REGRESSION PERIODS IN HUMAN INFANCY

EDITED BY

MIKAEL HEIMANN

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Preface

This book has grown out of a loosely formed European project, the intercultural study of infantile regression periods (ISIRP), with the aim to test if indicators of regression can be found at similar ages in a number of different countries and cultures. The idea that motivated this book was initially put forward by Frans X Plooij and Hedwig van de Rijt-Plooij who claimed that 10 periods of regression could be identified during the first 15 months of life, periods that they suspected to be biologically anchored and thus, valid across cultures—a finding that came to be viewed as both challenging and provoking by the scientific community. For the group behind this volume, the researchers in the ISIRP group, this idea created a renewed interest in processes of change in early infancy, and it became a necessity to both replicate and develop a coherent psychobiological theoretical understanding of the phenomenon. These common interests eventually lead to the suggestion of a book that addressed these issues and the first detailed plans were formed at one of the initial group meetings. This was at a symposium held at Göteborg University, Sweden on October 10—11, 1997 (The First Research Conference on Regression Periods in Early Infancy; chair: M. Heimann), a meeting used to discuss both replication studies and current theoretical issues. More specifically, preliminary versions of four papers included in this book were discussed (chapters 2, 4, 5, and 8).

Before a more detailed description of the book and its content is presented, a word of caution is warranted: The term *regression* might be confusing to some readers because of the many different connotations it has. To prevent confusion, the reader is advised to forget these connotations. The term is used here in a very restricted sense, in that it only refers to the return to a high frequency of mother–infant contact, characteristic of the earliest period, and the phenomenon *regression period* is positive in the sense that it announces progress. It is this understanding of the term that is used throughout this volume—a volume that can be seen as organized in three different parts.

Part I is made up of chapters 1 to 4 of which the first is a brief introduction that presents some more detailed background regarding how to understand the term *regression periods*. Next, chapters 2, 3, and 4 present studies from Spain (Sadurni, & Rostan), England (Woolmore & Richer) and Sweden (Lindahl, Heimann, & Ullstadius). These replication studies form the core of this book and can even be said to constitute the central motivation for putting the book together. They were all part of the ISIRP group, the aim being to test if similar indicators of regression where to be found at the same ages in a various countries and cultures. Efforts were made to match those procedures used in the original Dutch study (see van de Rijt-Plooij & Plooij, 1992, 1993) although cultural variations also created important differences between the studies. Some studies, like the Spanish study (chap. 2), almost exactly replicate the original Dutch findings, whereas others (e.g., the Swedish study, chap. 4) can be said to replicate the findings on a general level with differences when it comes to details. However, taken together, chapter 2 to 4 present evidence in favor of the existence of several specific regression periods during a child's first 15 months.

Part II of the book (chaps. 5–7) consists of three chapters authored by Frans X. Plooij together with Hedwig H. C. van de Rijt-Plooij and colleagues. These chapters encompass further in-depth studies and analyses that broaden our understanding of how the regression periods affects early developmental processes. In chapter 5 Plooij and van de Rijt-Plooij discuss different kinds of noise in the dataset and possible consequences of not adequately dealing with such influences. Important findings might be overseen if factors influencing the data are not adhered to. They especially focus on factors that might be difficult to control for (e.g., extremely strict regimes in caring for the young infants or concealed mental illness in the mother). Factors like these exert strong influence and might, according to the authors, conceal the expected regression periods. Among other issues, this chapter re-analyses data previously published by others (see Weerth & van Geert, 1998) claiming that the dataset supports different conclusions when noise factors are sorted out.

Chapter 6 (by Plooij, van de Rijt-Plooij, van der Stelt, van Es, & Helmers) expands our understanding regarding the regression phenomenon by investigating the complex interactions between the 10 regression periods and the CNS-immune system. More specifically, the chapter explores the hypothesis that the distribution of illnesses over development should be nonlinear and display a multimodal distribution during the first 20 months of life—an idea that is also partly confirmed by the analysis. Peaks in illnesses and regression periods seem to be linked, although the exact mechanism behind this finding is largely unknown. The last of the three chapters in Part II of the book (chap. 7) presents a report on a possible link between early regression periods and a negative developmental outcome. More specifically, the chapter discusses data that indicate a connection between the Sudden Infant Death Syndrome (SIDS) and observed regression periods. In summary, the authors claim that the frequency distribution of the number of SIDS victims over age shows a multimodal distribution for girls, not for boys. At present, we have no good explanation for this effect. This is clearly an observation that warrants further study.

The final chapters (Part III of the book: chaps. 8 & 9) tackle more theoretical issues. In chapter 8, Trevarthen and Aitken present an impressive review of current developmental data from several fields: embryology, genetics, psychobiology, and developmental psychology. Their integrative attempt contrasts modern dynamic systems theory with a more traditional biological view of "intrinsically regulated development in an organism". The outcome of this comparison and discussion will probably be surprising to some people. It is not automatically so that a "modern" theory always provides a better answer than a "traditional" one. Trevarthen and Aitken define their starting point in the following way: "In short, we ask what kind of biological theory, at what level of organismic self-regulation, do we need to understand what infants do, how they conceive and care about their world, and how they change themselves and their world." In understanding how the infant becomes an active agent in the world they propose that we are born with a system they call IMF (*Intrinsic Motive Formation*). This system is part of how the immature central nervous system works and has an important regulative function. Moreover, they also suggest that the regression periods that are the core objects of study in this volume might be better thought of as *Periods of Rapid Change* (PRCs).

Finally, in chapter 9, Frans X. Plooij presents an integrative view of the book, as well as an in depth theoretical discussion based on the observations presented in this volume. The title of this last chapter reflects this integration; "The Trilogy of Mind" refers to the need of adhering to motivational processes based on thinking, feeling, and desires (or cognition, affection, and conation). This is discussed within a framework largely based on Power's (1973) hierarchical perceptual control theory. In this view, it becomes possible to include gene controlled processes with individual development and early interactional experiences.

It is my hope that the picture created by this volume will help to broaden our knowledge regarding phases of change or instability during early infancy. There seems to be more such phases than previously believed. However, the evidence put forward here is far from final. As becomes obvious when reading the chapters, there are still many unanswered questions. But this fact does not preclude a conclusion saying, based on our current evidence, that regression periods ought to be considered as a real phenomenon and dealt with accordingly whenever developmental processes in infancy are discussed. The reader should read each chapter and judge the data presented, as well as the arguments put forward. Hopefully, the reader will reach a conclusion similar to that put forth herein.

—*Mikael Heimann*

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1

Regression Periods in Human Infancy: An Introduction

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The regression phenomenon discussed in this book is, evolutionarily speaking, probably very old and has been observed among humans, primates, and nonprimate mammals. Horwich (1974) reported specific regressive periods (peaks in nipple contact among 12 species of monkey) in primate behavioral development and also indicated that these peaks occur at similar times in development and become less pronounced as the infant develops. Regression, according to Horwich, specifically refers to the return to a high frequency of mother–infant contact, characteristic of the earliest period, and is supposed to rest on graded emotional states of insecurity. Later, van de Rijt-Plooij and Plooij (1987) expanded Horwich's findings when they reported they had found regression periods when studying free-ranging chimpanzees. Before each "leap" in independence, when a sharp decrease in mother–infant body contact was found, a regression period occurred followed by a period of mother–infant conflict over body contact. Regression was expressed, first, in a temporary shift back to mainly staying closer to mother, and, second, in a temporary increase in the amount of ventro-ventral contact.

Next, van de Rijt-Plooij and Plooij (1992) studied human infants and found 10 regression periods in the first 20 months of life. The data, based on questionnaires and weekly interviews, revealed an impressive consensus in the mother–baby pairs on the ages around which the baby shows regressive behavior and is experienced as "more difficult." These difficult time periods occurred around weeks 5, 8, 12, 17, 26, 36, 44, 51–53, 61–62, and 72–73 (van de Rijt-Plooij & Plooij, 1992; see Fig. 1.1); these observations were validated by direct observation on mother–infant contact in two homes.

Furthermore, van de Rijt-Plooij and Plooij (1993) found that, just like in chimpanzees, increases in conflict were associated with the observed regression periods also in humans. Mother's reaction to regressive behavior consisted of three mutually exclusive forms: *Annoyance*, *Promoting Progress*, and *Clashes*. Annoyance was typical for parents of small babies, Promoting Progress was predominant in the second half of the first year, and Clashes were observed from 6 months onward. All three reflect con-

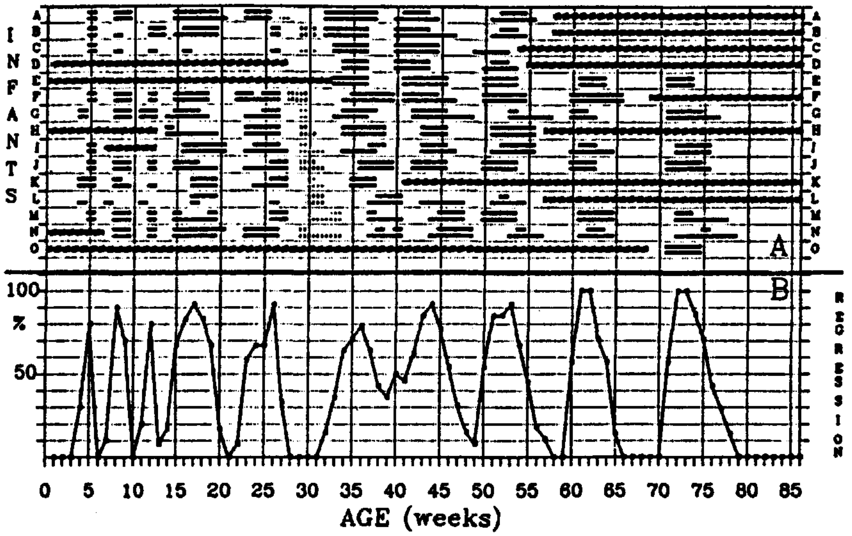

FIG. 1.1 Regressive periods during infant development. (A.) The pairs of solid, horizontal bars stand for regressive periods. The top bars represent weeks experienced as difficult by the mother. The bottom bars represent concrete regressive infant-behaviors as reported by the mothers. The hatched bars stand for weeks when an infant was not observed. The dotted bars around 30 weeks represent the 'checking back pattern' as reported by Mahler et al. (1975, p. 55). This behavior was new and not regressive. (B.) The percentage of mothers that reported concrete, regressive infant behaviors over age. From "Infantile regressions: Disorganization and the onset of Transition periods," by H. H. C. van de Rijt-Plooij and F. X. Plooij, 1992, *Journal of Reproductive and Infant Psychology, 10*. Copyright © 1992 by Taylor & Francis, LTD. Reprinted by kind permission of Taylor & Francis, LTD.

flict of interests between mother and baby that were clustered in distinct periods, which shortly followed the regression periods (see van de Rijt-Plooij & Plooij, 1993).

