later in life would be deemed healthy.

Another problem is that some of the children that we see have enhanced abilities in a selected area. In some

circumstances such an island of expertise might be highly valued, yet such heightened abilities can also lead to undesirable consequences in the child's overall mental functioning (Howe, 1989). For example, some children with autism have a heightened ability to match and discriminate stimuli, but this can cause problems in how they form categories: especially if it leads them to construct overly narrow categories, which can, for example, disrupt their ability to make sense out of the variability inherent in the speech stream.

The problem becomes even more serious if the skill in question should happen to be one that caregivers value above all other aspects of the child's well-being. The example of the castrati immediately comes to mind: i.e., the practice of castrating young boys before puberty in 18th century Italy in order to preserve their ability to sing soprano or mezzo-soprano. But perhaps similar forms of abuse are evident in young children today who demonstrate a precocious musical or athletic talent and are immediately subjected to a training regimen that sacrifices crucial aspects of the child's overall social and emotional functioning.

In more general terms, we are confronted here with the problem that the manner in which one conceptualizes a healthy mind is inextricably bound up with one's social values. For example, one culture might prize the capacity to repress one's emotions, whereas another might value their expression. One culture might stress the importance of empathy, while another see this as a symptom of moral weakness (Harkness et al., 2007). One culture might embrace as one of its defining values that no child should be left behind, while another might adopt a social Darwinist program of educational streaming based on natural selection.

Many of these problems are really a version of the classical dilemma that has plagued cultural anthropology from its inception: namely, whether there are any universals of healthy mental functioning. Closely related is the objection, made famous by R.D. Laing, that even to speak of a healthy mind is to imply that there is such a thing as a diseased mind, as opposed to the much more anodyne claim that there are simply different kinds of minds.

Laing was, of course, concerned with the manner in which individuals diagnosed with a mental disorder are stigmatized as ill simply because their behavior departs from a society's accepted norms of behavior. It is hard not to be sympathetic with the humanist animus inspiring this argument, especially in light of the further entrenchment of the medical model of mental illness that has taken place since the publication of *The Divided Self* (see PDM Task Force, 2006). But given our mandate at MEHRI to help children—all children—flourish in school, we have set out to identify the pathways that lead to their cognitive, communicative, social, emotional, and physical well-being when they enter this challenging environment; the factors that impede or cause deviations from these pathways; and the experiences that can mitigate the developmental consequences of these deviations.

Plato and the Search for *Eudaimonia*

The very assumption that there is such a thing as a healthy mind, and that it is in a society's best interest to study the ways it can best promote its development in young children, is one of the oldest and, in some ways, constitutive themes in Western thinking about the mind. It dates back to the Ancient Greeks, and most notably, Plato. Over and over Plato compared mental with physical health so as to question what would constitute mental health and how one would attain such a state, which Plato himself saw as one of balance (Cooper & Hutchinson, 1977). He argued that, just as someone who eats and exercises properly will experience "physical health," so too someone who tempers his appetites and desires, enjoys relationships of social intimacy, and is unafraid of death, will "flourish."

At the heart of the psychological as well as philosophical revolution that Plato instituted was his attempt to formulate a model for the development of a child's mind such as would lead to this overall state of health. Plato was every bit as aware of the intimate relationship between physical and mental health as any contemporary scientist writing on the subject (see Cotman, Berchtold, & Christie, 2007; Cotman & Berchtold, 2002; Brene et al., 2007). Indeed, Plato was perhaps the first to examine the complex interplay between innate character traits and the effects of different types of caregiving practices on such a temperament (cf. Kagan, 1994), where the ultimate goal is to understand which type of upbringing is best suited to which type of personality in order to maximize that individual's capacity to enjoy a state of *eudaimonia*: of flourishing or happiness.

Over the past two millennia there have been endless debates as to how to define *eudaimonia*. However much one might wish to avoid being dragged into this philosophical quagmire, the reality is that one cannot begin to study the processes that promote the development of a healthy mind without having formed some position on this foundational issue. So while we were developing our psychological and neuroscientific tools at MEHRI, we found ourselves engaged in a classic philosophical in-

quiry into what sorts of capacities constitute healthy mental functioning, within the parameters of modern post-industrial society.

