Altered brain development following global neglect in early childhood

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www.ChildTrauma.org

*This is an Academy version of a paper presented at Society for Neuroscience Annual Meeting, New Orleans, 1997

Official citation: Perry, BD and Pollard, D. *Altered brain development following global neglect in early childhood.* Society For Neuroscience: Proceedings from Annual Meeting,New Orleans, 1997

Introduction

Each year in the United States alone, over 500,000 children suffer from some version of "neglect." Neglected children brought to the attention of the Child Protective Services has a much higher probability of emotional, behavioral, cognitive, social and physical delays and dysfunction than "comparison" children. It is becoming increasingly clear that the nature, timing and extent of neglect in childhood are critical in determining the nature and extent of these deficits (Perry et al., 199 5; Courchesne et al., 1994).

This observation may seem somewhat obvious to individuals familiar with the principles of neurodevelopment and the animal studies documenting the critical role of sensory stimulation in organizing the developing central nervous system. Indeed, use (or activity) dependent development and modification of neural systems is one of the core principles of neurodevelopment (see Singer, 1995). In animals raised in sensory depriving situations, a host of abnormalities in neurochemical and neuroarchitectural organization have been documented (e.g., Darwin, 1868; Ebinger, 1974; Cragg, 1975). The functional consequences of sensory deprivation during neurodevelopment can be significant. Indeed , in some severe deprivation situations, sensory deprivation or sensory disorganization during critical or sensitive periods can result in permanent dysfunction (e.g., Spitz & Wolf, 1946; Perry, 1997). This has ominous implications for human development.

While many studies have described various functional consequences following neglect in childhood, few have examined aspects of neurodevelopment in neglected children. The present study reports a preliminary examination of measures of brain growth in a large group of neglected children.

Method

Children (ages 0 to 17) were referred to our specialty clinic for evaluation by Child Protective Service or other agencies working with children following abuse or neglect. Comprehensive physical, developmental and neuropsychiatric evaluations were conducted to assist in placement and treatment planning. As part of this evaluation, comprehensive pre- and perinatal history were obtained, as were various measures of growth (height, weight and frontal-occipital circumference: FOC).

Charts were reviewed for evidence of pre-natal drug exposure (PND) and neglect. Neglect was considered global neglect when a history of relative sensory deprivation in more than one domain was obtained (e.g., minimal exposure to language, touch and social interactions). Chaotic neglect is far more common and was considered present if history was obtained that was consistent with physical, emotional, social or cognitive neglect. When possible history was obtained from multiple sources (e.g., investigating CPS workers, family, police).

Based upon these reviews, the neglected children (n= 122) were divided into four groups: Global Neglect (GN; n=40); Global Neglect with Prenatal Drug Ex posure (GN+PND; n=18); Chaotic Neglect (CN; n=36); Chaotic Neglect with Prenatal Drug Exposure (CN+PND; n=28). Measures of growth were compared across group and compared to standard norms developed and used in all major pediatric settings.

In cases where neuroimaging studies had been conducted as part of a medical or neurological evaluation, these images were examined in a retrospective fashion. Neuroradiologists had read the scans in context of the original medical or neurological referral and, typically, were unaware of the neglect or psychosocial situation of the child.

Results

Growth

Dramatic differences from the norm were observed in FOC (suggesting de creased brain growth) for the globally neglected children (see Figures). This group 6;s mean FOC was only in the 10^{th} percentile, while height and weight measures of growth demonstrated less difference ($30\text{-}40^{th}$ percentile). In contrast , the chaotically-neglected children did not demonstrate this marked group difference in FOC.

Pre-natal drug exposure appeared to have an interactive, but complex effect on growth. In the global neglect population, it appeared to exacerbate the observed growth differences. In the chaotic neglect group, however, no differences in growth were observed.

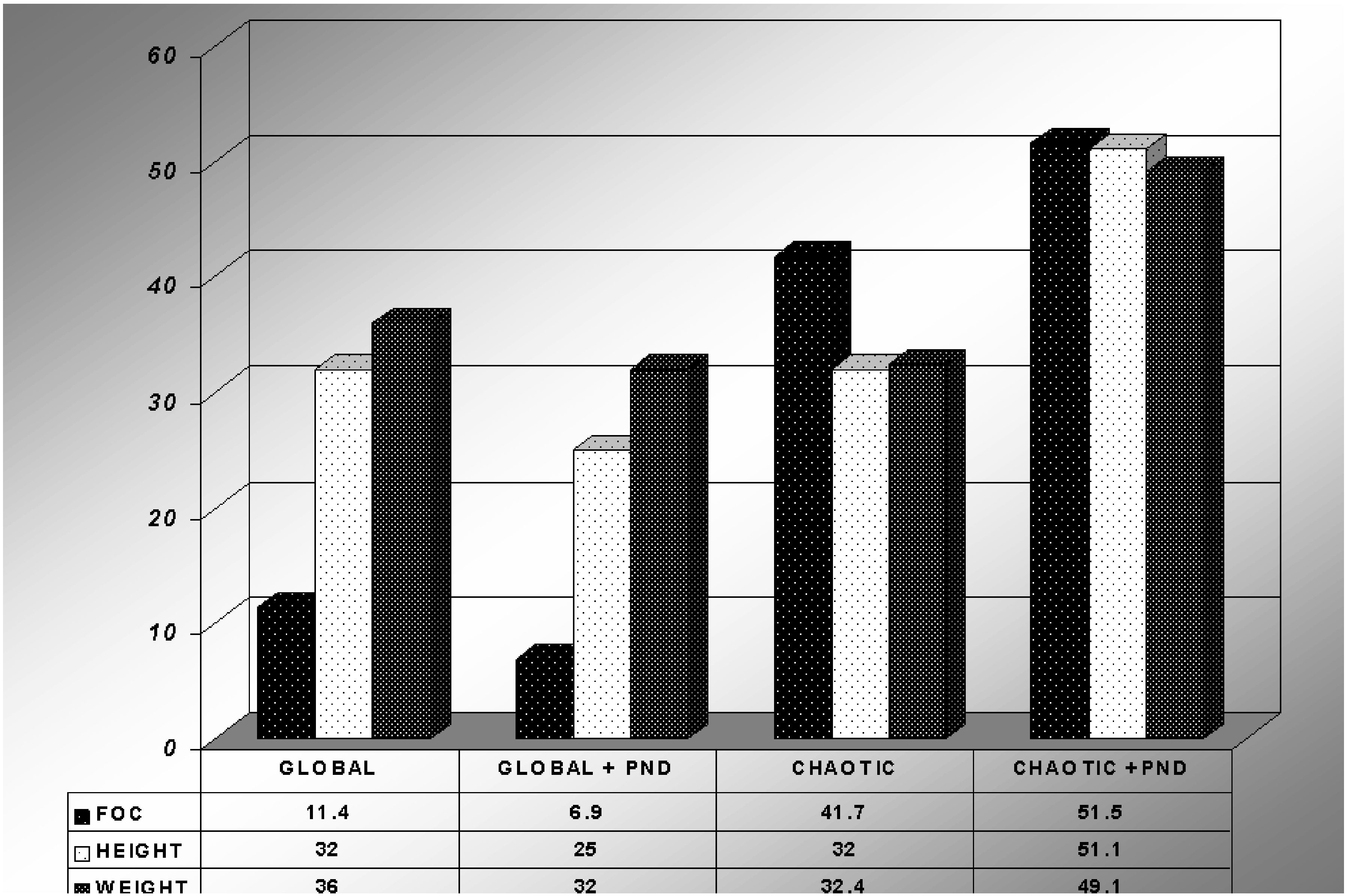
Neuroimaging

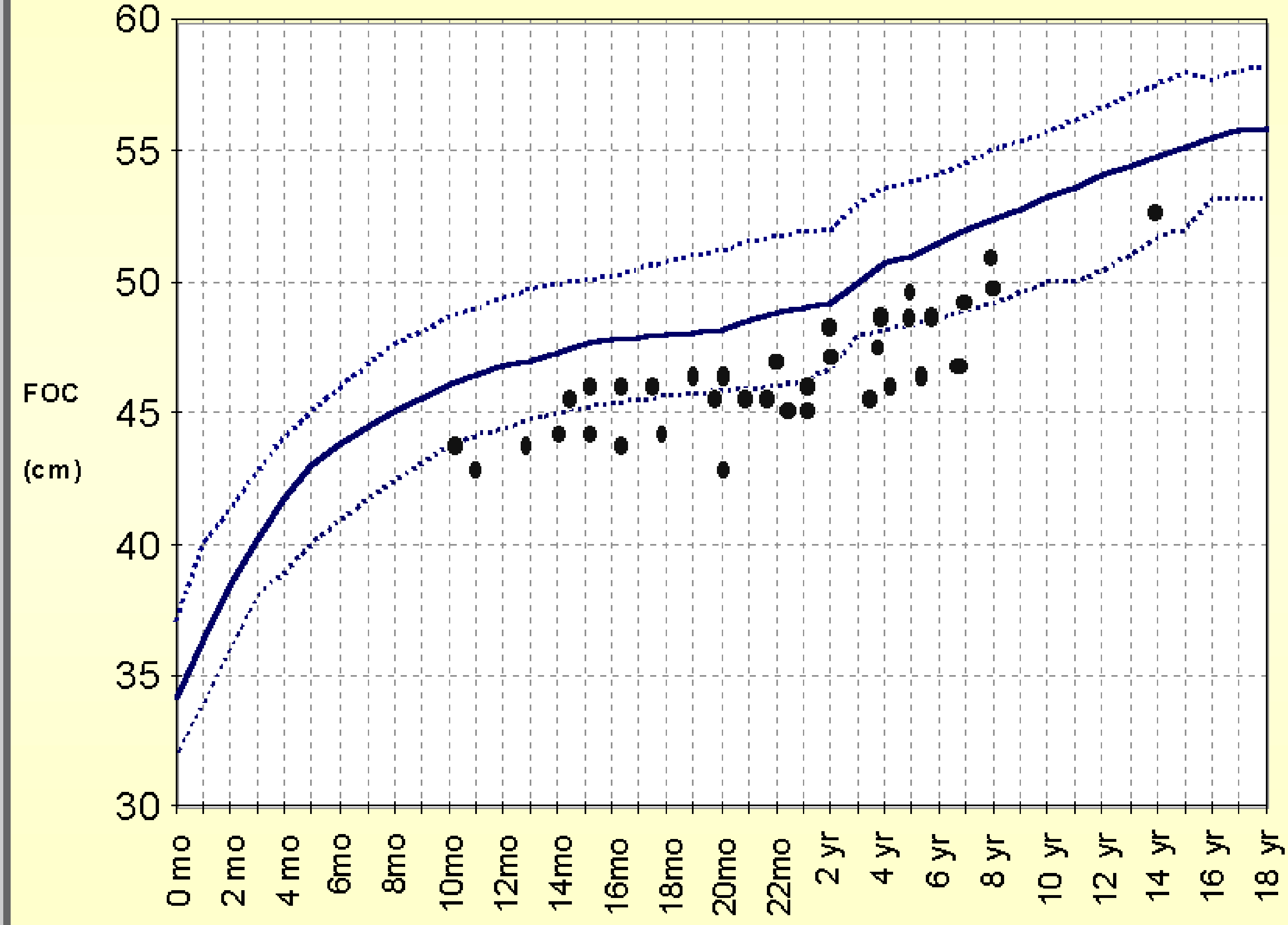
Neuroradiologists interpreted 3 of 26 scans abnormal from the children with chaotic neglect (11.5 %) and in 11 of 17 of the children with global neglect (64. 7 %). The majority of the readings were "enlarged ventricles" or "cortical atrophy." Few focal abnormalities were noted.