McKenna (1979) concluded that "the concepts of socialization and attachment, traditionally the pivotal theories around which mother-infant relationships are explained, need to be reexamined with respect to underlying neurological mechanisms that may govern these phenomena at particular points in ontogeny" (p. 284). Several observations have been made showing strong links between changes in behavior and intrinsic changes in the baby's brain (see Fisher, 1998; Fischer & Rose, 1994; Mende, Wermke, Schindler, Wilzopolski, & Höck, 1990; Wermke & Mende, 1993; Surbey, 1998; Trevarthen, & Aitken, chap. 8 in this vol.). These findings indicate a central role for regression periods in the psychological development of the human baby. On the one hand, there is the temporal link with brain changes. On the other hand, each regression period signals forthcoming periods of developmental advance and the emergence of an array of new skills as a consequence of parent–infant conflict and renegotiations of old privileges, and might be linked to increased risk of pathology. Because brain changes are not directly observable and the emergence of new skills shows tremendous individual differences (Rosenblith, 1992, pp. 311–320), the age-specific regression periods found by the Dutch team (van de Rijt-Plooij & Plooij) stand out as unique hallmarks to direct a study of developmental change.

It is an obvious statement to add that the basic idea discussed in this book is an old one. The relation between regression (or disorganization) on the one hand and progression (or reorganization) on the other hand has been considered for almost a century by scientists from various backgrounds (e.g., Bever, 1982; Kortlandt, 1955; Kozulin, 1990; Mahler, Pine & Bergman, 1975; McGraw, 1945/1974; Mounoud, 1976; Peterfreund, 1971; Schore, 1997; Scott, 1986; Smotherman & Robinson, 1990; Thelen, 1989; Werner, 1948). Playing such a central role, regression periods deserve further study. Horwich (1974) concluded that "although the precise occurrence of regressive periods may be determined by individual genetic variations, it is obvious that species and subspecies genetic variation, gender, and environmental conditions have an effect on the emotional state of the individual and presumably also on these regressive periods" (p. 147). Having documented species genetic variation already and with Horwich's statement in mind, the following four questions were found to be of central importance:

1. Can the phenomenon of regression periods as found by van de Rijt-Plooij and Plooij (1992) be replicated in other countries and cultures\
2. What environmental conditions have an effect on these regression periods and how\
3. Are there physical conditions in infants that show a nonlinear distribution over age similar to regression periods\
4. Have brain changes been detected since the review of Fischer and Rose (1994) at other ages than the six reported by them, and, if yes, how do these relate to the ages at which regression periods are found\

The remaining chapters tackle these questions. The first one, that of replication, is addressed by the first part of the book (chaps. 2, 3, & 4) while questions number two and three are addressed by chapters 5 to 7. They deal with various environmental conditions and other factors that might influence the regression periods (e.g., depression, rigid feeding schemas and SIDS). Finally, chapters 8 and 9 take on the fourth question. In chapter 8 the literature of the last 10 years on age-specific brain changes is reviewed and new theoretical insights suggested, and in chapter 9, conclusions are drawn, suggestions for future research are made, and models of the processes underlying the regression phenomenon are discussed.

The replication studies form a central unit of this book in that they present supporting observations from three independent research groups. Efforts were made to create a situation in which the procedures of subject selection and observation in each country closely matched those used in the original Dutch study (van de Rijt-Plooij & Plooij, 1992, 1993). All three studies also used similar criteria for deciding when a regression period had occurred and similar coding criteria (reliability becomes a critical factor in studies based on intense longitudinal data collection from single subjects). However, the reader will note that the studies carried out in Sweden, Spain, and England also differ in how they were actually carried out. Variations occurred as a result of differences in resources (e.g., funding), of necessary cultural adaptations, and as an effect of some slightly different focus in some of the specific research questions asked. Despite these variations, all three studies come up with similar conclusions in that they favor van de Rijt-Plooij and Plooij's hypothesis.

It is my view that the observations presented throughout the book provide good support for the fact that up to 10 regression periods might exist during the first 15 months of life. However, it is also a fact that this book leaves out important issues for further studies to explore and discuss. It is, for instance, still an open question how the regression periods discussed in this volume might influence later psychopathology, the early attachment formation process and early emerging cognitive capacities (e.g., imitation; see Heimann, 2001, 2002). Furthermore, we also lack detailed knowledge on how these periods might be affected by individual differences or modulated over time by temperament and by the early parent-infant relationship. Nevertheless, the rest of the book will provide us with observations and theoretical formulations that ought to be taken seriously by anyone interested in understanding development in the infancy period.

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2

Reflections on Regression Periods in the Development of Catalan Infants

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This chapter is part of a wider research project focused on the study and analysis of mechanisms and processes underlying sociocognitive development in the first 3 years of life. Children continually evolve and develop in a process that at first would appear to be gradual. Observation of any capacity or ability would, hopefully, find a continuous and increasing developmental curve. Traditionally, the processes of development have been viewed as a succession of structural and functional levels that assume a homogenous basis underlying the manifest heterogeneity. In this sense, development is both continuous and discrete, characterized by a constant addition of new dimensions belonging to the same organizational structure. One example is the growth of vocabulary from the second year onward. However, development is also characterized by dramatic transitions affecting wide behavioral dimensions. In accordance with Werner, transitions can be defined by the emergence of behavioral forms that are not reducible to extant forms, as well as by the absence of intermediary forms. In the case of language, following from the previous example, the step from gestural communication to word use can be seen as a qualitative change. In other words, the transition represents a discontinuous, qualitative leap in the organization and manifestation of a child's abilities and competencies.

During the past 50 years, developmental psychology has focused on the localization and nature of these transitions. More recently, this issue has been linked to the loss of competencies or abilities shown by a child on the threshold of a developmental change—a phenomenon known as *regression.* These regressions indicate instability in the system, a developmental moment during which organizational forms are beginning to be lost while new patterns have yet to be consolidated. Thus, such instability is the result of the transitional change on which the child's organism is experimenting. Van de Rijt-Plooij and Plooij (1992) suggested the existence of regression phenomena in children's emotional development. They found 10 periods of emotional regression in the first year of life, located at 5, 8, 12, 17, 26, 36, 44, 52, 61–62, and 72–73 weeks. These periods are mainly characterized by a loss of the child's increasing independence and a return to forms of attachment or demands for maternal attention. Among these behavioral traits are an increase in crying, easy waking, reduction of appetite, shyness with strangers, an increase or decrease in activity, dressing or bathing difficulties, and displays of affection toward the mother or objects. According to one of the hypotheses put forth by van de Rijt-Plooij and Plooij, these regressions indicate a soon-to-come developmental transition, that is, they are indicators of impending change.

CURRENT LITERATURE ON TRANSITION AND REGRESSION PERIODS

Many scholars have found qualitative changes at determined ages in early childhood, which have repercussions for the transformation of various capacities or competencies. Spitz (1973, Sp. trans.) referred to three transition periods during the first 18 months of life. Later, McCall, Eichorn, and Hogarty (1977) proposed the existence of four periods, which they specified as emerging at 2, 7, 13, and 14 months. A more specific example is offered by Kagan (1984), who proposed the emergence of self-awareness in the second year as a qualitative change that has repercussions for the understanding of social customs and the awareness of one's own emotions, intentions, and competencies. The period between 18 and 24 months is likewise seen as one of profound changes—changes in abilities and attention control (Ruff & Rothbart, 1996) or in the ability to remember past experiences and predict future events (Meltzoff & Gopnik, 1989). Along the same line, Trevarthen (1982) proposed two important transitions in the development of human intersubjectivity: the emergence of primary intersubjectivity at around 2 months and a new reorganization between 9 and 12 months, giving rise to secondary intersubjectivity.

Some authors have stated that discontinuity implies not only developmental leaps over time, but also retraction and loss of behavior and capacities apparently acquired. This phenomenon is usually called *regression.* For example, Maratos (1982) observed that a few-days-old child's capacity to imitate the movements of the tongue, the mouth, and crying disappears after 2 months only to return around 6 months in a more robust and elaborate way. In addition, at around 2 months, the child's capacity to put a hand in its mouth or to suckle and look at the same time is lost (Monoud, 1982). And, at the age of 4 months, the child's vocal development seems to be retarded in terms of both rate and differentiation (Bever, 1982). At 4 months, it has also been observed that the behavior of grasping with the hand, as well as the tonic neck reflex, the Moro reflex, and the dorsal sole reflex, disappear. The former reappears at 5 months (Trevarthen, 1982), and the others are replaced by more effective behavioral patterns (Bever, 1982). Karmiloff-Smith's (1994) representational redescription model shows how children go through different cyclical developmental phases, which implies temporary losses or retraction of acquired behavioral mastery. Another example showing regressions is that of Zelazzo (1982), who found that, at 9½ months, there was a reduction in the production of both vocalizations and visual fixation in response to physical and social stimuli.

In light of these findings, it would appear that, just as with transitions, there are different classes of regressions affecting different arenas. Additionally, as regards both transitions and regressions, findings often originate in diverse fields of study, making it difficult to draw general conclusions concerning the nature of these phenomena. However, the concept of regression per se is general in nature. It encompasses either implicitly or explicitly the notion of a return to previous structures or forms of behavior and can be applied to a multitude of processes or areas in development.

The explanations given of the phenomenon of regression are diverse. Many scholars claim that regression is caused by the mechanisms underlying observable behaviors. For example, Monoud (1982) interpreted the child's inability to put its finger in its mouth and to look at its mother when suckling as being caused by a reelaboration of the mechanism enabling the coordination of such behavioral sequences. He suggested that the new mechanism, which does not emerge until 6 months of age, serves to regroup two representations into one totality. In Karmiloff-Smith's representational development model, the temporary loss of correct behavioral patterns is caused by a reorganization of the data necessary in the transformation of implicit representations into explicit ones. In a similar way, Zelazzo (1982) asserted that the observed regressions reflect the child's progression from execution of indiscriminate responses to stimuli up to the capacity to choose responses to specific situations.

Another group of scholars (Fisher & Rose, 1994; Thelen & Smith, 1994), without contradicting the previous explanation, emphasize the competitive processes occurring when a new ability is emerging or when different subsystems are developing nonsynchronically. For example, Thelen and Smith (1994) explained that the disappearance of reflex behaviors, such as automatic walking, may be caused by an increase in fat deposits in the child's muscular tissue. The increased weight due to fat inhibits the walking reflex. If the child is put into a bath where water compensates for the excess weight, then the reflex reappears.