The notion of functional/emotional capacities is central to our view of healthy mental functioning (Greenspan & Shanker, 2004). The capacities that we have in mind are those that enable a child to master her emotions and thus attend to the world (i.e., those that are grouped together under the rubrics of emotion- and self-regulation and executive functioning); to form a strong attachment with her primary caregivers; to engage in back-and-forth communicative interactions with her caregivers, which involves the development of intentional or purposeful behavior; to engage in sustained, joint problem-solving with her caregivers; and then, to develop symbolic and language capacities and the capacity to think logically and reflectively. Accordingly, we are not so much interested in how many facts a child might have memorized when she enters school, or even in a number of specific skills that can be formally measured, but rather, in her capacity to rise to the challenges to which she will be exposed (see Kirp, 2007).

To understand the importance of this point, one need only consider the pace at which technology is evolving. For example, the speed at which information is now disseminated and becomes outmoded may seriously test the limits of a mind that is capable of coping with simpler processing demands. Whereas an earlier culture might have focused on developing memorization skills, it now seems imperative to develop more creative "tools of mind" (to use Vygotsky's term) to deal with the challenges of the future. But then, the import of this last point is that we should indeed be more concerned with developing the whole child and not some narrow aspect of the child's academic performance such as can be easily measured by formal testing. This, we came to believe, was Plato's greatest insight when he came to focus on the importance of *eudaimonia*: the capacity to rise to the challenges that one will be faced with, which, in the modern world, are changing at a pace that even a generation ago could scarcely have been envisaged.

The Capacities That a Child Needs in Order to Flourish Today

Over the past century, there has been a massive shift in developed nations from rural to urban living. There is a growing concern amongst scientists studying this phenomenon that such a transformation brings with it all sorts of challenges that test a mind that might have coped fairly well in a more rustic setting, but is stressed by an urban environment.[1] Those studying the impact of these changes on children in Canada and the US have expressed concerns for example, over the number of visual, auditory, social stressors in cities (see Field, 2007); by the shortage of green spaces and nature-based experiences (see Kahn & Kellert, 2002); by the decline in exercise as it becomes problematic for children to walk to school, or to exercise while at school (see Franco et al., 2007); by changing family and social patterns (see Mustard, McCain, & Shanker, 2007); changing leisure pursuits, eating and sleeping patterns (Olfman, 2005); and so on.

The important point to bear in mind here is that these challenges that the child must deal with range across a number of domains, many of which are easy to overlook if one's focus is too narrowly cognitive. For example, one of the hardest challenges many children experience is the first day of school. Accustomed to the security of being alone with their primary caregiver, or in a small group setting, the child suddenly finds herself thrust into a room filled with noisy children, many of whom are feeling equally overwhelmed. Children vary in all sorts of ways and have all sorts of sensory likes and dislikes, all sorts of interaction preferences and aversions. If the child has come from a nurturing environment, her parents have learned what sorts of experiences best help her to stay regulated. The transition from this warm and highly personalized environment to a classroom can be quite overwhelming.

Not only must the child quickly adjust to these new surroundings, but she must also become attached to an adult that, whether we acknowledge the point or not, is now going to play the role of surrogate parent for a significant proportion of the child's weekday life. Even in the best of circumstances the child can only expect to get a fraction of her teacher's attention. Meanwhile, she is expected to understand and conform to the rules of classroom behavior, all the while attempting to master myriad new concepts and skills that many of those around her may seem to acquire with ease.

In order to be able to rise to such challenges, the child has to be able to maintain a calm and regulated state in different environments and to settle herself when she becomes anxious or frightened. She needs to learn how to

1. We can get some idea of these trends from the latest Government of Canada Report (2006) on "The Well Being of Canada's Young Children." In 2002/2003, 16.7% of Canada's children 2–5 years of age displayed signs associated with emotional problems. This is up from 13.8% in the year 1998/1999. In 2002/2003, 12.7% of children 2–5 years living in rural areas were reported to have emotional problems, versus 17.2% of children in urban centers. In 2002/2003, 7.7% of male children living in urban centers were reported to display signs of hyperactivity and inattention versus 5.15 of rural males.

control her emotional outbursts, and if she is to mix comfortably with other children and take an active role in social interactions, she needs to understand what they are thinking and feeling.