Normal vs. Abnormal CT or MRI Scans in Neglected Children

	Normal	**Abnormal**
Chaotic Neglect	18	1
Chaotic Neglect + PND	5	2

Global Neglect	3	8
Global Neglect + PND	3	3




60
55
50
45
40
35
30
FOC
(cm)
0 mo
2 mo
4 mo
6mo
8mo
10mo
12mo
14mo
16mo
18mo
20mo
22mo
2 yr
4 yr
6 yr
8 yr
10 yr
12 yr
14 yr
16 yr
18 yr

Discussion

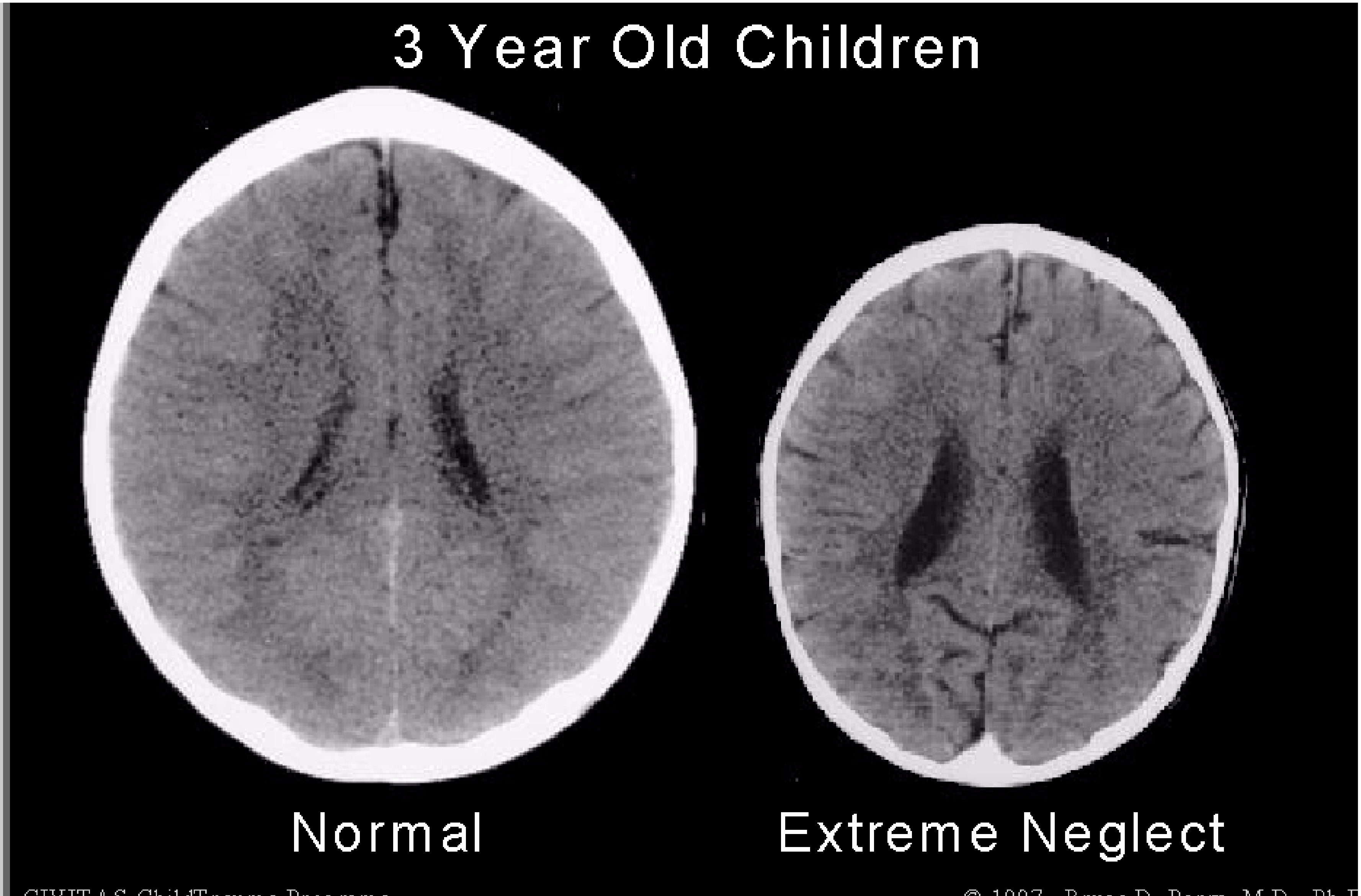
These findings strongly suggest that when early life neglect is characterized by decreased sensory input (e.g., relative poverty of words, touch and socia l interactions) it will have a similar effect on humans as it does in other mammalian species. Sensory deprivation has been demonstrated to alter the physical growth and organization of the brain in animals.

The present studies suggest that the same is true for children globally neglected in the first three years of life. It is important to emphasize the timing of the neglect. The brain is undergoing explosive growth in the first years of life, and, thereby, is relatively more vulnerable to lack of organizing experiences during these periods. These unfortunate globally neglected children (some literally were raised in cages in dark rooms for the first years of their lives) appear to have altered brain growth.

There are likely many factors contributing to this observation. Nutrition is one key aspect. Based upon the relative impact on the brain as opposed to other growth, a total nutritional explanation is inadequate. It is likely that the actual lack of experiences (sound, smell, touch) associated with global neglect in these children plays a major role.

While the actual size of the brain in chaotically neglected children did not appear to be different from norms, it is reasonable to hypothesize that organizational abnormalities exist.

Volumetric studies of key areas are indicated, as are MRI studies to examine the functional impact of neglect; global or chaotic.



These images illustrate the negative impact of neglect on the developing brain. In the CT scan on the left is an image from a healthy three year old with an average head size. The image on the right is from a three year old child suffering from severe sensory-deprivation neglect. This child's brain is significantly smaller than average and has abnormal development of cortex.

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ARTICLE

Infant Growth and Development

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IMPORTANT POINTS

1. **Infant development occurs in an orderly and predictable manner that is determined intrinsically. It proceeds from cephalic to caudal and proximal to distal as well as from generalized reactions to stimuli to specific, goal-directed reactions that become increasingly precise. Extrinsic forces can modulate the velocity and quality of developmental progress.**
2. **Each developmental domain must be assessed during ongoing developmental surveillance within the context of health supervision. Generalizations about development cannot be based on the assessment of skills in a single developmental domain (ie, one cannot describe infant cognition based on gross motor milestones). However, skills in one developmental domain do influence the acquisition and assessment of skills in other domains.**
3. **Speech delays are the most common developmental concern seen by the general pediatrician, yet they often are not well understood or diagnosed expediently. A sound understanding of the distinction between an isolated speech delay (usually environmental and often can be alleviated) and a true language delay (a combined expressive and receptive problem that implies more significant pathology) will help the clinician refer appropriately for precise diagnosis and appropriate management.**
4. **It is essential to understand normal development and acceptable variations in normal developmental patterns to recognize early patterns that are pathologic and that may indicate a possible developmental disability.**
5. **Assessment of the quality of skills and monitoring the attainment of developmental milestones are essential to early diagnosis of developmental disabilities and expedient referral to early intervention programs.**

Introduction

"Infant" is derived from the Latin word, "*infans*," meaning "unable to speak." Thus, many define infancy as the period from birth to approximately 2 years of age, when language begins to flourish. It is an exciting period of "firsts"—first smile, first successful grasp, first evidence of separation anxiety, first word, first step, first sentence. The infant is a dynamic, ever-changing being who undergoes an orderly and predictable sequence of neurodevelopmental and physical growth. This sequence is influenced continuously by intrinsic and extrinsic forces that produce individual variation and make each infant's developmental path unique. Intrinsic influences include the child's physical characteristics, state of wellness or illness, temperament, and other genetically determined attributes. Extrinsic influences during infancy originate primarily from the family: the personalities and style of caregiving by parents and siblings, the family's economic status with its impact on resources of time and money, and the cultural milieu into which the infant is born.

Neurodevelopmental sequences can be viewed broadly in terms of the traditional developmental milestones. Developmental milestones provide a systematic approach by which to observe the progress of the infant over time. Attainment of a particular skill builds on the achievement of earlier skills; only rarely are skills skipped. When this happens, the advanced skill may represent a "splinter" skill, that is, a deviant developmental pattern. For example, five-word sentences in a 2-year-old child who does not follow simple commands may represent echolalia typical of autism. The sentences are not meaningful and have no communicative intent. Delays in one developmental domain may impair development in another domain. For example, immobility due to neuromuscular disorders prevents exploration of the environment and, in turn, impedes cognitive development arising through manipulation of objects. Last, a deficit in one domain may compromise the assessment of skill levels in another domain, even though development in the second domain is normal. For example, it is difficult to assess problem-solving skills in a child who has cerebral palsy because the child may understand the concept of matching geometric forms, yet be unable to insert them physically into a formboard.

Developmental milestones serve as the basis of most standardized assessment and screening tools. Although these screening tools provide the clinician with a structured method of observing the infant's progress and help define a developmental delay, many lack sensitivity. Parental concern in the face of normal results in developmental screening should not be disregarded. Focusing narrowly on discrete milestones may fail to reveal atypical organizational processes that are involved in the child's developmental progress. Thus, it is important to analyze all milestones within the context of the child's history, growth, and physical examination as part of an ongoing surveillance program. Only then is it possible to formulate an overall impression of the child's true developmental status and the need for intervention.

Although milestones form the foundation of the discussion, the primary intent of this article is to provide broader insights into infant developmental processes and to help the clinician recognize warning behaviors ("red flags") indicative

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of developmental deficits. The milestone ages are not repeated in the text to allow a more fluid discussion of developmental themes within each domain. Milestones have been organized into domains to assist the clinician in recognizing their independence as well as their interrelationships. Tables illustrating all domains at each age can be found in Vaughan (see Suggested Reading). Problem-solving and language milestones facilitate early identification of cognitive deficits. Adaptive skills (ie, skills related to independence in feeding, dressing, toileting) traditionally have been included within the fine motor domain. However, because these milestones are influenced by the social environment, we have included them in a "psychosocial domain." Lists for emotional and socialization milestones also are included in this domain. In contrast to motor and cognitive milestones, psychosocial behaviors are influenced more by extrinsic factors, making them less well-defined.

Evolution of Developmental Theory

Developmental theory has been shaped by the persistent debate of whether nature (intrinsic forces) or nurture (extrinsic forces) is the predominant influence. At the turn of the century, developmental theories promoted nature as the major influence. Gesell (early 1900s) was one of the first to study infant development systematically and establish developmental norms. Development was seen as a function of neurologic maturation and growth. Because advancing age and genetic endowment were the chief mechanisms for change, babies were believed to develop at a predetermined biological pace, with parents needing to do little more than provide a good nurturing environment.

By mid-century, theories that stressed the importance of nurture began to prevail. Pavlov (1930s), Watson (1950s), and Skinner (1960s) promoted the opposing view that development was a function of learning. Operant conditioning (positive and negative reinforcements through social interactions or environmental changes) promoted learning and shaped the child's development. This line of thinking formed the philosophical basis for the Head Start program of the 1960s. Freud (1920s) and Erikson (1950s) promoted developmental progress as a function of the resolution of conflict. The quality of the infant's relationships with key individuals was considered central to future development.