Although there is a great deal of scientific evidence for periods of regression and transition, few studies empirically relate these phenomena. However, van de Rijt-Plooij and Plooij suggested the existence of regressions that affect the emotional arena and are inextricably related to developmental transitions.

RESEARCH ON REGRESSION PERIODS IN THE CATALAN POPULATION

An investigation was begun in 1995 to discover whether the regression periods described by van de Rijt-Plooij and Plooij (1992, 1993) could be observed in a sample of Catalan infants, and whether the ages at which they emerged and their characteristics were likewise comparable to those found in Holland.

Participants

The sample of subjects studied consisted of 18 babies (10 boys, 8 girls) between 3 weeks and 14 months old, distributed across four mother–infant cohorts. Each cohort consisted of five dyads and was followed for approximately 5 months, as shown in Table 2.1. Two children participated in two cohorts, thus there were only 18 babies but four cohorts of five dyads (see Fig. 2.1, children 1E and 2D). The infants chosen belonged to Catalan families of middle socioeconomic and cultural class, and all mother–in-

TABLE 2.1
Distribution Per Periods of the Cohorts Studied

	Age	*Periods by Weeks*	*No. of Pairs observed*
1 cohort	3 weeks–5 months	3 –20	5
2 cohort	3 months–8 months	12–33	5
3 cohort	6 months–11 months	24–44	5
4 cohort	9 Months–14 months	36–56	5
			Total: 20 pairs

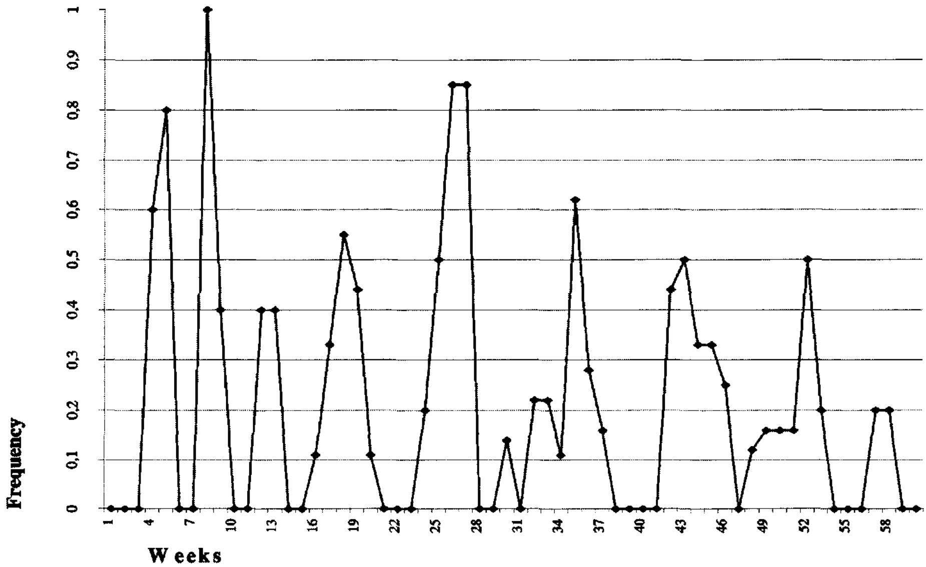

FIG. 2.1. Regression periods: Frequency per week. From an article published in *The Spanish Journal of Psychology, 5*(1), 2002, by M. Sadurni and C. Rostan. Copyright © 2002 by *The Spanish Journal of Psychology*. Reprinted with permission.

fant pairs had sufficient social support and did not present relational problems of any kind.

All babies observed were full-term, except for one girl who was born after 7 months; she was followed according to her gestational age. No infant presented serious health problems or developmental delays. Ten babies were firstborns, seven had one older sibling, and one had two older siblings. Although it would have been preferable if all families had lived in the same urban center, only five fulfilled this criterion. Nevertheless, the rest lived in small towns or residential areas very near the city, over a range of less than 40 kilometers, so that a possible distinction between rural and urban families is unlikely.

Finally, the families recruited for the study were acquaintances of some members of the research group or of students from the university. Their participation was voluntary and unpaid.

Procedure

The methodology used adheres to that proposed by van de Rijt-Plooij and Plooij for the study of regression periods. The research design corresponds to a cross-sectional and longitudinal model. For this reason, the 18 mothers were divided into cohorts covering 5-month age intervals.

A multiple case study approach was used to analyze the data. This allows intraindividual comparison throughout the period of investigation. Subsequently, the study checked whether the supposed signs of regression periods correlated with the occurrence of qualitative behavioral change in all babies.

Instruments Used

A *questionnaire* completed by the infants' mothers was collected weekly. This questionnaire is a translation and adaptation of the instrument used by van de Rijt-Plooij and Plooij. The changes made were based on the suggestions of a group of Catalan mothers (with babies in the age range of the subjects) who had read the translation (Rostan, 1998).

A *semi-structured interview* was conducted weekly and was always recorded on tape. In this open interview, mothers were asked about their experience with their baby in the course of the week. The information mothers spontaneously provided was complemented with a series of questions that indirectly and informally revealed relevant aspects of their infants' development.

Finally, a 3-hour *observation* was carried out every fortnight during the first 5 months and once a month from that time onward. The aim of the observation was to corroborate the information provided by the mother with the researchers' own perceptions, so that the data would be as objective as possible. To this end, a check sheet was designed on which to note the frequency of particular emotional behaviors. The study also assessed the degree of contact or physical distance of the mother–infant pair, using the categories of the Ethological Observation System proposed by van de Rijt-Plooij and Plooij (1992).

RESULTS

The following results on regression periods correspond to the data obtained through the questionnaires and the interviews, as already described. The analyses focus on those periods of infant behavior perceived by mothers to be difficult.

The mothers gave detailed, weekly accounts of the changes in their babies' emotional behavior. The criterion used to code a regression period was the coexistence of three of the behavioral categories that typify the episodes specified by van de Rijt-Plooij and Plooij (1992): an increase in bodily contact between mother and child (e.g., the mother says that the infant cannot be alone for a moment and is only calm when carried or held), and an increase in crying and irritability behaviors (e.g., the infant is described as extremely sensitive or vulnerable; statements most frequent in the data were of the type: "I don't know what's the matter with him" and "I don't know how to soothe her"). Some mothers try to find a physical basis for these disruptive behaviors, deducing that perhaps the child does not feel well or "is incubating something." Visits to the pediatrician are not uncommon during these episodes. Note that those cases when an ache or illness has proved to be physical have not been classified as regression periods. The final category is the presence of a third disruptive element, such as alteration in the sleep–wake cycle, decreased ingestion, or very altered activity, drowsiness, and so on.

Following the criteria for coding a regression period, inter- and intracoder assessment reliability was calculated for regression period categorization, starting from the questionnaires and interviews. Intercoder agreement was 78.2%, and intracoder agreement was 90.1%.

Figure 2.1 shows a graphic representation of the results. Time in weeks is plotted on the x-axis, and relative frequency is represented on the y-axis. Peaks in relative frequency of regression periods were found for the following weeks: 5, 8, 12–13, 18, 26–27, 35, 43, 52. The mean length of the regression periods was 2 weeks, with a range of 1–4 weeks.

Although the percentages in this initial analysis indicate a fit less than 100%, a closer look at Fig. 2.2 reveals that nearly all mothers reported a pe-

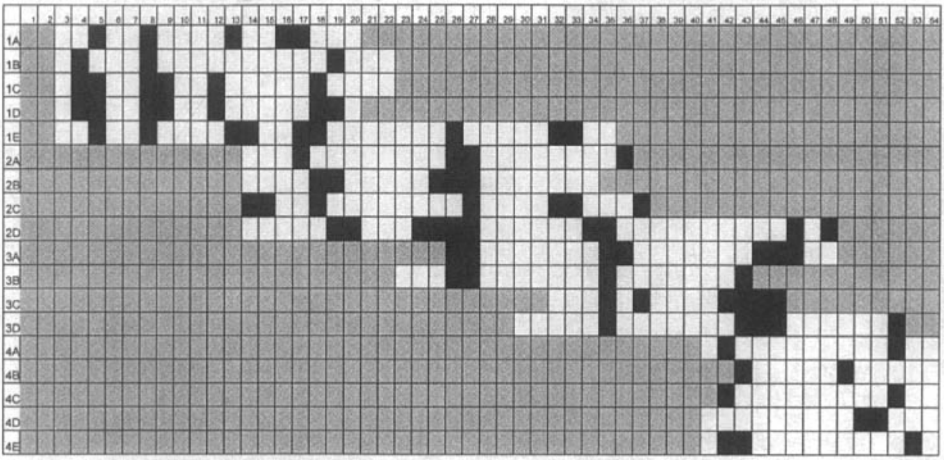

FIG. 2.2. Distribution of regression periods for each mother and each week. From an article published in *The Spanish Journal of Psychology, 5*(1), 2002, by M. Sadurni and C. Rostan. Copyright © 2002 by *The Spanish Journal of Psychology*. Reprinted with permission.

riod of regression around the expected ages, with the exception of two (dyads 1B during Week 12 and 4D during Week 41). As can be easily seen, the "range interval" is placed 1 week before or 1 week after the period in which the highest number of regression periods is concentrated.

The previous observations highlight two basic points: The descriptions of behaviors characterizing a regression period are uniform and the emergence of these developmental episodes is regular. Certainly, a comment must be made on some differences among the dyads studied. For instance, some children concentrate this disruptive period, whereas others have prolonged periods of instability. Temperamental and relational characteristics are also evident. Children are varyingly calm even within the same regression period, and mothers experience these moments as differentially annoying and difficult. Likewise, it can be observed that regression periods appear more concentrated in the first weeks and more dispersed during the last. This observation should be considered more carefully, although for the moment this discussion underlines only that this difference does not affect the continuous distribution of such periods. A clear way of representing the location and minimum interval of weeks necessary to gather the maximum percentage of regression periods is presented in Fig. 2.3, where the *y*-axis shows the percentages and the *x*-axis the weeks.