These "mindreading" abilities are clearly not innate; nor are they simply a function of social/cognitive development (Legerstee, 2005). To be capable of acting in a warm and empathetic manner with her peers, a child needs to experience such warmth and empathy, and she needs to confront a broad range of new emotions. All young children find certain emotions frightening or overpowering, depending on the circumstances of their upbringing. For example, a single or sheltered child who has never had to deal with competition or aggression finds herself on a steep learning curve as she struggles to navigate her way through the minefields of playground politics.

In the classroom proper the child needs to be able to attend to a lesson for a relatively long period of time and inhibit distractions, of which there are likely to be far more than to which he is accustomed. The child can't be self-absorbed or retreat into some private interest, like a Gameboy, that keeps him quiet for hours on end. Furthermore, he has to be able to recognize patterns and solve problems in different domains, and to sequence his thoughts and remember what he has learned. He also needs to be able to work independently, deal with frustration, and above all, be curious and eager to acquire new information and develop new interests.

In the area of language development, the child should be able to understand and use a broad range of nonverbal affect signals (e.g., facial expressions, gestures, posture), and be competent in more formal areas, such as using and understanding sentences that include subordinate clauses, passive constructions, and inflectional endings. She has to be able to ask appropriate "wh" questions, and not only respond appropriately to what others say, but most importantly, initiate conversations and express, report, describe, etc., her intentions, desires, beliefs. It is also vital that she is able to engage in a reciprocal flow of conversation and know the basic principles of repair strategies.

There has been a tendency, when looking at a child's cognitive development at school-entry, to focus on very concrete skills, such as the number of color words that the child has mastered; or whether she is starting to count and to understand the simple application of numbers; or to read and write simple words. But when one is thinking of the development of the whole child, there are a number of foundational cognitive skills that are absolutely vital. For example, the child should be able to focus on a problem, restrain his impulses, form a step-by-step solution and stick to it; he should be able to build logical bridges between ideas; he should be engaging in complex symbolic play; and he should be able to distinguish between fantasy and reality.

And, of course, Plato was right: one cannot ignore the physical dimension in all this. The child has to be able to deal with the physical demands of a school day and the inner resources necessary to spend so much time on her own in the equally demanding contexts of the classroom and the playground. The child needs to be developing both her fine and gross motor skills, and, as a number of studies have established, she should have developed good sleep, hygiene, exercise, and eating habits. The child also needs to learn how to deal with frustration and to develop a strong sense of working cooperatively with others, skills that are in part developed through sports. It is no surprise that those societies that have laid the greatest stress on communal forms of physical activity have also seen the greatest successes in the language, cognitive, and social development of their children (e.g., Sweden and Cuba are two outstanding examples of this point: see Lagerberg, 2005).

In Pursuit of a Normative Model of Healthy Development

None of the capacities outlined above is a zero-sum phenomenon, i.e., a matter of a child either having or not having such-and-such a skill. Rather, a child's capacities vary in all sorts of subtle ways—both within and across domains and according to different situations. Moreover, the child's capacities vary according to both endogenous and exogenous factors: for example, how the child is feeling; how well she has slept; whether she has had a nutritious breakfast; the nature of the classroom environment; how warm and nurturing the teacher is; and so on.

For us, one of the most important points is simply that the development of these abilities is not a maturational phenomenon, even though, to be sure, genetic and biological factors play an enormously important role. But we have learned from cases of extreme neglect that if a child is deprived of warm, nurturing experiences in the early years of life this can have a devastating effect on the development of these core capacities (Greenspan & Shanker, 2004). Furthermore, recent experiments with rats and monkeys illustrate that early nurturing and stimulation influence the expression of genes and can even modify genetic codes that are passed along to the next generation (Roma et al., 2006).

Nor does one want to say that there is some single or genetically-controlled pathway to healthy mental functioning. Children vary in myriad ways in terms of their sensory and regulatory proclivities, or their individual strengths and weaknesses in processing different kinds of

information. Hence even if we can identify milestones of healthy mental functioning in a 5-year-old, children may arrive at this state by a unique and highly idiosyncratic manner, where the experiences that they undergo play a pivotal role in the development of their cognitive, communicative, social, and emotional abilities.