During the second half of the century, the name of Piaget became almost synonymous with child development. Piaget was the first to describe the infant as having intelligence. For centuries, it had been assumed that the infant's mind was a "blank tablet waiting to be written on." Because infants could not tell us what they were experiencing, it was believed that they saw and heard little and thought even less, with consciousness as adults knew it not existing. Piaget revealed that infants were, indeed, capable of thinking, analyzing, and assimilating. He viewed development as stage-like cognitive changes. The child actively explores objects in an effort to understand his or her environment. Depending on the developmental stage, a child organizes this information to form new theories about the way the world works.

It was not until the last part of this century that emotional and social development began to receive the same degree of attention as that given to the motor and cognitive domains. Research has revolved around theories regarding infant expression of emotion (Mandler, 1970s), attachment (Bowlby, 1960s; Mahler, 1970s; and Ainsworth, 1980s), and temperament (Thomas and Chess, 1970s). Once it was recognized that newborns could demonstrate distress (pain and hunger), interest, and disgust, these facial expressions have been used to study information processing in infancy prior to the age when thoughts can be verbalized. As the 20th century comes to a close, remarkable advances in behavioral genetics, together with recent discoveries regarding innate infant abilities, have swung the pendulum back in favor of nature as the primary influence on the developmental process.

One principle of development in infancy is that it proceeds from head-to-toe—thus, arm movement comes before leg movement.

Developmental Snapshots: The First Two Years of Life

Before dissecting infant development into discrete steps within each developmental domain, it is valuable to view the infant at discrete intervals. These 6-month "snapshots" are displayed graphically in Figure 1. This gestalt approach may help the clinician make sense of the interrelatedness of the precise changes within each developmental domain.

These four snapshots illustrate several generalizations about neuro-developmental maturation over time:

1. Responses to stimuli proceed from generalized reflexes involving the entire body, as seen in the newborn (and fetus), to discrete voluntary actions that are under cortical direction. This specialization allows the child to move from obligatory symmetric reactions when attending to a stimulus (ie, vocalizations, arm waving, and kicking) to voluntary, asymmetric, and precise movements toward a stimulus (ie, grasping with one hand and inspecting with the other).
2. Development proceeds from cephalic to caudal and proximal to distal. Thus, arm movement comes under cortical direction and visual guidance before leg movement. With this, the child progresses from hand-mouth to foot-mouth play. The upper extremities become increasingly accurate in reaching, grasping, transferring, and manipulating. Distal development is seen when the infant can isolate and use the

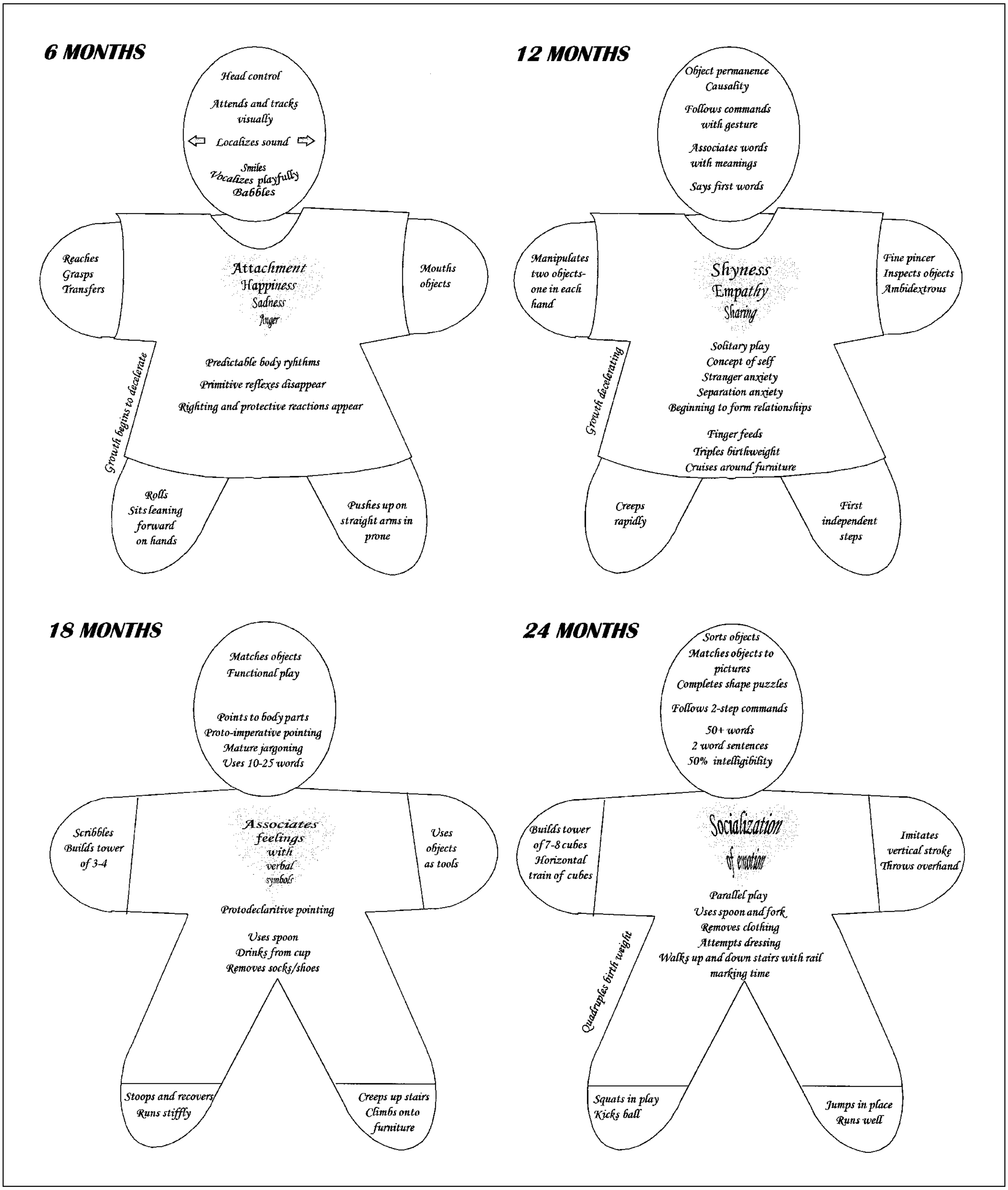


FIGURE 1. Developmental "snapshots" at 6, 12, 18, and 24 months.

index finger to poke and explore object parts. When this occurs in concert with thumb opposition, the fine pincer grasp is mastered. Precise release of tiny objects follows, so that fundamental manipulative skills reach adult levels by the end of infancy.

3. Developmental progression is from dependence to independence. The totally dependent newborn progresses to a toddler who has mobility and manipulative skills that enable him or her to explore most of the environment. Toddlers can move about the house independently, opening doors, maneuvering stairs, and fetching desired objects. They can feed and undress themselves and even may be toilet trained. This new autonomy becomes the foundation for the challenging "twos."

TABLE 1. Average Physical Growth Parameters

AGE	OCCIPITOFRONTAL CIRCUMFERENCE	HEIGHT	WEIGHT	DENTITION
Birth	35.0 cm (13.8 in)	50.8 cm (20.0 in)	3.0 to 3.5 kg (6.6 to 7.7 lb)	Central incisors—6 mo Lateral incisors—8 mo
	+2 cm/mo (0 to 3 mo) +1 cm/mo (3 to 6 mo) +.5 cm/mo (6 to 12 mo) Mean = 1 cm/mo	+25.4 cm	Regains birthweight by 2 wk Doubles birthweight by 5 mo	
1 year	47.0 cm (18.5 in)	76.2 cm (30.0 in)	10.0 kg (22 lb)	First molars—14 mo Canines—19 mo
	+2 cm	+12.7 cm	Triples birthweight	
2 years	49.0 cm (19.3 in)	88.9 cm (35.0 in)	12.0 to 12.5 kg (26.4 to 27.5 lb)	Second molars—24 mo
			Quadruples birthweight	

Physical Growth

Growth milestones are the most predicable, although they must be viewed within the context of each child's specific genetic and ethnic influences. It is essential to plot the child's growth on gender- and age-appropriate charts. Charts now are available for some ethnic groups as well as for a few genetic syndromes (eg, Down and Turner syndromes). Fetal weight gain is greatest during the third trimester. During the first few months of life, this rapid growth continues, after which the growth rate decelerates (Table 1). Birthweight is regained by 2 weeks of age and doubles by 5 months. Height does not double until between 3 and 4 years of age. Head growth during the first 5 or 6 months is due to continued neuronal cell division. Later, increasing head size is due to neuronal cell growth and supporting tissue proliferation.

RED FLAGS IN PHYSICAL GROWTH

Occipitofrontal Circumference

Large and small head size both are relative red flags for developmental problems. Microcephaly is associated with an increased incidence of mental retardation, but there is no straightforward relationship between small head size and depressed intelligence. As a reflection of normal variation, microcephaly is not associated with structural pathology of the nervous system or with low intelligence. Furthermore, microcephaly can be seen with above-average cognitive capability. Microcephaly associated with genetic or acquired disorders reflects cerebral pathology and almost always has cognitive implications.

Macrocephaly may be due to hydrocephalus, which is associated with an increased incidence of cognitive deficits, especially learning disabilities. Macrocephaly without hydrocephalus, far from being a predictor of advanced intelligence, also is associated with a higher prevalence of cognitive deficits. It may be due to metabolic or anatomic abnormalities. In about 50% of cases, macrocephaly is familial, and the implications are benign in terms of intellect. When evaluating infants whose macrocephaly is isolated, the finding of a large head size in one or both parents can be reassuring.

Height and Weight

Although the majority of individuals who are of below- or above-average size are otherwise normal, there is an increased prevalence of developmental disabilities in these two subpopulations. Many genetic syndromes are associated with short stature; large stature syndromes are less common. Again, when considering deviation from the norm in the specific child, family characteristics must be reviewed. The concept of mid-parental height is useful in determining whether a given child's size is appropriate for his or her familial growth pattern.

Dysmorphism

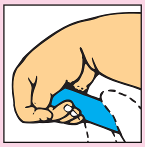
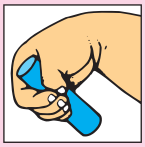
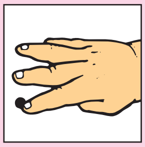
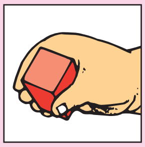
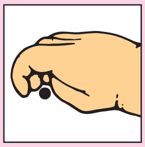
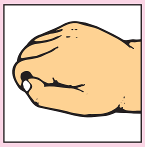
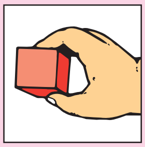
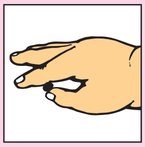
Although most isolated minor dysmorphic features are inconsequential, the presence of three or more may indicate the presence of developmental dysfunction. Almost 75% of these minor superficial dysmorphisms can be found by examining the face, skin, and hands. The presence of both minor and major abnormalities may indicate a more serious genetic syndrome. In many instances, dysmorphic features will lead to the diagnosis of a clinical syndrome during the neonatal period and predate the recognition of any neurodevelopmental deficits.