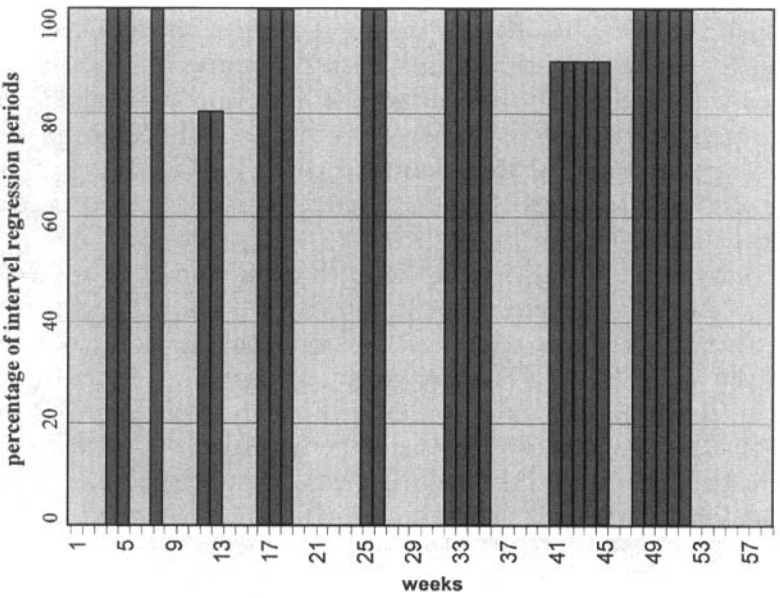

FIG. 2.3. Intervals (in weeks) of regression periods.

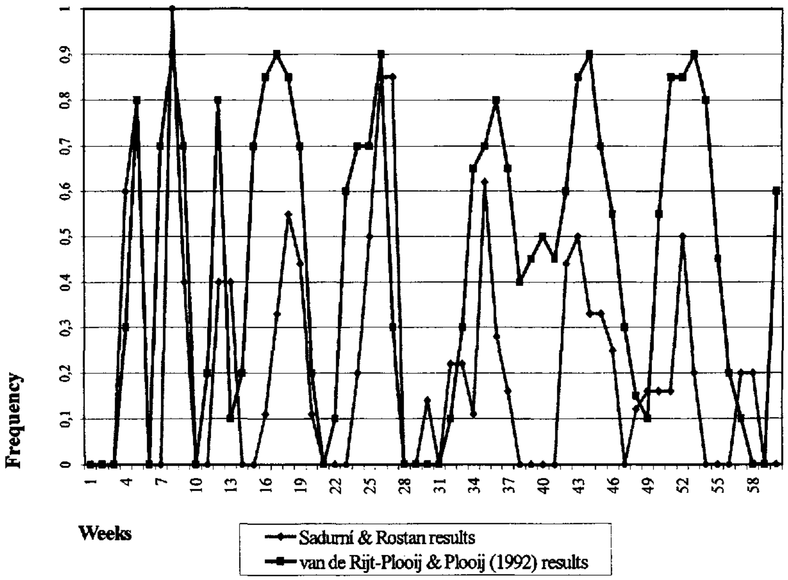

FIG. 2.4. Comparative results between the current study and data previously reported by Rijt-Plooij and Plooij. From an article published in *The Spanish Journal of Psychology, 5*(1), 2002, by M. Sadurni and C. Rostan. Copyright © 2002 by *The Spanish Journal of Psychology*. Reprinted with permission.

A comparison of the data here (see Fig. 2.4) with that obtained by van de Rijt-Plooij and Plooij shows, first, that the number of regression periods found throughout the first 60 weeks of life coincide. In both studies, eight regression periods were observed. Second, the weeks around which regression periods are distributed are quite concordant for four of the indicated periods. For the other four, the discrepancy is on the order of plus or minus 1 week.

Despite similarities in findings from the two studies, consider that, whereas the maximal percentages in van de Rijt-Plooij and Plooij's work were never under 80%, in our research five of the regression periods are located between 40% and 62%. Seen graphically (see Fig. 2.4), the distributions of regression periods are more diffuse than those of van de Rijt-Plooij and Plooij. One possible explanation is that the instruments used to collect information differed between the two studies. In our case, as mentioned in the procedure section, a questionnaire and a direct interview with the mother were used, whereas in the original Dutch study information was collected mainly through a check sheet on which the mother reported every half hour the changes in her child's behaviors. These methodological differences, to be sure, have consequences for the way mothers perceived and reported their infants' behavior. Nevertheless, the concordance between the two studies is high, suggesting a quite regular pattern as regards the existence and emergent ages of the regression periods identified by van de Rijt Plooij and Plooij (Sadurní and Rostan, 2002).

MOTIVES FOR STUDYING REGRESSION PERIODS

Van de Rijt-Plooij and Plooij suggested that regression periods can be understood as behavioral signs of brain reorganizations that the infant experiences during the process of development, particularly during the postnatal period. According to this line of reasoning, the maturation experience causes loss of control and of homeostatic regulation. The infant cannot restore equilibrium itself, so there is an intrinsic need to activate the systems that guarantee the attention and care necessary to the infant's organism during a phase of instability and change. Although these periods deserve scientific attention in their own right, they are particularly relevant for other reasons. First, as also pointed out by van de Rijt-Plooij and Plooij, during regression periods the infant's mind is very sensitive and open to external stimuli, mainly to the socioaffective stimuli coming from the mother. Through crying and expression of uneasiness, the infant seeks and usually gets more motherly attention. However, the mother and other adults interacting with the infant are not merely important sources of affective stimuli. At the same time—and this is the crucial idea—they make up the dialogical matrix through which children acquire and share the dominant meanings of their culture (Sadurní, 1994). The theory of development suggested by Vygotsky (1978) is very clear in stating that the interrelation created between two people at different levels of psychological development (the adult–child system) constitutes the main process through which the child's mind is psychically constructed. The idea to be emphasized is that intensification of adult–child interactive behaviors right on the threshold of a developmental transition contains an element that reaches beyond supplying the emotional security and stability the child needs. At a time of transformation and change, this intensification is part of the process that allows the individuals' internal structure to be modified and their psychic development to be oriented toward new levels of functioning. The following sections tackle this point.

It is a well-accepted notion that child development occurs through recursive loops between the endogenous and the exogenous—between the biological abilities present at birth and the external disturbances capable of stimulating their fundamental structure or organization. This is the essence of the concept of an organism as an "open system," that is, a system whose existence and structure are realized through constant interaction with the environment. Nevertheless, the crucial idea is that organism and environment are not two independent entities. In fact, the environmental elements with which the organism establishes its life interactions are not a result of chance or opportunism; on the contrary, they are dictated by the organism's own constitution. This is what Maturana and Varela (1990) referred to with their notion of structural determination. The idea of organisms as structurally determined means that they themselves specify the environmental disturbances capable of affecting them. These perturbations, in turn, bring about the changes that will enable the individual's own development—the changes that will facilitate expansion of ways of functioning. The important point here is that this connection between organism and environment is of a fundamentally social order. In other words, for the human infant, the input it receives from its "the other" is not only necessary for its survival, but also contributes to shaping it as a person. Bråten (1988, 1998) postulated that infants are born with the necessary prerequisites for entering into a dialog. Thus individuals possess, at birth, a dialogic mind.

In recent years, the field of developmental psychology has certainly paid special attention to research highlighting the psychobiological abilities enabling the human baby to pursue ways of understanding and cooperating with others. Trevarthen's captivating work has been paradigmatic in this area. The thread of his ideas is that the bases of culture must be found in human beings' motives for mutual understanding and cooperation. In a developmental perspective, children show a fundamental communicative competence a short time after birth, and they develop this competence remarkably throughout their first 3 years of life. From their first months, infants perceive emotive expressiveness auditorily and visually. Trevarthen (1984) talked about an innate predisposition to share and tune into the basic motivational states of the other (primary intersubjectivity). Between mother and child, an alternation of expressive movements and of "mutual engagement" takes place. Through the interchange of expressive signals, the adult–child dyad spins an affective net that engages the mother and child and leads the child on its first steps toward knowledge of the surrounding world. It is this connection between the motivational systems of infant and mother that, by opening their minds to a first level of understanding, lays the foundation for a subsequent cooperative frame. According to Trevarthen (1995), "A newborn searches for conversation with a partner. Before gaining capacities for tracking and manipulating objects, he or she will strive to enter into imitative games or expression, stimulating and attending the affectionate parental responses. In the first year, before language, these same behaviors will facilitate learning of meanings through intersubjective negotiation" (p. 375).

Although development and emergence of other internal and external mechanisms are necessary for the child's mind to advance toward complete intersubjective ability (Sadurní, 1995), it seems evident that the emotional interchange between adult and child, which is characteristic of infants' first years, constitutes a first developmental matrix that opens and encourages the child's mind to seek new forms of knowledge. So, through dialogue and interaction with their fellow creatures, children become open to culture—to the meanings dominating the social interchanges of their community members. As Tomasello, Kruger, and Ratner (1993) argued, although many higher mammals are organized in social groups, only man lives immersed in a culture. This implies a whole range of artefacts and skills, the knowledge of which must be shared by all members so that cooperation among them for (or not for) the benefit of society is possible. The interchange of information about intentions, moral rules, social meaning, and socializing guidelines is transmitted from generation to generation through human communication. In this sense, it seems logical to postulate that, throughout evolution, it has been necessary to ensure the survival of mechanisms that predispose human beings to understand one another. This suggests that regression periods are activators of the relational bonds between mother and child. These periods occur at moments in which the infant's brain is predisposed to new transformations and changes, and are therefore of vital importance in the organization of the ontogenetic process of knowledge acquisition.

CONCLUSION

The beginning of this chapter mentioned that the present study is part of a wider project concerning children's sociocognitive development. During recent years, our line of research has focused on the process enabling the human mind to become an intersubjective mind (Sadurní, 1995). During the past 20 years, developmental psychology has intensified its efforts to understand this process, as well as to report on the relevant factors permitting the emergence of intersubjective knowledge. Current discussions within the field hold that the child, contrary to notions based on Piaget's theory, does not construct by itself the meanings permeating people's everyday lives. Nor is it possible to explain development as primarily influenced by environment and learning, as if the cognitive system were formed by simple "internalization" of preestablished symbolic structures. As a reaction to this last tendency, which is deeply rooted in Vygotsky's theory, the pendulum has swung toward nativist positions that explain development in terms of genetic specification and maturation. Both positions lead to a polarized debate between "nature-nurture." However, excluding discussions to endogenous or exogenous restrictions keeps researchers from discovering the complex interactions occurring between organism and environment. As maintained by Sadurní and Perinat (1994), the key to understanding the process of sociocognitive development is analysis of the relation between biological aspects and the impact of cultural factors in formation of the human mind.

The study of transition and regression periods in the process of development provides clear examples of the complex relations between organism and environment. This chapter has promoted the idea that, at an emotional level, regressions experienced during the first 2 years of life constitute an endogenous mechanism that facilitates the intermental connection between adult and child. As Trevarthen (1984), Campos (1994), and other scholars revealed, emotions are born to regulate contacts and relationships among people. The fact that this mechanism becomes particularly active when the infant's brain is extending and reorganizing its internal neural structures suggests that emotional systems emerge at certain points in development to facilitate interpersonal communication between adult and child. At the same time, this experience and social interaction involving the infant's mind will have repercussions for the nature and orientation of biological changes in the human brain. The effects of experience on the brain are well known and it is not necessary to insist on that score (Campos, 1994; Greenough, Black, Wallace, 1987; Hofer, 1987).