This last point has profound implications for our efforts to develop a normative model of healthy development. It means that we must not assume that there is a unilinear causal relationship between a psychological/neurobiological state observed at, say, 18 months or in a 3-year-old, and the capacities that the child demonstrates at 5 years of age, for the abilities of the 5-year-old are downstream effects of her intervening experiences. To be sure, certain biological factors may strongly influence the kinds of experiences that the child undergoes; but by no means is this trajectory inalterably fixed in advance. Indeed, the whole point of trying to detect biological, social, and/or environmental factors that might compromise healthy functioning as early as possible is to design treatment methods that restore a child to a healthy developmental trajectory.

And that raises a crucial question in its own right—namely, how exactly can we conceptualize the relationship between the development of the mind and the development of the brain so that we avoid falling back into all the old patterns of thinking about the interaction between nature and nurture? We know that neurobiological processes and structures strongly influence our mental development (Tucker, 2007; Kagan & Herschkowitz, 2005). But we also know that a child's growing levels of consciousness cannot be explained by neurophysiological processes alone, or as the result of a genetic blueprint; for in a fundamental sense, the development of the child's mind is heavily influenced by her social-emotional interactions (Greenspan & Shanker, in press).

One of the most important theoretical questions that drive our research at MEHRI, therefore, is how these social-emotional interactions that develop the mind thereby affect the development of the brain, which is forced to meet the demands of increasingly complex social-emotional relations. After all, we may be the species with the most developed prefrontal cortex, but what make us human are the experiences that promote the growth and functioning of this prefrontal cortex.

Developmental Pathways

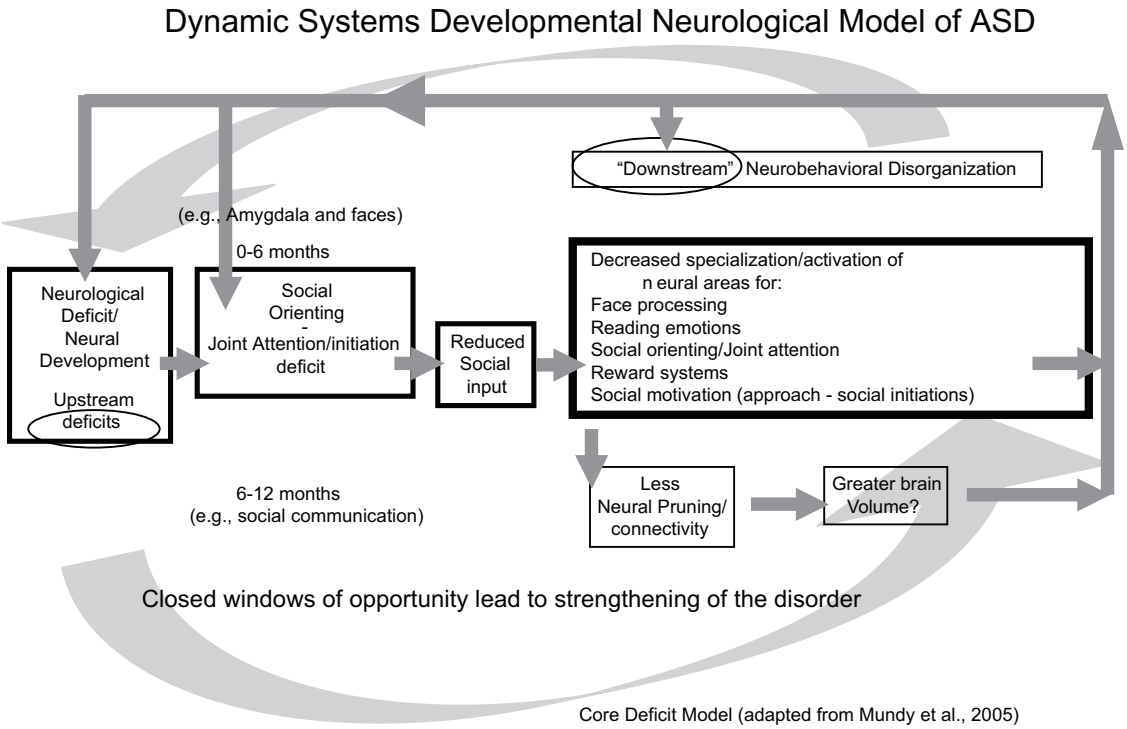
As has been stressed throughout this article, MEHRI has been designed in such a way as to study the pathways that lead to mental health at both the psychological and the neurobiological level. The purpose here is not to look for correlations between these two levels but rather, interactions between them. In recent years developmental neuroscientists have been exploring the notion of "cascading constraints" as a means of understanding this interaction. The idea here is that some biological event during a sensitive period modifies brain circuits in fundamental ways, causing neural pathways to become highly stable and thereafter difficult to change. These changes in the cortex and subcortex are said to involve a loss of "developmental freedom," and in that sense, "constrain" the scope of future developmental possibilities (Lewis, 2005; Knudsen, 2004).