Motor Development

To make a meaningful statement about an infant's motor competence, the pediatrician should organize data gathered from the history, physical examination, and neurodevelopmental examination according to the following schema: 1) motor developmental milestones, 2) the classic neurologic examination, and 3) cerebral neuromotor maturational markers (primitive reflexes and postural reactions). Motor milestones are extracted from the developmental history as well as from observations during the neurodevelopmental examination. Reference tables of sequential gross and fine motor milestones are necessary (Table 2).

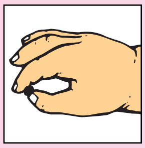
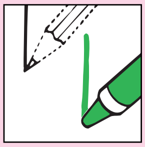
Results of assessment in any domain is summarized best as indicating a developmental age for the

TABLE 2. Motor Development

MOS.	GROSS MOTOR SKILLS	FINE MOTOR SKILLS		RED FLAGS
1	Head up in prone	Hands tightly fisted		
2	Chest up in prone position Head bobs erect if held sitting	Retains rattle (briefly) if placed in hand Hands unfisted half of time		Rolling prior to 3 months may indicate hypertonia
3	Partial head lag Rests on forearms in prone	Hands unfisted most of time Bats at objects Sustained voluntary grasp possible if object placed in ulnar side of hand		
4	Up on hands in prone Rolls front to back No head lag	Obtains/retains rattle Reaches/engages hands in supine Clutches at objects		
5	Rolls back to front Lifts head when pulled to sit Sits with pelvic support Anterior protection	Transfers objects hand-mouth-hand Palmar grasp of dowel, thumb adducted		Poor head control
6	Sits-props on hands	Transfers objects hand-hand Immature rake of pellet		
7	Sits without support Supports weight and bounces while standing Commando crawls Feet to mouth Lateral protection	Radial-palmar grasp of cube Pulls round peg out Inferior scissors grasp of pellet; rakes object into palm	 	W-sitting and bunny hopping, may indicate adductor spasticity or hypotonia
8	Gets into sitting position Reaches with one hand while 4-point kneeling	Scissors grasp of pellet held between thumb and side of curled index finger Takes second block; holds 1 block in each hand		
9	Pulls to stand Creeps on hands and knees	Radial-digital grasp of cube held with thumb and finger tips Inferior pincer grasp of pellet held between ventral surfaces of thumb and index finger	 	Persistence of primitive reflexes may indicate neuromotor disorder

continued

TABLE 2. Motor Development (continued)

MOS.	GROSS MOTOR SKILLS	FINE MOTOR SKILLS		RED FLAGS
10	Cruises around furniture Walks with 2 hands held	Isolates index finger and pokes Clumsy release of cube into box; hand rests on edge Pincer grasp, held between distal pads of thumb and index finger	 	
11	Stands alone Walks with 1 hand held			
12	Independent steps Posterior protection	Fine pincer grasp of pellet between finger tips Marks with crayon Attempts tower of 2 cubes Precise release of cube Attempts release of pellet into bottle		Failure to develop protective reactions may indicate neuromotor disorder
14	Walks well independently	Tower of 2 cubes Attains third cube		
16	Creeps up stairs Runs stiff-legged Climbs on furniture Walks backwards Stoops and recovers	Precise release of pellet into small container Tower of 3 cubes Imitates scribble	 	
18	Push/pulls large object Throws ball while standing Seats self in small chair	Tower of 4 cubes Crudely imitates single stroke Scribbles spontaneously		Hand dominance prior to 18 months may indicate contralateral weakness
20	Walks up stairs with hand held	Completes square pegboard		
22	Walks up stairs with rail, marking time Squats in play	Tower of 6 cubes		
24	Jumps in place Kicks ball Walks down stairs with rail, marking time Throws overhand	Train of cubes without stack Imitates vertical stroke		Inability to walk up and down stairs may be the result of lack of opportunity

Illustrations and accompanying text modified with permission from the Erhardt Developmental Prehension Assessment. In Erhardt RP.* Developmental Hand Dysfunction: Theory Assessment, Treatment. 2nd ed. *San Antonio, Tex: Therapy Skill Builders; 1994.

child. This approach makes it possible to consider the child in terms of his or her level of functioning compared against chronologic age. For example, the developmental quotient (DQ) is the developmental age divided by chronologic age times 100 (see Example below). This provides a simple expression of deviation from the norm. A quotient above 85 in any domain is considered within normal limits; a quotient below 70 is considered abnormal. A quotient between 70 and 85 represents a gray area that warrants close follow-up. Values in the upper limit of normal do not particularly indicate supernormal abilities. Whether truly gifted athletes can be recognized early by use of this method is thought-provoking but speculative.

GROSS MOTOR DEVELOPMENT

Gross motor development proceeds from a sequence of prone milestones (beginning with head up and ending with rolling), to sitting, and then through a standing/ambulating sequence (Fig. 2). Motor milestones do not take into account the *quality* of a child's movement. These sequences must be considered in the context of the motor portion of the neurologic examination, including observations of station and gait, where qualitative features can be assessed. However, the neurologic evaluation of tone, strength, deep tendon reflexes, and coordination is difficult in very young infants because of the subjective nature of the assessments and the infant's limited ability to cooperate. Clinical experience is essential for obtaining accurate and useful information.

Eliciting reflexes requires patience and repeated, yet gentle, trial and error. Muscle tone (passive resistance) and strength (active resistance) are a challenge to distinguish in the contrary infant. The best clues can be obtained from *observation*, not handling. Spontaneous or prompted motor activities (eg, weight-bearing in sitting or standing) require adequate strength. Thus, weakness may be appreciated best from observing the quality of stationary posture and transition movements. The Gower sign (arising from sitting on the floor to standing, using the hands to "walk up" one's legs) is a classic example and indicative of pelvic girdle and quadriceps muscular weakness. Not until 2 to 3 years of age does the neurologic examination become easier and more meaningful as cooperation improves.

Station refers to the posture assumed in sitting or standing and should be viewed from anterior, lateral, and posterior perspectives, looking for body alignment. Gait refers to walking and is examined in progress. Initially, the toddler walks on a wide base, slightly crouched, with the arms abducted and slightly elevated. Forward progression is more staccato than smooth. Movements gradually become more fluid, the base narrows, and arm swing evolves, leading to an adult pattern of walking by 3 years of age.

The motor neuromaturational markers are the primitive reflexes, which develop during gestation and generally disappear between the third and sixth month after birth, and the postural reactions, which are not present at birth but develop sequentially between 3 and 10 months of age (Fig. 3). The Moro, tonic labyrinthine, asymmetric tonic neck, and positive support reflexes are the most useful clinically (Fig. 4). As with all true reflexes, each requires a specific sensory stimulus to generate the stereotyped motor response. Normal infants demonstrate these postures

Example: Motor Quotient

A 12-month-old boy is seen for health supervision. He is not walking alone, but he pulls up to stand (9 months), cruises around furniture (10 months), and walks fairly well when his mother holds both hands (10 months). This child has a gross motor age of 10 months at a chronologic age of 12 months. Should this 2-month discrepancy be a concern? To decide, one should calculate the DQ by using these gross motor milestones:

$$DQ = \frac{\text{motor age}}{\text{chronologic age}} \times 100 = \frac{10 \text{ months}}{12 \text{ months}} = 83$$

The motor age and the developmental quotient are good summary descriptors of the child and have more meaning than plotting each milestone. Because the lower limit is 70, this boy's DQ falls within the "suspect" or gray zone. In reality, infants falling into the gray zone of motor domains usually do quite well and rarely require referral to an early intervention program. This is in contrast to those falling in the gray zones of the cognitive domains.

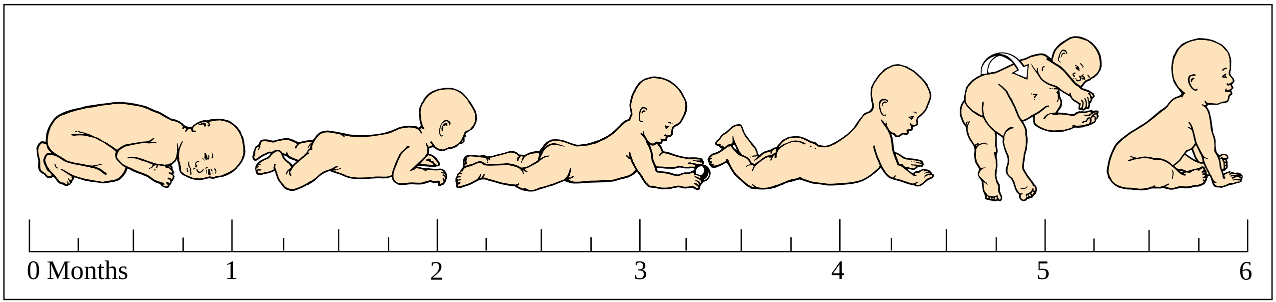


FIGURE 2. Chronologic progression of gross motor development. Adapted with permission from Piper MC, Darrah J. Motor Assessment of the Developing Infant. *Philadelphia, Penn: WB Saunders Co; 1994. Illustrations by Marcia Smith.*

inconsistently and transiently; those who have central neurologic (ie, cerebral) injuries show stronger and more sustained primitive reflex posturing. Primitive reflexes are somewhat difficult to gauge, even in expert hands. The appearance of postural reactions in sequence beginning after 2 or 3 months of age is easier to elicit clinically and can provide great insight into the neuromotor integrity of young infants. Postural reactions are sought in each of the three major categories: righting, protection, and equilibrium. These movements are much less stereotyped than the primitive reflexes, and they require a complex interplay of cerebral and cerebellar cortical adjustments to a barrage of sensory inputs (proprioceptive, visual, vestibular) (Figs. 5 and 6). They are easy to elicit in the normal infant but are markedly slow in appearance in the infant who has central nervous system damage.

FINE MOTOR DEVELOPMENT

In the first year of life, fine motor development is highlighted by the evolution of a pincer grasp. During the second year of life, the infant learns to use objects as tools during functional play. There are many stages in accomplishing these two skills; selected ones are illustrated in Table 2. In the early months, the upper extremities assist with balance and mobility. As balance in the sitting position improves and the infant assumes biped mobility, the hands become more available for manipulation of objects—their ultimate function. Primitive reflexes are integrated, and the upper extremities come under cortical control. Reaching becomes more accurate, and objects are brought to the mouth for oral exploration. As development progresses from proximal to distal, reaching and manipulative skills are enhanced further, and precise manual exploration replaces oral exploration. During the second year, fine motor skills are assessed by observing the manner in which the hands use objects as tools (eg, blocks to build and crayons to draw). The close association between gross and fine motor skills in the first year of life evolves into a similar relationship between problem-solving and fine motor skills during the second year. One skill enables or promotes the development of the other. If progress in manual dexterity is slow, this may impede cognitive development via manipulation of objects.

RED FLAGS IN MOTOR DEVELOPMENT

It is important to begin the motor evaluation by observing the infant. Pay particular attention to the hands; persistent fisting at 3 months of age often is the earliest indication of neuromotor dysfunction. Spontaneous postures (eg, froglegs and scissoring) provide visual clues to hypotonia/weakness and spastic hypertonus, respectively. Delays in the appearance of postural reactions herald future delays in voluntary motor development. An infant will be unable to sit or walk independently without intact protective and equilibrium mechanisms. Abnormal movement patterns may indicate pathology. For example, early rolling (1 to 2 months), pulling directly to a stand at 4 months (instead of to a sit), W-sitting, bunny hopping, and persistent toe walking may indicate spasticity. Hand dominance prior to 18 months of age should prompt the clinician to examine the contralateral upper extremity for weakness associated with a hemiparesis.