Following the thread of the previous reflections, the data from our empirical work must be interpreted. On the one hand, regularity in the emergence and behavioral manifestations of the regression periods has been noted. Such regularity might suggest a strong "genetic timing" influence, although, according to Hofer (1987) and others, the social relation established between mother and child also plays a role in setting the child's biological clock. On the other hand, despite regularities, each mother–child pair is unique in relation to the group studied. If the figures provided are considered, then it is possible to see how the duration of regression periods differs from one child to another. For some of them, moments of difficulty appear concentrated to a brief time interval, whereas others persist in the manifestation of the disruptive behaviors that characterize them. Nor is the behavior of mothers homogeneous. As in the study by van de Rijt-Plooij and Plooij (1993), our mothers could be categorized according to their interactive style during difficult moments. Although the intent was to analyze this aspect more rigorously in later work, some mothers tend to become extremely nervous when faced with their infant's irritable behaviors, whereas others avoid direct contact using socially acceptable justifications such as "I mustn't get him used to it/ he's all right/ he's just kidding/ pulling my leg." Still other mothers do not seem to consider their children's difficult periods as conflictive. On the contrary, they seem to experience a certain relief upon intensifying care for and physical contact with their children. At present, there is no data permitting analysis of the repercussions of the relational differences between mother and child for the manifestation and quality of regressions, or their impact on the qualitative changes in the developmental process. However, the expectation is to find a clear connection between the quality of communicative mother–child parameters and the orientation of the infant's course of development.

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3

Detecting Infant Regression Periods: Weak Signals in a Noisy Environment

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In 1992, van de Rijt-Plooij and Plooij reported observation and questionnaire/interview data indicating the existence of 10 regression periods in the first 17 months of life for full-term normal infants from intact families. These periods started at almost the same gestational age in all the infants studied.

Drawing on perceptual control theory (Powers, 1997), van de Rijt-Plooij and Plooij argued that these periods mark times of brain reorganization. At the end of each period, the baby is capable of new understanding, even though the skills that flow from that understanding may not appear immediately.

De Weerth and van Geert (1998) challenged the existence of strictly timed regression periods. Their study, which followed four mother–infant dyads, was the first publicized replication of the work of van de Rijt-Plooij and Plooij and failed to support the original findings. However, an increasing number of researchers are providing empirical support for their findings (chaps. 2, 4, & 5, this vol.). This has led to some debate about frequency and timing of the regression periods (e.g., Cools, 1998, de Weerth, 1998; de Weerth & van Geert, 1998; Plooij, 1998).

THE PRESENT STUDY

This chapter describes part of a project undertaken in Oxford, UK. One object of the research was to see if the Plooijs' findings of the existence and timing of regression periods at around 12, 17, and 26 weeks could be replicated. Another object was to see if maternal postnatal depression affected the length and timing of regression periods. (It did; Woolmore, 1998; Woolmore & Richer, in prep.). Two groups of mothers and their infants were studied, one suffering from postnatal depression, the other not. This chapter reports only data from the 30 *non*depressed mothers.

IDENTIFYING REGRESSION PERIODS

Identifying regression periods is not straightforward, and this difficulty may partly account for the conflict of findings in the literature. In their early work, the Plooijs used two strands of information. One was the mother's feeling that her child was more (in Dutch) "hangerig" (experiencing a difficult time, being in need of mother). The other strand was the mother's observations of discrete infant behaviors. These observations were validated by the researchers' own direct observation of the infant's behavior. Out of this work the Plooijs developed an algorithm to identify regression periods. This algorithm (Fig. 3.1) was used in the present study.

The identification of a regression period relies on the observation that infants' behavior has changed compared to the previous week(s), and that they have become more distressed, clinging, difficult, and so on. A number of factors can make this difficult:

- It requires a comparison over a longish time, albeit by someone, the mother, who is (usually) intensely focused on her baby.
- It requires comparison of frequencies of behavior (more difficult) as opposed to noting the presence or absence of a behavior (easier).
- Other causes of regressive behavior (illness, separation, changes, etc.) may occur and give a false impression.
- It requires sensitive questioning of mother and a good relationship with mother, which maintains her interest in the project, in order that she is attentive to the things the researcher is interested in and she is willing to be open with the researcher and not to mislead.

1. Fractious or Changeable Mood

- Baby cried or fussed more easily
- Baby had more mood-swings

Continue if either of the above are present

Else, it is not a Regression Week

2. Attachment Related Behaviour

The infant:

- Wanted more closeness, body contact or proximity
- Tried to make even more intimate physical contact during feeding
- Attempted to gain proximity to mother, e.g. by clinging to her leg.
- Was more demanding of mother's attention

Continue if any of the above are present

Else, it is not a Regression Week

3. Additional Regression Items

The infant:

- Had sleeping problems or Nightmares
- Had eating problems
- Resisted being changed
- Was shy with strangers
- Was less vocal
- Was less active
- Sucked thumb more often
- Behaved more babyishly
- Was jealous, wanted their mother all to themselves
- Was very naughty
- Was very friendly
- Threw more temper tantrums

If at least two of the above are present
the week is classed a Regression Week

Else, it is not a Regression Week

FIG. 3.1. The Plooij algorithm for determining regression weeks.

It is easy, therefore, for observers who are insensitive or use inappropriate methodology to miss these changes; equally, observers must be vigilant not to read regression periods into their data. In signal detection theory terms, these are weak signals within a lot of noise, so there is an increased danger of making both false negative and false positive findings.

Finally, as well as the difficulties in identifying regressive behavior, there is the difficulty of measuring each baby's age, in order that the putative constant age of regressive periods across babies may be revealed. This is discussed later.

METHOD

Recruitment

Participants' first point of contact with this study was through their health visitors.[1] Health visitors introduced the study to the mothers of newborn infants in the period from 2 weeks postpartum to 8 weeks postpartum. Interested potential participants gave their permission for their details to be forwarded to the researchers. One of the researchers (AW) then contacted these potential participants and arranged a home visit.

The key inclusion criteria for mothers were that they had easy access to a telephone, they had fluent spoken English, and there was no evidence of current psychiatric condition. For the infants, the key criteria were that there should be no evidence of, or diagnosis of a condition that might be associated with, developmental delay; infants' Apgar score should be a minimum of 5 at 1 minute postpartum; and the infant should not be more that 6 weeks premature or have a birthweight lower that 2 kgs.

Initial Meetings With Mothers

During this meeting researchers outlined the project and the demands of involvement. If potential participants were happy to continue to participate in the study, they were asked to complete a consent form. After consent had been given, the Standard Clinical Interview (First, Spitzer, Gibbon, & Williams, 1996) was used to determine the existence of postnatal depression in the potential participants. The Initial Interview for Regression Period Studies (Rijt-Plooij, von der Stelt, & Plooij, 1996) was then administered to collect demographic and contextual information about the family, pregnancy, delivery, and infant. A mutually convenient time was then arranged for a weekly telephone interview—ideally the telephone interview would take place at the same time on the same day of the week.

Data Collection

The Telephone Interview. The questions for the telephone interview were compiled from the original weekly questionnaire for regression

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[1] Health visitors are specialist nurses. Their role is to make contact with the families when there is a newborn infant. They monitor the health and well-being of the infant and other family members. They may continue regular contact with the family until the infant is approximately 5 years old.

periods (Rijt-Plooij & Plooij, 1992) and from the weekly interview (Plooij, 1997). Questions for infants outside the age group being studied and any duplicated questions were removed. One question was added "How would you rate your mood over the past week (from 0–very low, to 10–very bright)\" This resulted in a 57-item questionnaire. Of the 57 items, 37 relate to specific infant behavior and 20 to mother's well-being. A computer program ("Interview") was written to facilitate the use of this questionnaire in an interview format. This program prompted the interviewer with questions, recorded responses, and displayed remaining unanswered questions. The program also permitted the interviewer to pose questions in any order. These features allowed the interviewer to ask questions in a "conversational" way and follow the mother's recounting of the infant's behavior. When all items from the interview had been coded, the program wrote a data file in a format compatible with data analysis software. The interviewer was unaware of the infants' gestational age because he was recording the babies' age from birth. Using this their chronological age did not yield a significant pattern, so in effect the interviewer was blind to the infants' real age. The mothers too were effectively blind in the data collection. All but two were unaware of the work of the Plooijs. The data from these two mothers was also in effect blind because the gestational age was different from chronological age in both babies.

When participants were on holiday, and during 2 weeks when no telephone calls were made (Christmas and Easter), mothers were supplied with a written version of the questionnaire and a stamped addressed enveloped to send the questionnaire back to the researchers.

Procedure. Telephone calls to mothers were made weekly, at the agreed time, starting from approximately Week 10 postpartum to approximately Week 26 postpartum. All 57 interview items were coded during the interview, which lasted approximately 10 minutes. In addition to recording responses to the specific questions, the interviewer made notes, which referred to the current family environment and allowed the recording of information not possible using the structured interview.

If the mother was not available at the arranged time, then the researchers attempted to contact the mother regularly for up to 3 days. If the call could not be completed within 3 days of the arranged time, then it was deemed to be missing data. If telephone calls were not made on the appropriate date, the mothers were encouraged to report only behavior that would have occurred by the usual interview time.

Second Home Visit. Mothers were visited at the end of the data collection period and given feedback about their infants, specifically about the timing and length of their infant's regression periods. Mothers were also presented with a booklet containing typed interview notes, which served as a journal of their infant's development. These were warmly received.

Preparation of Data for Analysis

Applying the Plooij Algorithm

A second computer program was written. This program read data from the files created during the interview. The program scans the data file for the 19 questions that define a regression period (see algorithm in Fig. 3.1.). This program then displays summary data for each week, in values from 0 to between 1 and 5 depending on the number of questions in each category. The following are key behaviors:

1. Cry (0-2): The infant has been crying more.
   The infant has had more changeable moods.
2. Attention (0-5): The infant has been making more intimate contact during feeding.
   The infant has resisted contact being broken between itself and its mother.
   The infant has demanded to be picked up.
   The infant has demanded increased contact with mother.
   The infant has been more demanding of mother's attention.