Following a study by MEHRI's Director of Neuroscience, however, which showed that an intensive therapy program on aggressive 8–12 year-olds produced striking neurological changes in a significant number of the subjects (Stieben et al., 2007), we have become very mindful that to speak of "cascading constraints" is not at all the same thing as to speak of "cascading closures." Granted, the more entrenched a neural pattern becomes, the more effort required to promote a neural reorganization. Yet, every day we are learning more about the ongoing plasticity of the brain and the kinds of experiences that can tap into this potential (see Doidge, 2006).

It is for this reason that we were drawn to Peter Mundy's neurodevelopmental pathways model (Mundy & Burnette, 2005). As noted earlier, the basic principle of this model is that an initial biological event can have a powerful effect on the kinds of social experiences that a child is receptive to or seeks out, which may further reduce the input to certain neural systems whose development hinges on these social experiences. That does not mean that it is impossible for the child to engage in the sorts of experiences that provide these neural systems with the needed input.

To take a case in point, and something that we study closely at MEHRI, there is a part of the brain, the fusiform gyrus, which is critically involved in our ability to read facial expressions of emotion. Not surprisingly, when imaging studies were conducted on adult subjects with autism, it was discovered that there was a striking lack of activity in this part of the brain. This led researchers to question whether autism was somehow the result of a genetic malfunction in the fusiform gyrus or some lower system feeding into the fusiform gyrus (Baron-Cohen, 1995). A dramatic discovery by Morton Gernsbacher and her colleagues at the University of Minnesota revealed a more complex developmental picture (Gernsbacher et al., 2003).

Adults with autism were shown photographs of actors displaying happiness, anger, or fear. Half of the photographs had the agent's eyes looking straight ahead and half had their eyes averted. There was indeed a significant



diminishment in the activation of their right fusiform gyrus, along with a significant increase in the activation of centers involved in conflict monitoring and the detection of threat, when these subjects viewed the eyes-straight-ahead photographs. But there was no comparable effect when the subjects viewed the photographs in which the actors' eyes were averted. Thus, the Gernsbacher study suggests that subjects with autism avert their gaze in order to reduce the stress that is created in direct social encounters. That is, the explanation for this behavior would appear to lie in sensory over-reactivity to social/visual stimuli, not in a genetic malfunction of a dedicated face-processing system.

The upshot of this way of thinking, then, is that an initial neurological deficit constrains the child's dyadic interactions, which results in reduced social input and thence decreased activation of specialized systems for functions like face processing, reading emotions, social orienting, and social motivation, which in turn constrains the child's capacity to engage in these very social interactions and has other measurable effects on brain development.[2] We have shown elsewhere (Greenspan & Shanker, 2004) how these dyadic interactions are critical for the development of the neurobiological systems that underpin a child's social, emotional, cognitive, and communicative development. A neurobiological deficit at birth or in the early years that obstructs these interactive experiences can result in a reduction of the input on which the development of these systems depends. If these neural systems are deprived of the input needed for their development, this can further impinge on the child's willingness or ability to engage in the necessary social experiences, resulting in a further constriction in the network of capacities necessary for healthy development (Segalowitz & Schmidt, 2007).