Analysis of the information gathered in these areas makes it relatively easy for the practitioner to reassure him- or herself (and the parents) about a child's motor competence or to identify motor impairment at an early age. Once a motor abnormality has been identified, further assessment of its exact nature and etiology is essential. This almost always warrants referral to an appropriate subspecialist or subspecialty team. Based on clinical examination and history, the astute clinician usually can decide into which category the motor disorder falls: 1) static central nervous system disorders, 2) progressive diseases, 3) spinal cord and peripheral nerve injuries, or 4) structural defects.

Cognitive Development

Cognitive processing skills are the substrate for intelligence and include a wide range of abilities (Table 3). Intellectual development depends on learning that contains three components: attention, information processing, and memory (which includes both encoding and retrieval of information). Intellectual development is reflected in advancing abilities to comprehend, reason, and make judgments. Standardized intelligence tests generally measure two forms of intelligence in the school-age child: verbal and performance (or nonverbal). Such standardized

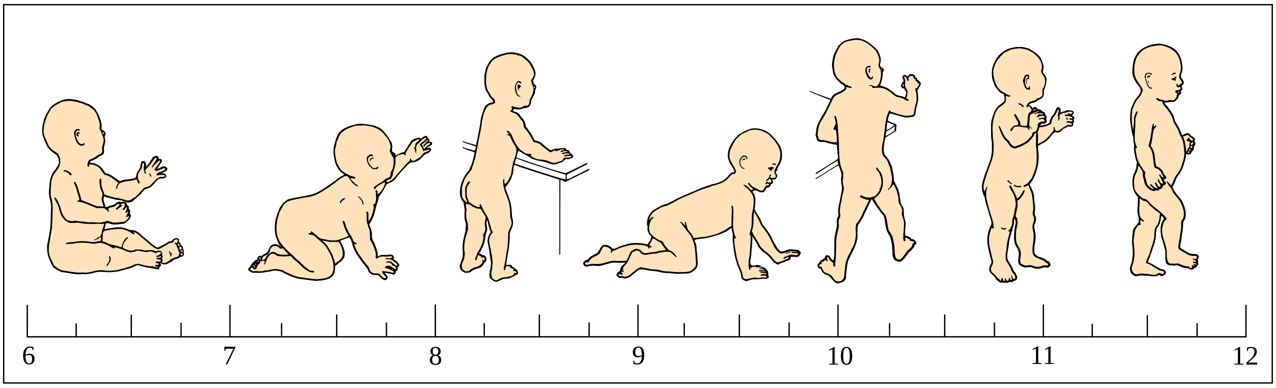


FIGURE 2. Continued

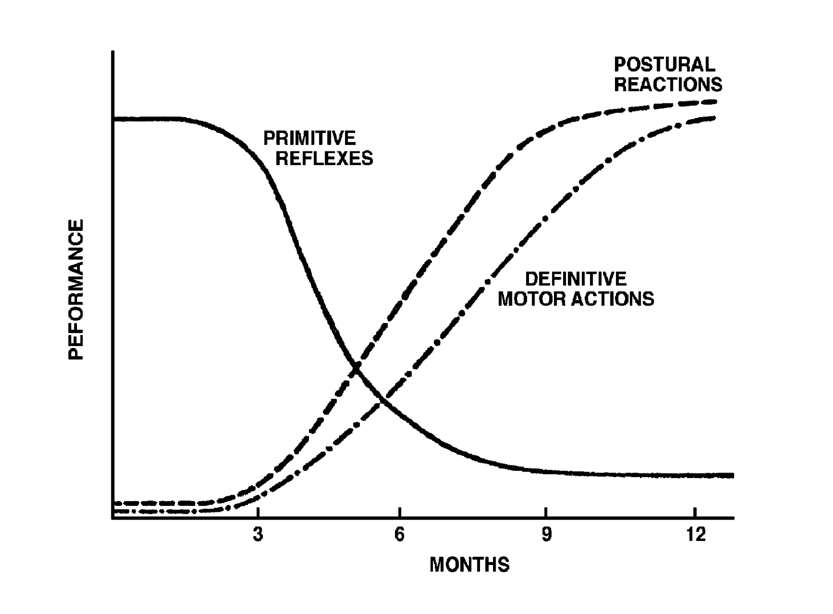


FIGURE 3. The declining intensity of primitive reflexes and the increasing role of postural reactions represent at least permissive, and possibly necessary, conditions for the development of definitive motor actions. From Capute AJ, Accardo PJ, Vining EPG, Rubenstein JE, Harryman S. Primitive Reflex Profile. *Baltimore, Md: University Park Press; 1978. Reprinted with permission.*

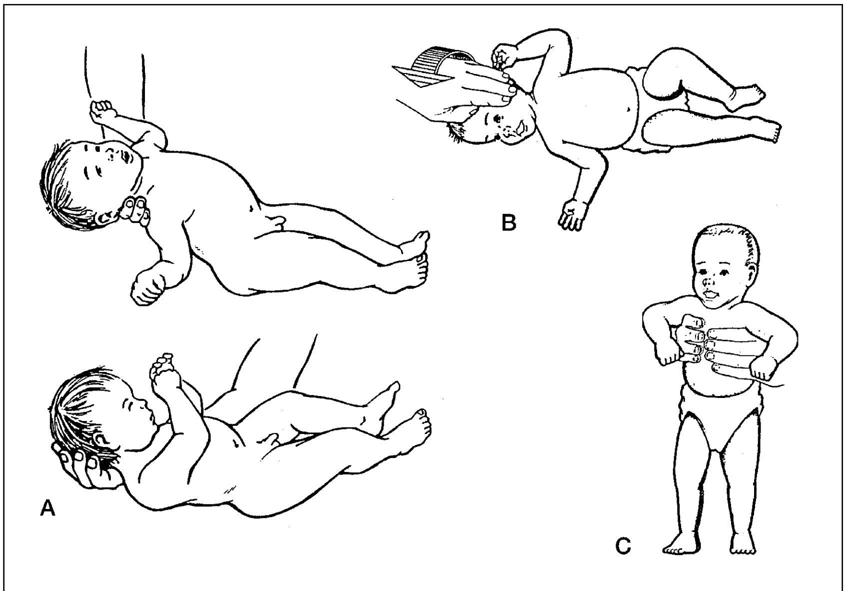


FIGURE 4. Clinically useful reflexes. A. Tonic labyrinthine reflex. In the supine position, the baby's head is extended gently to about 45 degrees below horizontal. This produces relative shoulder retraction and leg extension, resulting in the "surrender posture." With head flexion to about +45 degrees, the arms come forward (shoulder protraction) and the legs flex. B. Asymmetric tonic neck reflex (ATNR). The sensory limb of the ATNR involves proprioceptors in the cervical vertebrae. With active or passive head rotation, the baby extends the arm and leg on the face side and flexes the extremities on the occiput side (the "fencer posture"). There also is some mild paraspinous muscle contraction on the occiput side that produces subtle trunk curvature. C. Positive support reflex. With support around the trunk, the infant is suspended and then lowered to pat the feet gently on a flat surface. This stimulus produces reflex extension at the hips, knees, and ankles so the infant stands up, completely or partially bearing weight. Children may go up on their toes initially but should come down onto flat feet within 20 to 30 seconds before sagging back down toward a sitting position. From Blasco PA. Pediatric Rounds. *1992;1(2):1–6. Reprinted with permission.*

tests are not available to measure infant intelligence. How then, does one recognize the attributes of verbal and nonverbal intelligence in infants? In the past two decades, the discovery of visual habituation techniques to assess infants' attention was considered a breakthrough in the study of infant cognition. It is exemplified by one study that describes 4-day-old infants listening to a long series of "bee-see-lee" sounds. When a novel "da" sound was heard, the infants responded with a change in heart rate and faster, stronger sucking on a pacifier, thereby indicating that very young infants can perceive differences in vowel sounds.

More complex studies using simultaneous auditory and visual stimuli indicate that infants also are capable of organizing perceptions across sensory modalities (cross-modal matching) without the language skills to describe them. For example, 11-month-old infants were presented a sequence of continuous and interrupted pure tones. Two pictures were in the infants' view throughout the experiment: one contained a continuous line, the other a dashed line. The infants consistently matched the correct visual stimulus to the auditory one, inferring cross-modal matching and some rudimentary understanding of the concept of interruptedness. Using these techniques, it has been demonstrated that infants younger than 1 year old can form a wide range of fairly complex categorical representations, including those for faces, color, geometric shapes, and orientation of lines.

The attempts to measure infant responses precisely, such as those described previously, depend on sophisticated technology, including infra-red photography for tracking infant eye gaze and pupillary dilatation, videotaping of facial reactions, and electrophysiologic monitoring of heart rate and evoked potentials. The primary pediatrician can best estimate infant intelligence by evaluating problem-solving and language milestones. Language is the single best indicator of intellectual potential; problem-solving skills are the next best measure. Gross motor skills correlate least with cognitive

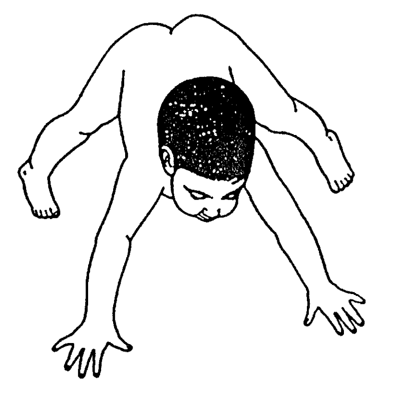


FIGURE 5. Normal parachute reaction. The examiner has suspended the child horizontally by the waist and lowered him face down toward a flat surface. The arms extend in front, slightly abducted at the shoulders, and the fingers spread as if to break a fall. From Blasco PA. Pediatric Rounds. *1992;1(2):1–6. Reprinted with permission.*

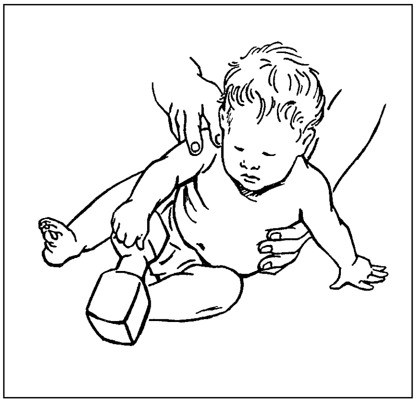


FIGURE 6. The infant is seated comfortably, supported about the waist if necessary. The examiner gently tilts the child to one side, noting righting of the head back toward the midline, protective extension of the arm toward the side, and equilibrium countermovements of the arm and leg on the opposite side. From Blasco PA. Pediatric Rounds. *1992;1(2): 1–6. Reprinted with permission.*

potential; most infants who are diagnosed later with mental retardation walk on time.