3.1. Food (0-2): The infant has consumed less food.
The infant has shown less interest in food.

3.2. Sleep (0-2): The infant has slept less.
The infant has had disturbed sleep/bad dreams.

3.3. Change (0-1): The infant has resisted being changed.

3.4. Baby (0-2): The infant has shown more "babyish" or "regressive" behavior.
The infant has sucked their thumb or finger more often.

3.5. Fear (0-2): The infant has been more shy around strangers or unfamiliar people.

The infant has developed new fears.
3.6. Vocal (0-1): The infant has been less vocal.
3.7. Active (0-2): The infant has moved less.
The infant has had a decreased level of activity.

To be classified as a regression period, scores had to be more than zero in Categories 1 and 2, and more than one in at least two subcategories in Category 3 (3.1–3.7).

Increasing the Sensitivity of the Analysis

Illness and Immunization. The Plooij algorithm gives the initial behavioral measure of a regression period. However, there was a strong suspicion that illness and immunization might produce the same behaviors and thus lead to false positive findings, that is, it would lead to weeks that were not regression weeks being classified as such. The following procedure was developed.

The interview records were used to identify weeks in which immunizations occurred.

The weeks in which the infant could reasonably be said to have been ill were also identified. For this identification to be made, the infant had to have reported clear physical symptoms such as diarrhea and vomiting, rashes, and high temperature. The mother simply feeling that the infant was out of sorts was not adequate.

There were four categories for illness and four for immunization. The four for illness were: Nonregression week (from Plooij algorithm), no illness; nonregression week, plus illness; regression week, no illness; and regression week, plus illness. The same was done for immunizations. Two 2 × 2 tables could thus be prepared, one relating to illness, one to immunization.

Reliability. To determine the reliability of these categorizations, an independent rater categorized a randomly chosen subset of 12 infants' data (179 weeks). The interrater reliability for the classifications was tested statistically using Cohen's Kappa, and was found to be .82 (Standard Error .04). This indicates "almost perfect" reliability (Landis & Koch, 1977).

The Influence of Illness and Immunization. The two 2 × 2 tables were drawn up to see if there was any association between the occurrence of a regression week (Plooij algorithm only) and either illness or immunization (independent rater). There proved to be no significant association between immunization and regression weeks, $\chi^2(1) = .63$. However, there was a significant association between the illness and regression weeks, $\chi^2(1) = 9.07$; $p < .01$. (Table 3.1).

This implies that for some regression weeks identified using the algorithm alone, the regressive behavior may in fact be due to illness. To leave these illness weeks would increase the number of false positives, and these weeks were reclassified as nonregression weeks. The data presented in the remainder of this chapter is this "corrected" classification of weeks as regression or nonregression weeks. This almost certainly increased the number of false negatives, but it also reduced the level of "noise" in the data and so made it more likely that the "weak signals" of "real" regression periods could be detected.

Correction for Gestational Age. The timing of regression periods in this study is based on gestational age and not the infants' age "from date of birth." Participants supplied what had been the expected date of birth, which was then used to calculate the infants' gestational age. Thus, an infant born 2 weeks premature was viewed to be 2 weeks "younger" than an infant born to term—if they had the same birth date. Similarly,

TABLE 3.1
The Co-incidence of Regression Weeks (Using Algorithm, Fig. 3.1.) and Weeks Categorized as "Illness" or "Immunization" by Independent Raters

	Regression Week	*Not Regression Week*	*Total*
Immunization	16	33	49
No Immunization	150	240	390
Total	166	273	439
		($\chi^2(1) = .63$; ns)	
Illness	35	29	64
No Illness	131	244	375
Total	166	273	439
		($\chi^2(1) = 9.07$; $p < .01$)	

Note. There was a significant association between the illness and regression periods.

an infant born 2 weeks overdue was viewed as 2 weeks "older." For all infants, data collection continued until at least 26 weeks postpartum.

Checking the Coherence of the Plooij Algorithm by Cluster Analysis

In an attempt to throw further light on the validity of the classification of regression weeks, a cluster analysis methodology was used. The essential question was, do the behaviors that the Plooijs put together in their algorithm actually cohere in certain weeks (i.e., do they cluster together in time or are they just a random collection\) Furthermore, do these clusterings tend to occur at the ages the Plooijs' work would predict\

A data matrix, consisting of the 37 questions related to infant behavior, for each of the 15 weeks of the study, was prepared for cluster analysis for each child. From the matrix, 6 questions were removed: questions relating to infant illness, infant immunization, and the arrival of a new tooth; in addition, three items that could not be coded in binary form were also removed. All weeks identified as illness weeks by the raters were also removed to avoid spurious clusterings. The remaining data matrix was analyzed using a hierarchical cluster analysis. The weeks in which clusters occurred were examined.

The question can now be answered, did these clusters tend to occur at the predicted weeks\ This was done by seeing if there was any correlation between these statistically identified weeks and the regression weeks identified by the raters using the methods already described. Cohen's Kappa for this comparison was .67 (Standard Error .04), indicating "substantial" agreement (Landis & Koch, 1977). Thus, this analysis supports the idea that the Plooij algorithm is a coherent collection of behaviors and even when the clusters are identified by this "blind" statistical procedure they still tend to occur more during regression weeks. So the algorithm can confidently be used as an objective tool for the identification of regression weeks.

RESULTS

Participation and Participants

Participation. Thirty mother–infant dyads participated in the study, and data was collected from 31 infants; there was one pair of nonidentical twins. This reflected approximately 7% of all births referred to participating Health Visitors in Oxford City during the 6-month recruitment period. Once participating, none dropped out of the study (see Table 3.2).

TABLE 3.2
Subject Characteristics

Infant Characteristics		
Females	14	
Males	17	
Mean birthweight for the 31 infants	3.43 kgs (SD = 0.55 kgs)	
Median Apgar score at 1 minute after birth	9 (range 5–10)	
Mothers' Characteristics		
Anaesthesia during labor	40%	
Mean length of labor	476 mins (SD = 339 mins)	
Mean maternal age (at infant's date of birth)	32.05 yrs (SD = 5.38 yrs)	
Mean length of education	14.93 yrs (SD = 2.33 yrs)	
Social economic class (calculated using the UK Office of Population Censuses & Survey's manual, 1991)	I	57%
	II	13%
	III	23%
	IV	3%
	V	3%
Number of children in family	1	18
	2	7
	3	4
	6	1

Completed Interviews. Data was collected from the 30 mothers during 502 telephone interviews (the mother of twins gave information about both infants during the same interview). Data for 16 interviews were missed. For 14, data were lost due to unreturned written questionnaires. Two weeks of data were lost due to missed calls.

Data Set. Although data was collected from 10 weeks[2] to at least 26 weeks, the following results refer only to data collected between Week 12 and Week 26 postpartum and corrected for gestational age: 439 interviews.

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[2] Data collection started at Week 10 postpartum in order to still have data on children who turned out to be overdue. In Oxford pregnancies are rarely allowed to proceed more than 2 weeks beyond the expected date, so starting at Week 10 would mean that there was data from a gestational age of 12 weeks on children who were that much overdue.

Evidence for Regression Periods

z Test of Proportions. Data from each week of the study was examined, and the proportion of infants who were categorized as having a "Regression Week" was plotted (see Fig. 3.2). This figure shows that there are peaks at Weeks 12, 14, 16, 20, and 24. To test the statistical significance of these peaks, the *z* test of proportions was used.

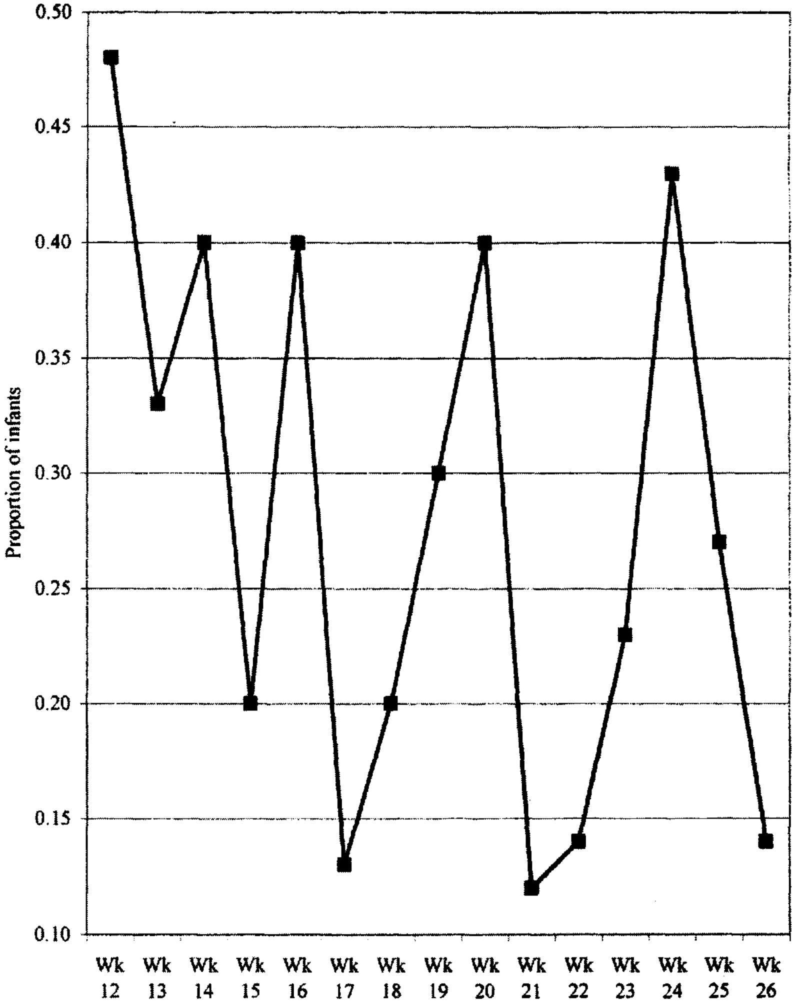

FIG. 3.2. Variations in the proportion of infants reported to have regression weeks.

The total number of weeks for the whole cohort categorized as regression weeks was divided by the total number of weeks that data was collected (122/439 = .28), giving the probability that any one week would be categorized as a regression week. For each week, this number was compared against the observed proportion of infants who were categorized as having a regression week using the following formula:

$$z = (Obs\ P - Exp\ P)\ /\ SQR(Exp\ P \times (1 - Exp\ P)\ /\ N(Obs\ P))$$

***Obs P* is the Observed Proportion and *Exp P* is the Estimated Probability (0.28).**

The calculated z scores for the peaks in Fig. 3.2 are: Week 12, $z = 2.24$, $p < .02$, one tailed; Week 14, $z = 1.47$; Week 16, $z = 1.47$; Week 20, $z = 1.47$; Week 24, $z = 1.88$, $p < .05$, one tailed.