Understanding the Causes of ADHD and Autism

Recent advances in the study of ADHD and Autism Spectrum Disorders (ASD) provide vivid examples of the promise that the developmental pathways approach holds out for the early identification and mitigation of these disorders. It is important to begin any such discussion with a note of caution, however, given that we are dealing with spectrum disorders that range from the moderate to the severe and can have quite different symptomologies. This heterogeneity not only makes it difficult to conduct accurate prevalence studies, but further complicates any attempt to develop a unitary causal model of the disorder. Furthermore, there is always the concern that we might be "over-pathologizing" some cases, i.e., treating as a

2. Adapting the model from Mundy & Burnette (2005), Jim Stieben, Director of Neuroscience at MEHRI, has developed the above flow chart to depict this model.

medical condition what might, in some instances, be a fairly common behavior that only becomes problematic because of current social conditions or demands. This is a particularly worrying issue with children diagnosed as having ADHD when their restlessness may in large part be due to a lack of physical activity and the strain of sitting for too long in a classroom (see Louv, 2005).

When one speaks about the causes of ADHD or autism, therefore, one may only be referring to a subset of the large number of children diagnosed with these disorders (currently estimated to be between 7–12% in the case of ADHD and .66%–1% for autism). Children who are prone to risk taking and impulsivity tend to be underreactive to sensations of touch and sound and thus crave a lot of sensations in order to obtain more feeling tone in their bodies. These children often have problems with motor planning and sequencing. That is, they can't sequence many actions in a row and they might have a hard time sequencing their thoughts.

Sagvolden has recently postulated that a shortage of dopamine—a neurohormone that supports the ability to wait for a reward—might also be a critical factor in the development of ADHD (Sagvolden, Johansen, Aase, & Russell, 2005). Sagvolden's model has stimulated considerable interest in the question whether, if a child is born with a short version of the genes involved in the production of dopamine, there is a heightened risk that these might be turned off (e.g., by heightened stress), with the result that the child has a shortage of dopamine and thus experiences delay as aversive (see Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2007). Such a child would then be prone to engage in behaviors that favor immediate reward, leading ultimately to the symptoms that characterize ADHD.

As Sagvolden himself stresses, the challenge that we face here from a dynamic systems perspective is that we do not allow this hypothesis to relapse into a mode of linear causal thinking. What Sagvolden's "hypo-dopamine" hypothesis draws attention to is how an early biological factor can have an enormous impact on child-caregiver interactions. If no effort is made to lengthen the timeframe in which a reward must be delivered in order for it to be associated with a behavior, or to help the child deal with distractions, or to help the child develop the capacity to self-organize and see a task through to completion, then the child's craving for instant gratification could well result in a lack of input to the parts of the brain regulating attentional control. This outcome might be especially true in the case of a highly anxious caregiver who perhaps himself suffers from a shortage of dopamine and thus responds to his child's delay aversion by constantly catering to the child's need for rapid gratification, thereby exacerbating the under-development of the parts of the brain that help regulate the time window in which a behavior can be associated with a reward.

A comparable scenario applies to autism. A child who, for example, is hypersensitive to visual and auditory stimuli may find dyadic interactions highly stressful, even aversive, and withdraw into himself in order to avoid the very interactions that are so critical for the development of his so-called social brain. For example, as indicated earlier, the child may gaze-avert to reduce the stress of social encounters, thereby depriving circuits that comprise the social brain of the input they need to function automatically, beneath the threshold of conscious reflection (Ledoux, 1996). A child may also perseverate on an action, or engage in self-stimulatory behaviors in an attempt to reduce his anxiety. Such children are not born with autism, therefore, but one can certainly see how a serious biological deficit can significantly constrain the child's social experiences and thereby lead to a reduced input of the information that is necessary for activation of the neural areas involved in face processing, reading emotions, social orienting, and social motivation.

The fact that a pronounced dopamine deficit or problems in sensory regulation can have a profound effect on the child's interactive experiences hardly entails, however, that a biological event early in life sets the child on an unalterable developmental trajectory. The important point here is that these biological conditions impinge on, but they do not prohibit, the sorts of social interactions that are so critical for the development of the mind and of the brain, as we are learning from recent advances in the treatment of developmental disorders. For example, Adele Diamond reported in *Science* (Diamond, 2007) that a preschool program that uses dramatic play, visual aids, and peer interaction during reading and math instruction to teach children with ADHD important cognitive and social-emotional skills had a powerful effect on enhancing their ability to screen out distractions, to resist responding impulsively to a question, and to think creatively and reflectively (Diamond, Barnett, Thomas, & Munro, 2007; see also Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; Kerns, Esso, & Thompson, 1999). Similarly, the therapists working with young children with autism at MEHRI are exploring whether, through heightened affect, and working within the child's zone of proximal development, it is possible to woo a child who finds social interaction stressful into engaging in these interactions, with the result that the systems comprising the social brain begin to acquire their necessary inputs and the child attends to the world around them.