PROBLEM-SOLVING

Problem-solving skills consist of manipulating objects to solve a problem (eg, choosing the correct opening for a circular shape in a three-piece form board). The infant's ability to solve a problem depends on intact vision, fine motor coordination, and cognitive processing. During the early weeks of life, the infant explores the environment visually. Later, these visual experiences reinforce movement. As the upper extremities come under visual guidance, reaching and grasping are enhanced. At first, the infant brings objects to the mouth for oral exploration. Later, the infant visually examines an object held in one hand while manipulating it with the other. Isolation of the index finger promotes more refined manipulation of the various parts of objects, and the infant becomes successful in discovering how they work (eg, fingering the clapper of the bell). Mouthing of objects becomes less appealing. This precise manual-visual manipulation, triggered by a heightened curiosity and facilitated by a longer attention span, heralds true "inspection" of objects. The infant is progressing from "learning to manipulate" to "manipulating to learn." Improved macular vision (via myelination of the fovea) and refinement of the pincer grasp promote inspection of progressively smaller objects. As cognitive abilities continue to advance, the infant learns to shift attention between two objects (one in each hand), compare, make choices, and discard or combine objects. This sensory-motor phase of learning is the foundation for ongoing nonverbal intellectual development.

The 1-year-old child recognizes objects and associates them with their functions. Thus, he or she begins to use them functionally as "tools" instead of mouthing, banging, and throwing them. This child has left the period of sensory-motor play and entered the stage of functional play. Play serves as a window into the infant's thoughts and becomes particularly important during the next stage of symbolic play. At this point, the infant uses toys that represent real objects in actions toward him- or herself (putting a toy telephone to the ear and vocalizing) and later in actions toward dolls or teddy bears (putting a toy tea cup to the doll's mouth). The use of symbols lays the foundation for imaginary play. This next stage of play usually does not appear until 24 to 30 months of age.

The interdependence of language and problem-solving development becomes stronger as the child begins to label objects and actions. Midway through the second year, this ability to label and categorize allows the child to match objects that are the same (car to a car and spoon to a spoon) and later to match an object to its picture. Nonverbal intelligence is assessed by observing the infant interact with test objects. In the older child, it is assessed through standardized pencil and paper tasks or computerized tests.

One aspect of nonverbal cognitive development deserves extra attention: object permanence, a concept studied extensively by Piaget. Prior to the infant's mastery of object permanence, a person or object that moves "out of sight" is "out of mind"; its disappearance does not evoke a reaction. The ability to maintain an image of a person develops before that of an object. The child will show interest in peek-a-boo play, and separation anxiety will occur when a loved one leaves the room. Shortly thereafter, the child will begin to look for an object that has been dropped. At first, an auditory cue when it hits the floor is necessary to locate it. Later, the child will experience success in finding an object that was dropped from sight and landed silently. Next, the child will progress to finding an object that has been hidden under a cloth or cup. A more complex task is locating an object that has been wrapped inside a cloth. Success requires persistence and memory of the object long enough to complete the three-part unwrapping process. The next skill in this sequence is the ability to locate an object under double layers (eg, a cube is placed under a cup and then the cup is covered with a cloth). This is followed by the ability to locate an object after serial displacements. In this task, an object is hidden under one cover and then changed to another one. The younger infant always will look for it under the first cover, even though the position change was seen. Later, he or she will become successful with this task, as long as each successive displacement still is witnessed. Not until the end of the second year is the child able to

TABLE 3. Cognitive Development

AGE IN MONTHS	PROBLEM-SOLVING	LANGUAGE: RECEPTIVE	LANGUAGE: EXPRESSIVE	RED FLAGS
1	Fixes on red ring Follows face	Alerts to sound	Throaty noises Cries	Failure to alert to environmental stimuli may indicate sensory impairment
2	Tracks horizontally past midline Tracks vertically	Regards speaker	Social smile Coos Vocalizes single vowel sounds	
3	Regards a 1-inch block Follows ring circularly Visual threat		Chuckles Echoes speaker immediately Cry varies (hunger, pain)	
4	Reaches for objects Mouths objects Shakes rattle Regards objects while handling	Orients to voice	Laughs out loud "Ah-goo" Silent and listens to speaker; vocalizes when speaker stops	
5	Attains dangling ring Regards pellet	Orients Bell—I	Razzes (raspberries) Smiles and vocalizes to mirror Sing-song vocalizations that mimic speaker's voice	Failure to reach for objects may indicate motor, visual, and/or cognitive deficit
6	Looks to floor when drops toy Attains partially hidden object Removes cloth covering face Discriminates strangers		Babbles: "baba," "gagaga" Consonant production without symbolic meaning or communicative intent	Absent babbling may indicate hearing deficit
7	Bangs/shakes toys Attempts to grasp second cube; drops first Pats mirror image	Orients Bell—II	Adult reinforcement begins to give meaning to random babbling	Absent stranger anxiety may be due to multiple care providers (eg, neonatal intensive care unit)
8	Pulls string to obtain ring Inspects ring/bell Seeks yarn ball after fall; silent landing	Enjoys peek-a-boo and other gesture games	"Dada" inappropriately Mimics sounds already in repertoire	
9	Rings bell Bangs objects on table Uncovers hidden object under cloth	Associates words with meanings	"Mama" inappropriately Waves "bye bye"	
10	Bangs two cubes together Isolates index finger and explores by poking Looks at pictures in book	Comprehends "no" Orients to name Orients Bell—III	Dada/Mama appropriately	Inability to localize sound may indicate unilateral hearing loss

11	Uncovers toy under cup	Looks for familiar family member when named	First word Imitates simple sounds	
12	Looks selectively at round hole on form board Removes lid to find toy	Follows command with gesture (“Give me.”)	Immature jargoning Protoimpertive pointing (goal = desired object)	Persistent mouthing may indicate lack of intellectual curiosity
13	Solves glass frustration task Unwraps toy in cloth Functional play	Looks appropriately when asked “Where is (familiar object)?”	2 to 3 words “Oh-oh”	Normal receptive language up to this point is compatible with hearing loss
14	Combines two cubes into one hand to take third Dumps pellet after demonstration	Follows command without gesture	Names one object Says “no” meaningfully Protodeclarative pointing (goal = adult’s attention)	
15	Places circle in form board Symbolic play toward self	Points to a body part or favorite toy	3 to 5 words Mature jargoning	Lack of consonant production may indicate mild hearing loss
16	Pellet in and out without demonstration Finds toy hidden under layered covers Follows observed sequential displacements	Fetches object from another room on request Points to 1 to 2 body parts	5 to 10 words	Lack of imitation may indicate deficits in hearing, cognition, and/or socialization
18	Matches pairs of objects Round form in reversed board after searching Symbolic play directed at doll	Points to 3 body parts Points to self	10 to 25 words Giant-words (“Thank you,” “Stop it,” “Let’s go”) Names one picture on command	Lack of protodeclarative may indicate problem in social relatedness
20	Places square in form board Deduces location of hidden object (unwitnessed displacement)	Points to several clothing items on request Selects 2 of 3 familiar objects Points to 6 body parts	2 word combinations (noun-noun) Holophrases	
22	Completes 3-piece form board	Points to 3 to 4 pictures	25 to 50 words Rapid vocabulary expansion	Advanced, noncommunicative speech (echolalia, rote phrases) may indicate autism
24	Adapts to form board reversal after 4 trials Sorts objects Matches objects to pictures Attempts to fold paper	Two-step commands (“Close the book and give the doll to mommy”) Comprehends “another” Points to 6 pictures Understands me/you	50+ words 2 to 3 word sentences (noun-verb) Refers to self by name Intelligibility = 50% + Uses “I,” “you,” “me”	Absent symbolic play may indicate problems in cognitive and/or social development

deduce the location of an object that is hidden without observing the displacement.

Another important concept dominating this period of development is causality. Initially, the infant accidentally discovers that his or her actions produce a certain effect (eg, kicking the side of the crib activates a mobile overhead). The infant learns to repeat these actions to obtain the same effects. Later, he or she will vary actions to cause a novel effect (pulling a string to obtain the ring). The concept of causality parallels social development in which the infant learns to manipulate the environment by crying or smiling to obtain the desired reaction from caregivers. As the infant approaches 2 years of age, he or she will learn that apparent unrelated actions can be combined to produce an effect (eg, winding a key to make a toy move).

LANGUAGE DEVELOPMENT

Delays in language development are more common than delays in other developmental domains. Parents and pediatricians generally are less familiar with language milestones. Language is the most difficult domain to assess by observation because infants rarely vocalize spontaneously in the clinician's office. For this reason, it is essential for the clinician to obtain a thorough and accurate language history. The pediatrician should become familiar with milestone terminology and learn to give examples (eg, "razzing"). Between 10 and 18 months of age, word counts help in assessing a child's expressive skills; after 18 months of age, vocabularies increase exponentially, and it is difficult to keep up with counts.

Language includes receptive and expressive skills. Receptive skills reflect the ability to understand language; expressive skills reflect the ability to make thoughts, ideas, and desires known to others. Expression of language can take several forms: speech, gestures, sign language, writing, typing, and "body language." Thus, language and speech are not synonymous. Speech is simply the vocal expression of language. A child can have normal language and yet be unable to speak. Examples include children who are deaf and children who have severe cerebral palsy. The child who has a hearing impairment may use manual sign language to communicate. A child who has normal intelligence but cannot speak because of oral-motor dysfunction related to cerebral palsy may use a computer that is activated with a head stick. Conversely, a few children talk but fail to use speech to communicate (eg, children who have autism). Their vocalizations consist of "parrot talk" or echolalia that has no communicative intent and, thus, does not represent language.

Language development during infancy can be divided into three periods: prespeech, naming, and word combination periods.

1. Prespeech Period (0 to 10 months): Receptive language is characterized by an increasing ability to localize sounds. Sound localization is assessed by using a noisemaker such as a bell (Fig. 7). Expressive language consists of musical-like vowel sounds (cooing) that are interrupted by crying when the baby has a need. At about 3 months, the infant will begin vocalizing immediately upon hearing an adult speak. One or two months later the infant is silent and assumes a posture that implies he or she truly is "listening" to the speaker. These infants make no vocalizations until the speaker is quiet, mimic the speaker, and then quiet again when the adult speaks. They appear to enjoy the "vocal tennis" and repeat this for several cycles. At approximately 6 months of age, the infant adds consonants to the vowel sounds in a repetitive fashion (babbling). Soon the infant appears to initiate conversations. When a random vocalization (eg, "dada") is interpreted by the parents as a real word, they show pleasure and joy. In so doing, adults give meaning to these first "words" and reinforce their repeated use.
2. Naming Period (10 to 18 months): This period is characterized by the infant's realization that people have names and objects have labels. It is an important turning point in language development. The "dada" and "mama" that