Correction of Age. When the data sheets were further examined, it was noticed that the pattern of peaks for a number of mothers closely resembled the peaks in Fig. 3.2, except that regression weeks occurred either 1 week earlier (four mothers), or 1 week later (one mother). The starting age for each time series for each of these mothers was reset by 1 week in the appropriate direction. This resulted in significant results; calculated z for each of the 15 weeks of the study is plotted in Fig. 3.3.

DISCUSSION

Replication of Plooij Results

This study provides strong support for the findings of Rijt-Plooij and Plooij for both the existence and the timing of the regressive periods at around Weeks 12, 17, and 26. The additional peak of regressive behavior at 20 weeks was also found by Lindahl et al. (chap. 4, this volume). This peak coincides with the peak of conflict with mother reported by Rijt-Plooij and Plooij (1993). Interestingly, children of depressed mothers do not show this peak (Woolmore, 1998), supporting the Plooijs' idea that its meaning is different from the other peaks.

The emergence of the "weak signals" out of the "noise" in the data needs discussion because it is possible for critics to say that the data have been arbitrarily "corrected." Conversely, it also can be argued that studies

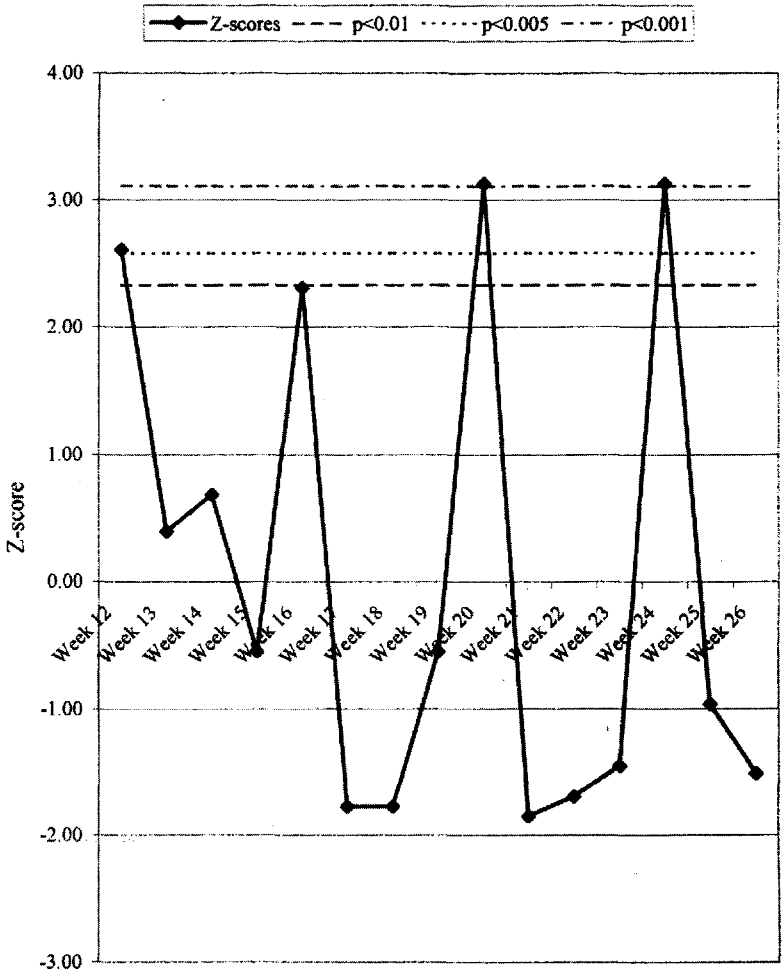

FIG. 3.3. Calculated z scores (z test of proportions) for the proportion of participants reporting regression weeks.

with simplistic methodology and inflexible data analysis would probably not reveal regressive periods.

The Detection of Weak Signals: Methodological Points

Data Collection. Emphasis was placed on building a good relationship with each mother and on the sensitivity and naturalness of the weekly conversations. The telephone interview, aided by the computer program "Interview," enabled data to be collected conveniently, reliably, and comprehensively, but in a conversational and flexible way that put mothers at their ease. This motivated mothers to continue (none dropped out, and many looked forward to the weekly contact), and allowed researchers to cross-check that they had understood the real meaning of the answers; the additional information put the basic information into a wider context.

Data Preparation: Calculation of Age from Conception not Birth. Insofar as the timing of regression periods is argued to be strongly genetically influenced, and because length of pregnancy (not gestation) in humans is variable, the babies' age was calculated according to length of gestation.

Data Preparation: Further Correction of Age. Five babies showed similar patterns of regression periods to the other 26, but their patterns were out of phase by 1 week. We felt justified in doubting our original calculation of age and reset the start time for the time series for the following reasons:

1. The numbering of weeks was based on the timing of the first call. A problem is inherent in using a timing unit as long as 1 week. For example, if an infant is 7 weeks and 4 days old at the time of the call, then should this week's data be timed as Week 7 or Week 8\ Weeks were rounded, so that in the previous example, the data would be counted as Week 8; if an infant were 7 weeks and 3 days at the time of the call, then it would be counted as Week 7. Thus, a difference in age of 1 day, could shift data forward or backward 1 week.
2. It should be noted that the "due dates" supplied by participants were calculated according to date of last menses, and date of conception could realistically differ from this date by several days.
3. The five babies showed similar temporal pattern of regression periods, that is, by resetting the time series, more than one regression period was brought into phase.

Data Preparation: Correcting for Possible False Positives. It was found that illness, but not immunization, was significantly associated with regressive behavior. To leave these potential false positives as regression periods would be to leave noise in the data set. Thus, these were reclassified as nonregression periods.

There are very likely to be other sources of false positive regression periods. Possible sources are changes in family routine, the arrival of a new caretaker, separation from mother, family stress, and so forth There were hints of these in the data; however, it was not possible to test this systematically. In any event, it is unlikely that all sources of "noise" can ever be eliminated.

Statistical Procedures. To try and separate the putative signal of a regression period from the noise, the study simply looked at whether significantly more babies showed regressive behavior in any particular week as compared to the number expected by chance. Chance was calculated from the overall proportion (.28) of weeks that were scored as regression weeks.

This procedure actually reduced the chance of finding regression periods. Regression weeks themselves added to the proportion of weeks with regressive behavior and so increased the calculated background probability of any one week being a regression week. Thus, for any one week, the number of babies scored as having a regression week would have to be higher to reach statistical significance.

The chance of finding the "signals" was also reduced by choosing the time period from 12 to 26 weeks. During that time, regression periods are more frequent than when the infants are older, based on the findings of Rijt-Plooij and Plooij (1992). This raises the background probability of regression weeks and thus reduces the chance of statistical significance being achieved. The fact that regression periods were still found at the predicted times strengthens the findings.

Participants. The sample was more heterogeneous than the Plooijs' sample in that not all mothers were primigravida. Additionally, some returned to work during the sampling period, resulting in their child being cared for by another person for part of the day. Both of these, especially the second, potentially introduce noise into the data. But, nevertheless, the Plooijs' findings were replicated.

The other group of mothers in the larger study (Woolmore, 1998; Woolmore & Richer, in prep.), whose data is not reported here, were 15 mothers suffering from postnatal depression. They differed from the control group in the timing and frequency of their regression periods. Therefore, any study that does not separate data of depressed mothers from those of nondepressed mothers, as de Weerth and van Geert (1998) did not, is likely to have "noisy" data. The likelihood of failing to find regression periods is substantially increased. Indeed, when the two groups in the study (control mothers and those with postnatal depression) were analyzed separately, each had highly significant results. However, when all participants were analyzed as one large group, all significant findings disappeared. The failure of de Weerth and van Geert (1998) to replicate the Plooijs' findings on the existence and timing of regression periods may be due to the heterogeneity of their sample and their choice of methodology.

CONCLUSIONS

Any work in this field requires sensitivity and rigor in the following areas:

- Developing good relationships with mothers so that they are motivated and attentive to the information in which the researcher is interested.
- Sensitive data collection that ensures a proper "negotiation of accounts" (Harré & Secord, 1972), such that the participant's real meaning is understood by the researcher.
- Attention to the baby's "real" age measured from calculated gestational age, not birth date (but also awareness of the possibility there are sources of error in this calculation).
- Attention to the accumulation of errors that might follow from choosing a period as long as a week as the unit for measuring age.
- Correction of false positives due to the baby showing distressed behavior due to other factors, particularly illness, and possibly separation, changes in routine, and so on.
- Choosing appropriate statistical techniques.
- Being careful about heterogeneity in the sample of participants, especially the existence of maternal depression.

Just as any study that finds regression periods must be carefully scrutinized to ensure spurious synchrony across babies has not been read into the data, so studies that fail to find regression periods must be carefully scrutinized to ensure they have not simply failed to see through the "noise" in their data, such that they have mistaken their own failure to find the phenomenon for the phenomenon's nonexistence.

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Occurrence of Regressive Periods in the Normal Development of Swedish Infants

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> Time is nature's way of preventing everything from happening at once ...
>
> —Philip Booth (1976)

Previous findings indicate the existence of several regression periods linked to developmental transitions within the infancy period (e.g., from birth to 15 months), but no consensus exists concerning how many periods are to be expected (Bever, 1982; Fischer, 1987; van de Rijt-Plooij & Plooij, 1992). The standard psychological literature usually reports only three periods centered around the ages of 2, 7, and 12 months (Plooij & van de Rijt-Plooij, 1989; Fischer, 1987), whereas in contrast, van de Rijt-Plooij and Plooij (1992) found evidence for nine regression periods during the infancy period (at 4–5, 7–9, 11–12, 14–19, 22–26, 32–37, 40–46, 49–52, and 61–64 weeks of age). These results, based on detailed observations of both free living chimpanzees and human infants, cast serious doubt on the current understanding of early infant development. Thus, these findings need to be replicated and extended in order to substantiate the existence of such regression periods and to specify their frequency and timing. The purpose of the present study is, therefore, to observe a group of Swedish infants in order to investigate whether a pattern of regressions similar to that reported by van de Rijt-Plooij and Plooij (1992) can be detected.