Furthermore, it turns out that affect plays a critical intermediary role between these different levels. At any

given point of development, the child's brain may *constrain* what is possible in her zone of proximal development, but it is the child's motivation, interest, curiosity, pleasure, etc. that enable her to exert the effort required for that next step in development, which in turn forces her brain to develop the new connections needed for the task at hand. The hope here is that even a child who starts out life with a severe biological impairment can, if wooed into the experiences necessary for the growth of the mind, begin to attend to her caregiver and the world, regulate her own emotions and arousal state, form warm affective relationships, engage in back-and-forth interactions and social problem-solving, master symbols and words, and begin to think logically (i.e., go through the stages of healthy mental development that are needed to provide the various parts of the brain involved in these tasks with the input that lays down the connections that will open up her universe of future developmental possibilities).

A further note of caution follows from all this. It has become commonplace for epidemiologists who are interested in the effects of epigenetic events on a child's developmental trajectory to speak about a child being "at greater risk" for such-and-such an outcome should such-and-such a gene be turned off or on. The reason for this cautious language is that these studies are performed on large populations in which one is looking for correlations between a biological marker and a mental or physical health outcome. But for a developmental scientist, the devil lies in the details: not in an intervening variable, but in the child's intervening life experiences.

An important example of this point can be found in a ground-breaking study by Avshalom Caspi, who discovered a significant correlation in the Dunedin birth cohort[3] between the short gene for serotonin production and an increased risk of adult depression (Caspi et al., 2003). But as Caspi and his colleagues were careful to warn, we cannot jump from this discovery to the conclusion that there is a linear relationship between this early genetic event and the adult's mental health; for one thing, the child's nurturing experiences clearly have a critical role on his resilience and his later susceptibility to depression.

What we need to understand, then, is the relationship between early biological states and how they may influence or constrain the kinds of social experiences that the child undergoes. Herein lies the basic point that tends to get lost in all the talk about how a child with such-and-such a short allele is at greater risk for such-and-such an outcome; for what this qualifier really means is that between an epigenetic event and a downstream outcome are countless interactions that enhance or inhibit the development of those neural systems that, in adults suffering from some disorder, are seen to be under-developed or hypo-functioning.

The Implications of the Developmental Pathways Model for Evolutionary Psychology

Despite our promise to avoid straying too far down the path of philosophical controversy, there was one temptation that proved too strong to resist: the debate over the modularity view that "the evolved structure of the human mind is adapted to the way of life of Pleistocene hunter-gatherers" (Barkow, Cosmides, & Tooby, 1992). The discovery of structural/ functional regularities in the brains of subjects with developmental disorders seemed, at first, to provide compelling evidence for the idea that dedicated modules were selected at the dawn of our evolutionary history to perform quite specific cognitive, communicative, and social tasks (Pinker, 1994). But invariably such imaging studies were performed on adult subjects with the disorder, raising the question of whether the regularity observed was the *effect* of the social interactions that the child has experienced or the *cause*.

For example, as Joel Nigg points out in his recent survey of *What Causes ADHD* (Nigg, 2006), our understanding of the neural systems implicated in ADHD is entirely derived from imaging performed on adult subjects. There are clearly regularities in the systems affected in adults with ADHD, although these can be extremely complex and subtle. But these regularities must be viewed in developmental time, and not as somehow static phenomena.

Furthermore, developmental neuroscientists have begun to document how different kinds of cells in different neural systems seem to be better suited for specific kinds of tasks (see Mareschal et al., 2007). So, for example, to return to the case that we have touched on here, it would seem that the cells in the fusiform gyrus are particularly well-suited for the kind of rapid processing involved in analyzing facial expressions (see Karmiloff-Smith, 1998). Hence what we really seem to be confronted with here is not the result of predetermined processing modules but rather, what Karmiloff-Smith refers to as the "progressive modularization of face processing in typically developing infants over developmental time" (Karmiloff-Smith et al., 2004).