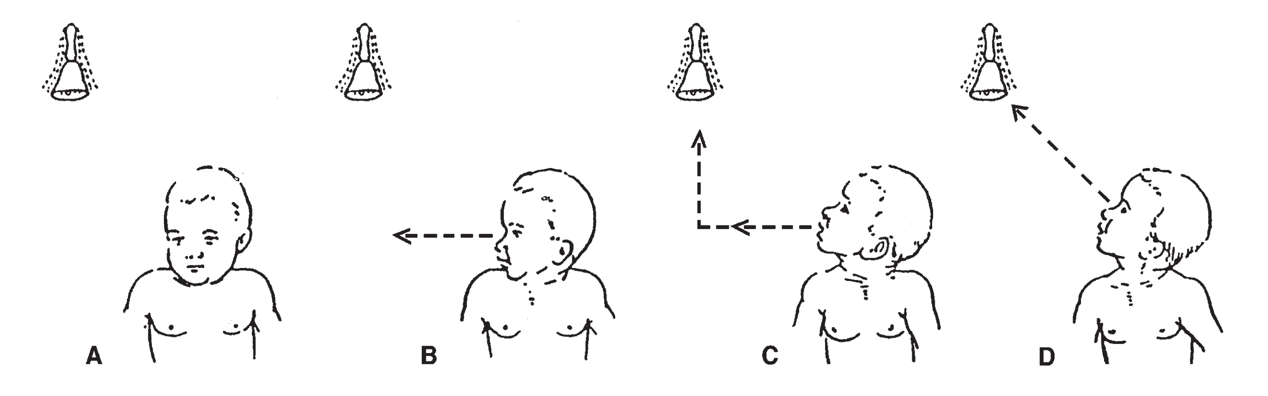


FIGURE 7. Orienting to sound of bell. In the first stage (5 months), when a bell is rung at one side of the infant's head (A), the infant turns horizontally to the correct side (B). In the second stage (7 months), when a bell is rung at one side of the head (A), the infant localizes the sound by a compound visual maneuver consisting of a horizontal followed by a vertical component (C). In the third stage (9½ months), when a bell is rung to one side of the head (A), the infant localizes the sound by a single visual movement (D). From Capute AJ, Accardo PJ. Clin Pediatr. *1978;17:850. Reprinted with permission.*

were vocalized randomly have been reinforced, so the infant now begins to use them appropriately. Infants next recognize and understand their own names and the meaning of "no." This marks the beginning of exponential growth in receptive language. By 12 months of age, some infants understand as many as 100 words. They also can follow a simple command as long as the speaker uses a gesture. Early in the second year, a gesture no longer is needed to aid in comprehension of the command. Expressive language progresses at a somewhat slower rate. The infant will say at least one "real" word (ie, other than mama, dada, or a proper name) before his or her first birthday. At this time, the infant also will begin to verbalize with sentence-like intonation and rhythm (immature jargoning). As the expressive vocabulary increases, real words are added (mature jargoning). By the end of the naming period, the infant will use approximately 25 words spontaneously.

During this period, pointing becomes important to both receptive and expressive language skills. Pointing already has become a method of exploration within the problem-solving domain. The infant beginning to look in the general vicinity where the adult is pointing is a receptive language skill. This ability is facilitated by the infant's new realization that objects have labels. Later, the infant begins to take part in pointing games. He or she will point first to family members, then objects, body parts, articles of clothing, and pictures upon request. These all reflect receptive language skills.

Pointing also is used for language expression. First, the infant points at an object and uses the adult as a tool to retrieve the object, referred to by linguists as protoimperative pointing. The infant first points to the object (eg, a cookie) and then looks back and forth between the adult and the object expectantly. At a later stage, he or she directs attention to the adult and alternately points at the adult and the desired object while vocalizing (eg, "uh...uh"). Next, the infant uses the object as a tool to obtain the parent's attention (protodeclarative pointing). Protodeclarative pointing is a social act; the parent is an active and important partner in a shared world. Rather than acquisition of the object, the infant's goal becomes the parent's acknowledgment of the interesting object. For example, when an infant hears an airplane overhead, he or she points to it and vocalizes to get the parent to look at it. If the parent does not comply with these initial efforts, the infant may approach the parent and turn his or her face toward the plane in a more determined effort to obtain what is sometimes called "joint attention." Finally, the infant will point at an object and vocalize ("uh?") in an effort to obtain the proper label or name for that object from the listener. This is called "pointing for naming."

3. Word Combination Period (18 to 24 months): Typically, children begin to combine words approximately 6 to 8 months after they say their first word. If word combinations appear much earlier, they are likely "giant words." Giant words are two- or three-word combinations that the infant hears frequently, such as "Thank you," "Stop it," or "Let's go." When the infant says one of these, he or she really is treating the phrase as a polysyllabic single word. At this stage of development the infant does not use either word separately or in novel combinations with other words. "Holophrases" also are beginning to appear at this time. For example, an infant may point to a mother's keys and say "mommy" instead of saying "keys." In this context, the single word, "mommy," has a sentence-like meaning, such as "These keys belong to mommy." Single words take on multiple meanings and no longer simply label an object. The infant usually does not combine words into true phrases or sentences until he or she has acquired an expressive vocabulary of approximately 50 words. Early word combinations are "telegraphic" in that they do not contain function words (prepositions, pronouns, and articles). They do, however, convey the same meaning as the more mature sentence. For example, "Go out," in the context of the situation, conveys the same meaning as "I want to go outside." Telegraphic speech is the first stage in the child's ability to "grammaticize" speech, that is, to form sentences with proper morphology and syntax. At this point in development, a stranger should be able to understand at least 50% of the infant's speech (intelligibility). Language blossoms after 2 years of age.

Word combination begins approximately 6 to 8 months after an infant says his or her first words.

RED FLAGS IN COGNITIVE DEVELOPMENT

Language development provides the clinician with an estimate of verbal intelligence; skill development in the problem-solving domain provides an estimate of nonverbal intelligence. If deficiencies are global (ie, skills are delayed in both domains) and significant (ie, >2 standard deviations below the mean), there is a possibility of mental retardation. Mental retardation refers to significant subaverage general intellectual functioning as measured by standardized tests. By current definition, these deficits must be associated with significant deficits in adaptive functioning. About 3% of the population is mentally retarded. If the deficiencies are very mild (ie, in the low range of normal), the child is considered to be of borderline intelligence or a "slow learner."

When a discrepancy exists between problem-solving and language abilities, with only language being deficient, one must consider the possibility of a hearing impairment or a communication disorder. If either language or problem-solving skills is deficient, the child is at high risk for manifesting a learning disability later. A learning disability refers to academic achievement that is substantially below what would be expected from a person's general intellectual potential. Approximately 5% to 7% of school-aged children have learning disabilities. A learning disability cannot be diagnosed formally until the child reaches school age and demonstrates an inability to keep up in one or more academic areas. Thus, a reading disability cannot be diagnosed until at least age 6 or 7 years when children normally are expected to read. A delay in language development is a "red flag" and should prompt careful monitoring and further evaluation if the child later demonstrates reading difficulties in school. The neurologic substrate for specific learning disabilities involves patchy dysfunction in cortical information processing that results in specific difficulties with academic tasks.

Unless the deficiencies are severe during infancy, a child rarely presents with a parental concern of "cognitive delay." Concerns usually present as speech delays, but such complaints are infrequent before 24 months of age. The average age at which mental retardation is diagnosed is 3 to 4 years. Usually, the more severe the degree of impairment, the earlier the diagnosis is made. Because the majority of children who are mentally retarded are in the mild category, most children are diagnosed well after infancy. Some are not diagnosed until they enter school. The child who is born with dysmorphic features and has a recognizable syndrome known to be associated with mental retardation will be diagnosed earlier regardless of the degree of impairment. Additionally, abnormal findings on magnetic resonance imaging (performed because of atypical head growth or because of a known cerebral insult) indicate that the child is at risk for intellectual deficits.

Although a cognitive deficit is the most common reason for language delay, all children who have delayed language development should receive audiologic testing to rule out hearing loss. The child who has a hearing loss will demonstrate normal expressive language skills through the babbling stage (6 months). He or she will begin to babble on time, but lack of auditory reinforcement for these vocalizations results in their disappearance and a general decline in verbal expression. Receptive language abilities continue to progress normally for a few more months. A 1-year-old who is deaf will follow a command with a gesture (relying solely on the gestural cue) and may seem to hear. This ability to use environmental cues can fool parents and professionals and is one of the chief reasons that the average age of diagnosis of a severe hearing loss is 2 years. Children who have a mild hearing loss will present even later with articulation errors, inability to localize sounds, or "attentional problems." An infant who is deaf will attempt to communicate by using gestures. If a child has delayed speech and fails to demonstrate a desire to communicate, a more pervasive problem, such as autism, should be considered. Although children who have autism may demonstrate protoimperative pointing (eg, pointing to obtain food or drink), they rarely point to the object for the purpose of having the adult join in the pleasure of admiring an interesting object (protodeclarative pointing) or point to obtain the name of an object. Prodeclarative pointing is a social action, and one of the cardinal features of autism is the lack of social relatedness. Another red flag is the finding that a child's expressive skills are advanced compared with his or her receptive skills. A child who speaks in five-word sentences but does not understand simple commands is at risk of having a pervasive developmental disorder. The advanced speech may not be functional or have communicative intent. Finally, some parents will excuse their child's lack of speech because of an "Uncle Albert" who didn't speak until he was 4 years old but grew up to be a rocket scientist. In reality, this is very rare. Normal receptive language skills in a child who has speech delay would be reassuring and typically are easy to demonstrate.

. . . all children whose language development is delayed should receive audiologic testing.

Other problems may masquerade as cognitive delay or impair the assessment of cognitive abilities. Problem-solving tasks require intact fine motor skills. Having poor fine motor skills puts the child at a disadvantage with certain manipulative tasks used to assess nonverbal cognition. Due to cerebral palsy, a child may not be able to place a square form in a form board; however, he or she might be able to indicate the correct position by pointing or by eye gaze. Thus, the child actually could "pass" the form board item in the problem-solving assessment. Similarly, visual impairment can interfere with a child's ability to perform many problem-solving tasks successfully.

Psychosocial Development

Emotional, social, and adaptive milestones have been assimilated from multiple sources (Table 4). These milestones are more variable than those in motor and cognitive domains because of the greater influence of environmental factors (nurture). An infant inherits a set of emotional-social characteristics and a style of interacting, but these are modified by parenting style, "goodness of fit," and the social environment. Emotions include the infant's feelings as well as the expression of these feelings. Social milestones include the steps necessary to form interpersonal relationships. Temperament influences social relationships and generally reflects a consistent pattern (or style) in "how" a child reacts. It is different from the

TABLE 4. Psychosocial Development

AGE IN MONTHS	EMOTIONAL	SOCIAL	ADAPTIVE	RED FLAGS
1–3	Interest Disgust Distress (pain, hunger) Enjoyment (social smile)	Understands relationships between voices and faces Bonding (parent → infant) Smiles reciprocally Follows moving person with eyes	State regulation Requires only one night feeding	Irritability Sleep/eating disturbances
3–6	Anger Happiness Joy Pleasure Sadness Displeasure	Recognizes mother Attachment (infant → parent) Anticipates food on sight Smiles spontaneously		Absent smile may indicate visual loss, attachment problems, or maternal depression
6–9	Personality unfolds Fear	Discriminates emotional facial expressions and reacts differently Preference for a given person Stranger anxiety Understands means-to-an-end relationship in social interactions (act → clap → repeat act)	Gums/swallows cracker Places hands on bottle Takes solids well Finger feeds dry cereal	Absent stranger anxiety may be due to multiple care providers (eg, NICU care)
9–12	Assertiveness Cautiousness	Differential fear response based on gender and age Concept of self Social interactions become intentional and goal-directed Separation anxiety	Holds bottle Holds, bites, chews cracker/cookie Drinks from cup held for him or her	
12–15	Shyness Empathy Sharing Self-comfort (eg, attachment to blanket)	Solitary play Begins formation of relationships • Love • Friendship • Acquaintance • Strangers Offers ball to mirror image Kisses by simply touching lips to skin or licks	Cooperates with dressing Drinks from cup; some spillage Removes socks/hat	
15–18	Shame/guilt Contempt	Self-conscious period; "coy" stage Hugs parents	Uses spoon; some spillage	Lack of social relatedness may indicate autism
18–21	Associates feelings with verbal symbols Begins to have thoughts about feelings	First application of attributes to self (eg, good, little, naughty) Initiates interaction by calling to adult Kisses with a pucker	Drinks from cup without spilling Moves about house without adult Emerging independence Removes a garment	
21–24	Beginning "socialization" of emotional expression by social/cultural influences • modulation of emotion • masking of emotion Infant's reaction to ambiguous events is shaped by emotional reactions of others	Imitates others to please them Recursive nature of social thought (ie, thinking about "How I behave to you and you to me") Parallel play Tolerates separation; will continue activity	Replaces some objects where they belong Uses spoon well Opens door by turning knob Removes clothes without buttons Unzips zippers Puts shoes on part way	Persistent poor transitions may indicate a pervasive developmental disorder

"why" (motivation) and the "what" (content) of social interactions. The inclusion of adaptive skills (ie, skills required for independence in feeding, dressing, toileting, and other activities of daily living) is unique to the discussion of psychosocial development and reflects the concept that these skills influence, and are influenced by, social factors.