Indeed, Karmiloff-Smith has produced compelling evidence to show that what we see in developmental dis-

3. The Dunedin Longitudinal Study began with a study of 1037 people born in Dunedin New Zealand between 1972 and 1973. Some of the major findings from this ongoing study were published in *From Child to Adult: Dunedin Multidisciplinary Health and Development Study* (1996).

orders is the exact opposite from what evolutionary psychologists proposed: namely, a *lack* of modularization, of the increasing segregation and specialization of neural systems that is seen in typically developing infants. Rather, what we see in children with developmental disorders is less synaptic pruning in the first year of life and, as a result, more cortical interconnection: i.e., more widespread cortical activity in performing tasks which, in typically developing children, are increasingly performed by a specific neural system (Karmiloff-Smith, in press). The deeper implication of this point is that the differentiation of cortical systems is bound up with very specific types of interactive affective experiences that involve the successive transformations of emotional experience and that are the product of cultural practices as well as our biology (see Greenspan & Shanker, 2004).

MEHRI's Platonic Mission

We have touched on Plato's influence on the mind/body and nature/nurture debates in Western thought here, not simply to illustrate how ancient these questions are, but to raise what is perhaps the most important goal of MEHRI. For Plato did not view these problems as simply a philosophical exercise, in the way, say, that Milton mocks when he describes, at the beginning of Book II of *Paradise Lost*, how a group of devils

> . . . sat on a Hill retir'd,
> In thoughts more elevate, and reason'd high
> Of Providence, Foreknowledge, Will, and Fate,
> Fixt Fate, free will, foreknowledge absolute,
> And found no end, in wandring mazes lost.
> Of good and evil much they argu'd then,
> Of happiness and final misery,
> Passion and Apathie, and glory and shame,
> Vain wisdom all, and false Philosophie:
> Yet with a pleasing sorcerie could charm
> Pain for a while or anguish, and excite
> Fallacious hope, or arm th' obdured brest
> With stubborn patience as with triple steel.

What drove Plato was the burning question (as Milton would put it!) of how one creates a healthy/just society, which, for Plato, amounted to one and the same thing.

Throughout his writings, we find Plato attacking the Hippocratic tradition for what he saw as the logical fallacy of seeking to reduce psychological concepts to biological processes. The reason Plato was so concerned with this logical argument was because the reductionist view of the mind does not explain *why* an individual suffers from some disorder. Plato clearly accepted the significance of innate biological factors, but that, he argued, creates all the more reason to study how such biological factors influence the kinds of experiences that a child seeks out, which are what mold his character. Plato's ultimate goal was to understand how a temperament that might lead a child along an unhealthy path could be nurtured so as to enable the individual to attain mental health. Over and over he returns to the theme of how the course of one's life is not set in stone at one's birth. Rather, we have to study how we can maximize the development of the individual, whatever his biological starting point.

It would be fascinating at this point to digress into a discussion of Plato's view of the role that the properly trained philosopher-physician has to play in this process, alongside the medical doctor; for only the philosopher, he felt, can bring an individual to *want* to adopt those actions that are necessary to achieve that state of balance without which true health is impossible and medicine ineffective (Cooper & Hutchinson, 1977). The history of the field over the past two millennia might suggest that it was Milton who had the more astute perception of the philosopher's capacity to enhance a nation's mental health. But there are larger themes in Plato's writings on this issue that demand our attention: the emphasis that he placed on application as the driving impetus of theory; his perception of the early social determinants of mental/physical health; the analogy that he drew between the health of the individual and the health of a society, and accordingly, on universality (although, to be sure, his views of social inclusion are rather disturbing).

The point is that it is one thing to demonstrate what might be possible in the scientific understanding of the pathways that lead to a child's mental health, but quite another to ensure that every single child receives the benefits of these scientific breakthroughs. Ultimately MEHRI was established to serve as a social as much as a scientific catalyst—to understand what is becoming possible in the early detection and mitigation of developmental, psychological, and behavioral problems in order to fuel the political will needed to ensure that every child benefits from these advances. All of the themes that we have touched on here attest to the enormity of this challenge in a world in which family dynamics are rapidly changing, resulting in a broad new range of social, psychological, and biological stresses (Baker, Gruber, & Milligan, 2005). The better we can understand the types of family experiences and community processes that promote the healthy development of a child's mind and brain, the more motivated we must become to ensure that every child receives those experiences.

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