EMOTIONAL DEVELOPMENT

Emotions are present in infancy and motivate expression (pain elicits crying). Emotion has three elements: neural processes, mental processes (feelings), and motor expression (facial, verbal) and actions. Emotions are mediated through the limbic system, which is responsible for receiving, interpreting, and processing emotion-producing stimuli and then initiating and modulating emotional responses. There is evidence that an infant can express emotion without direct cognitive mediation. An infant who has anencephaly or hydranencephaly may show disgust at sour flavors and interest in sweet flavors in ways very similar to a normal infant. Later, in the normal infant, these instinct-like reactions are modified by cognition. Although emotional feelings are constant over the life span, their causes change and become more abstract. The infant may show disgust for a bitter taste; the older child may show disgust for a revolting idea. Other emotions have a definite cognitive foundation. To experience fear, the 7- to 9-month-old child must be able to shift attention, compare, and recognize "familiar" from "unfamiliar" in the development of stranger anxiety. As the child develops, the interrelationship between emotion and cognition becomes increasingly complex. When the child begins to associate language symbols with emotions and memory, he or she can remember prior emotional experiences. A verbal reminder of the event then can evoke feelings identical to those experienced previously. Thus, language and cognition add flexibility and complexity to emotional behavior.

The expression of emotions also evolves with age and developmental advancement. Consider this example of an emotional reaction (fear) to a stranger, based on skill level:

9 months
Cries and turns head away *(mass body reaction)* and *(avoidance reaction)*
24 months
Runs away *(motor development)*
48 months
Says "Go away" or "Help" *(language development);* or tries to alter the threat *(cognitive development)*

In addition to developmental progress, the feedback loop between care providers and child modifies emotional expression. Social forces and cultural factors also modulate emotional expression to produce more restrictive and controlled facial signals. An older child may learn to modulate the expression of pain (a facial grimace only) and appear quite stoic. Furthermore, children can learn to mask emotions such as smiling at a disappointing gift. At early stages, however, the true emotion typically leaks out from under the mask.

Socioemotional milestones at 52 weeks include offering a ball to a mirror image and cooperating in dressing.

SOCIAL DEVELOPMENT

The infant is surrounded by a social network. Sensory processing is influenced by the infant's social needs. The infant has greater discrimination ability for social voices) than for nonsocial (environmental noise) stimuli. There are two primary theories: the Epigenetic Model and the Social Network Model. In the Epigenetic Model, the mother-child relationship is considered to be all important. If this relationship is negative, then other relationships will be poor. If it is positive, then future relationships will be good. The Social Network Model recognizes the relative importance of the mother-child relationship, but also recognizes the ability of other relationships to compensate for absent or poor mother-child interactions. The devastating effect of a poor relationship can be overcome by adequate substitutes and a supportive environment. The latter reflects the popular concept of childhood resiliency.

Social milestones begin with bonding, which reflects the feeling of the caregiver for the child. Attachment takes place within a few months and represents the feeling of the infant for the caregiver. These social relationships are manifested by the evolution of the smile, in which the level of stimulus required to elicit reciprocity decreases. At first, high-pitched vocalizations and a smile from the adult are needed; later, a smile alone is successful. When recognition of and attachment to a familiar caregiver develops, the simple sight of this person (smiling or nonsmiling) will elicit a smile. The infant also becomes more discriminating in producing a smile as he or she begins to differentiate between familiar and unfamiliar faces. As the infant acquires the concept of causality, he or she begins to use smiling to manipulate the environment and satisfy personal needs.

Later in infancy, other social relationships are established. Several behaviors are necessary for the development of these relationships. First, the infant must have a concept of self versus others. Next, he or she must be able to put self in the place of another, that is, to show empathy. The infant must perceive a separate identity with a different set of needs. He or she must realize the consequences of his or her interactions on others. Empathy is critical to forming a relationship. Next the child must be able to share, which is critical to maintaining a relationship. There are four basic types of relationships: with acquaintances, strangers, friends, and loves. Whereas relationships with acquaintances and strangers simply require a concept of self, friendship and love require all three (a concept of self, empathy, and sharing). About the same time that the child can label emotions (via language), he or she begins to think about social interactions. A child will demonstrate recursive social thoughts, that is, show early signs of thinking about how others behave toward him or her and how he or she behaves toward others.

Temperament, or the infant's overall style of reacting, can affect social relationships. The precise definition of temperament is controversial, but it generally is believed to represent the characteristic style of a child's emotional and behavioral response in a variety of situations. It is determined by genetic factors but is modified by environmental forces. Temperament shows considerable stability over time. Thomas and Chess describe nine traits that determine whether a child will have an "easy," "difficult," or "slow-to-warm-up" temperament:

1. Activity level—proportions of periods of activity to inactivity
2. Adaptability to change
3. Positive or negative mood
4. Intensity of emotional responses
5. Rhythmicity of biologic functions
6. Persistence in the face of environmental counterforces
7. Distractibility or ease of soothing
8. Approach versus withdrawal tendencies in new situations
9. Threshold of stimulation necessary to produce a response

The Carey Infant Temperament Questionnaire often is used to evaluate these traits formally. Approximately one third of infants will be characterized as difficult or slow-to-warm up. The other two thirds will be classified as easy infants. The easy infants fall into three subcategories: 1) gentle, tender, sensitive, affectionate; 2) changeable, variable, adaptable; and 3) social, playful, happy, attention-seeking. A child's temperament can influence developmental testing. The child who is difficult or slow to warm up may refuse to cooperate with test items, thereby receiving lower scores that do not reflect his or her true abilities.

ADAPTIVE SKILL DEVELOPMENT

Adaptive skill development is influenced by the infant's social environment, as well as by motor and cognitive skill attainment. A child who has quadriparesis may not be able to feed him- or herself, even with normal intelligence and a supportive social environment.

In contrast, acquisition of self-help skills by an able-bodied infant may be delayed in the face of mental retardation and the lack of motivation to become independent. In spite of normal motor and cognitive skills, an infant may demonstrate delays in adaptive skills when social support and encouragement are lacking. This is exemplified by delays in self-feeding skills when the caregiver is overly concerned about messy spillage or feels the need to rush mealtime. Additionally, parents may persist in dressing the older child in an effort to rush to child care. The decision to initiate toilet training often is influenced by both family and culture.

RED FLAGS IN PSYCHOSOCIAL DEVELOPMENT

Decreased rhythmicity (eg, colic) may be an early indication of a "difficult child." Delay in the appearance of a reciprocal smile may indicate an attachment problem, which may be associated with maternal depression. In severe cases, child neglect or abuse may be suspected. However, a delay in smiling also may be associated with visual or cognitive impairment. The lack of social relationships plays a key role in the diagnosis of autism when it is accompanied by delayed or deviant language development and stereotypic behaviors. History and observation of an infant's behavior at play may alert the clinician to abnormal social relationships. The emotional status of the parents and parenting styles may affect the infant's development of adaptive skills. A controlling, rejecting parenting style may be revealed in an oppositional child who refuses to cooperate with self-care. Delays in adaptive skills also may indicate overprotective parents or an excessive emphasis on cleanliness.

Conclusion

The journey through infancy truly is fascinating—a time of incomparably rapid changes in physical growth and motor development. By the end of this period, the child is mobile and explores his or her environment independently. The child's pincer grasp and release rival that of the adult. Cognitive and social changes are equally prodigious. The baby has progressed from simple methods of expression (crying and grimacing) to a "little person" who has a complex array of emotional expressions that are becoming "socialized." He or she has learned to use these emotions to manipulate the environment and obtain the attention and the objects that he or she desires. Additionally, the child can think about emotions and feel empathy for the emotions of others. He or she has strong love and friendship relationships with family members and a few significant others. The next few years are characterized by exponential language development, which will reveal the complex thoughts, feelings, and humor owned by this amazing creature destined to become an adult.

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PIR QUIZ

1. An infant lies supine on an examination table with his head in the midline, hands clasped together. He grasps an offered throat stick and brings it to the mouth. There is no transfer from hand to hand. In the prone position the infant lifts his head to a vertical axis, with the arms extended to raise the trunk. He rolls over from prone to supine and smiles and coos on social contact. When the contact is broken, the smile disappears. The developmental level of this infant appears to be *closest* to:

   A. 2 months.
   B. 4 months.
   C. 6 months.
   D. 8 months.

2. An infant sits without support on the examination table, with her back straight. When offered a throat stick, she grasps it and transfers it from one hand to the other. When asked to return the throat stick to the examiner's outstretched hand, she touches the stick to the hand, but does not release it. A toy is placed before her, and as she reaches for it, a cloth is thrown over the toy. Without hesitation she removes the cloth to retrieve the toy. When a raisin is placed before her, she reaches for it, puts her hand on the surface of the table next to the raisin, and traps it between the thumb and forefinger. Given a little bell, she uses the forefinger to explore the inside of it. Pulled with both hands to a standing position, she takes a few hesitant steps as her hands are held. The developmental level of this child appears to be *closest* to:

   A. 6 months.
   B. 9 months.
   C. 12 months.
   D. 15 months.

3. An infant sits in a highchair with a tray before him. He is offered paper and a crayon and is asked to imitate a scribbling motion, which he does. When asked to imitate a horizontal stroke, he produces a vertical stroke. Given a circular block and a three-place form board (circle, square, triangle), he successfully inserts the circular block into the form board. Shown how to make a tower of three 1-inch cubes, he clumsily makes a tower of two cubes. He ignores the third cube. He dumps a raisin out of a little bottle and reinserts it with difficulty. His mother reports that he walks alone, that he responds to a simple request to find an object in another room, and that he has two words other than "mama," although he vocalizes with a rich jargon that has some of the intonations of speech. He makes his wants or needs known by pointing and vocalizing. He points to his nose or eyes on request. The developmental level of this child appears to be *closest* to:

   A. 12 months.
   B. 15 months.
   C. 18 months.
   D. 21 months.

4. A child is sitting in a highchair, with a tray in front of her. Given paper and crayon and asked to scribble, she does so with gusto. Asked to copy a circle following a demonstration, she produces a circular scribble rather than a closed circle. She draws a vertical line upon demonstration. She builds a tower of six cubes and completes the three-piece form board. Her mother reports that she has become somewhat self-assertive, with a firm "no," and a wish to do things for herself. The developmental level of this child appears to be *closest* to:

   A. 18 months.
   B. 21 months.
   C. 24 months.
   D. 30 months.

5. In a 2-year-old child, the *best* indicator of future intellectual achievement will be the child's status in:

   A. Adaptive behavior.
   B. Fine motor activity.
   C. Gross motor activity.
   D. Language development.