This study used the same definition of regression as the Dutch researchers, a definition highlighting the importance of the phenomenon within the interpersonal domain: "The regressive phenomenon we are dealing with mainly in this article belongs to the emotional domain. It consists mainly of the temporary decrease/disappearance of the growing independence of the baby as measured through mother-infant body contact, combined with an increase in crying" (van de Rijt-Plooij & Plooij, 1992, p. 131). The term *regression periods* refers to periods in which infants temporarily loose stability due to intrinsic reorganizations. Such reorganizations are indicated by observable behaviors (i.e., by changes seen within the cognitive, emotional, or social domains; Zeanah, Neil, & Larrieu, 1997). Various hypotheses have been made about the nature of the mechanism underlying regression (e.g., biobehavioral, cognitive, perceptual, or complex dynamic processes; Bates, 1976; Fischer & Rose, 1994; Kozulin, 1990; Lewis & Ash, 1992; Trevarthen, 1982, 1987; van de Rijt-Plooij & Plooij, 1992; van Geert, 1991). Van Geert proposed a dynamic systems model of competitive growth in which regression is found in the intermediary stage, when two alternative strategies compete, whereas Plooij (1990) and Plooij and van de Rijt-Plooij (1989) employed a perceptual control theory to explain regressions within early infancy. According to this theory, infants are born with few and limited levels of control, but with age develop a hierarchy of perceptual control. Each change in perception signals the development of a new skill or strategy, and at the same time causes regression.

The aim of this study was to investigate whether or not Swedish infants show a pattern of regression periods similar to that found in the original Dutch study. The specific questions were: Does the number of periods detected among Swedish infants correspond to the Dutch reports\ To what extent do the observed periods match the proposed weeks\ And, to what extent do Swedish infants display regression at time points other than those previously reported\

METHOD

Participants

Seventeen firstborn infants (9 girls, 8 boys) participated in the study. Sixteen infants lived with both parents, one with a single mother. All infants were born full term and without any reported medical complications during pregnancy. The status of all infants at birth was generally fine, with an average weight of 3.639 kg (*SD* = 390 g) and a mean Apgar score 5 minutes postpartum of 9.60 (*SD* = 1.23). All but one infant was nursed for a minimum of 18 weeks (*M* = 43.2 weeks, *SD* = 19.7). The mothers were, on average, 29 years old (*SD* = 5.05) and the fathers were 32.7 years old (*SD* = 6.15). The socioeconomic status (SES) of the sample was, on average, middle to high (*M* = 47.38, *SD* = 13.79), according to Hollingshead's (1975) four factor index (the weighted sum of Education and Occupation scores for both mother and father with a possible range from 8 to 66).

Subgroups and Cohorts. As shown in Fig. 4.1, the participants were divided into two groups: One Observation Group (OG; five boys and four girls) and one Questionnaire Group (QG; three boys and five girls). Both groups filled out a weekly questionnaire during the complete 15-month period. The OG was furthermore divided into two additional cohorts: One was observed from 2 weeks to 7 or 9 months and the second group from 7 or 9 months to 15 months of age. During the period when the OG children were not observed, they were followed through questionnaires only. In contrast, the mothers of infants in the QG only answered weekly questionnaires during the entire 15-month period.

Inclusion Criteria. The study included married couples with full-term firstborn babies and no complications during pregnancy or delivery. This criterion was fulfilled by all participants except for one child: Infant Q lived with his mother only. Also, the parents stated that they planned to take care of the baby themselves during the first 15 months. That is, they did not initially plan to use day care during this period. All mothers explicitly stated that they intended to stay at home with their child for at least 9 months when entering the study. Unexpectedly, however , three mothers started to work (two of them part time) before that age (the mothers of Infants B, F, and P). In addition, six mothers started working (part time) when their infants were between 10 and 12 months old. When mothers worked, the fathers were at home with the infant.

Subject Loss. There were three dropouts. One mother–infant pair left shortly after entering the study and no data from this infant are included. One family left the study when the infant was 40 weeks old (Infant G), because the mother felt that she had become too observant and

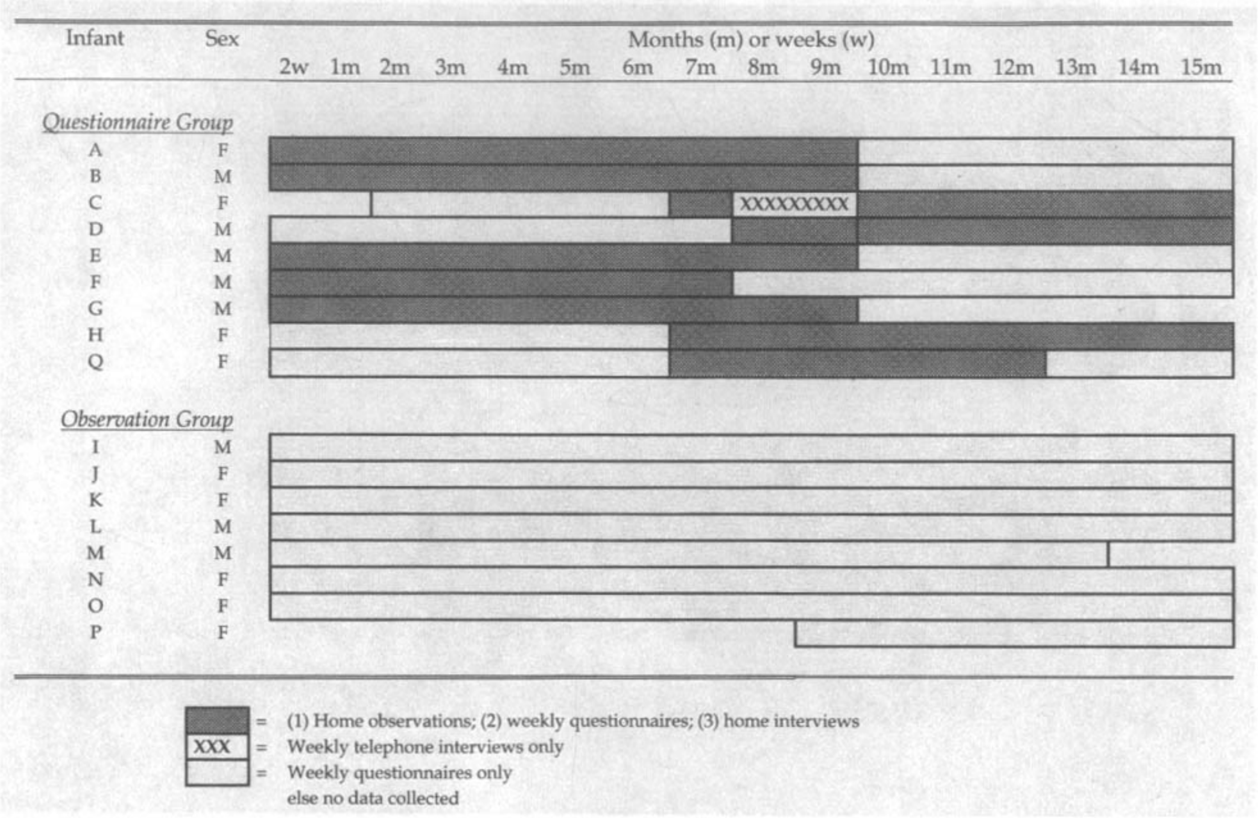

FIG. 4.1. The sample described in terms of cohorts and data collection.

thus felt hindered in her development of a relaxed relationship with her child. Another family (Infant M) left when the infant was 56 weeks old due to an increase in stressful life events (the family moved into a new house and the mother started a new job). To compensate for these losses, two additional families (Infants P and Q) were recruited, starting their participation at 24 and 40 weeks, respectively.

Procedure and Measurements

A multiple case study approach was used and a group of infants was followed longitudinally from birth to 15 months of age. The mothers were not told the exact purpose of the study, but were informed in broader terms that the aim was to study the infant's development and whether or not the baby was more difficult during some weeks than others.

Maternal Reports (questionnaires and interviews). Both the weekly questionnaire and the interview guide were translated to Swedish and kept as close as possible to the forms used by van de Rijt-Plooij and Plooij (1992). The questionnaire focused on the preceding week's signs of difficulties or signs of regression (e.g., crying/whining, extended need of body contact/support or soothing). Variables both indicating and not indicating an interpretation of a regression were included, thus observations of both positive and negative behaviors were requested. For the OG, a semi-structured home interview was added during the observation period. Interview questions overlapped the questionnaire, focusing on the mother's experience of her infant during the preceding week.

The participants in the QG received their first questionnaire during an initial home visit. When they had filled in the weekly questionnaire, it was generally sent by mail to the researchers. The questionnaires in the OG were instead collected at home visits. When it was not possible to observe the infants in the OG (due to vacation or illness), information about the infant was instead obtained through questionnaires and interviews conducted by telephone.

Observations. Nine mother–infant pairs (OG) were visited once a week at home in order to obtain 3 hours of observation. The visits generally lasted for 4 hours, but due to factors such as the length of the infant's sleep, shorter observations than the intended 3 hours were obtained (*M* = 142 min., *SD* = 23.17). During the visits, the observer, present in the same room as the infant, continuously recorded the amount of time the mother and infant had body contact and the amount of time the baby cried. In addition, fretting/fussing was recorded once every 60 seconds. All behaviors were recorded immediately on a laptop computer using a special software package (The Observer 3.0; Noldus, 1991), and the same ethogram as previously used by van de Rijt-Plooij and Plooij (1992, p. 134).

Data Analysis Criteria for regression periods. The same criteria as previously used by van de Rijt-Plooij and Plooij (1992) were implemented for judging regression periods on the basis of maternal reports. The process started by reading the maternal reports chronologically, "as a whole," in order to capture a mother's impression of her infant during each week. Every report was always compared to the previous ones, thus, researchers were able to notice if the mother had changed her description of the infant's behavior: that is, if she described the infant as more regressive/demanding/dependent than usual. As described in Fig. 4.2, a "regression period" was defined as lasting for a minimum of two consecutive days. In order to compare these results with the study by van de Rijt-Plooij and Plooij (1992), hypothesized periods with at least 60% (60+) of the infants regressive were considered as supported, and the ages that the nine time periods with the highest proportion of regressive infants occurred were identified.

Data from the observations were used to validate the questionnaires and interviews. Analyses of the observations focused on the percentage of

(a) Length	The period must last for at least 2 days.
(b) Indicators (frequency)	The infant must show a higher frequency of/more pronounced behaviors regarded as "indicators" of difficult periods," compared to the week/s before.
(c) Indicators (numbers)	At least two "indicators of difficultness" shall be apparent during the same period. During the first 2 months, an increased amount of crying/whining + closeness is sufficient as criteria. After 2 months of age, an additional indicator should also be apparent besides the two above.
(d) Exclusion	No other explanation, such as illnesses or increased amount of stress due to external factors, should be applicable during these periods.

FIG. 4.2. Criteria for regression periods.

time spent in "body contact" (both initiated by the mother and the infant), the percentage of time spent "crying," and the relative frequency of "fretting/fussing" compared to "not fretting/fussing." If observational data indicated a regression but not data from the maternal reports, then the week was *not* judged as a regression week.

To avoid confounding external effects that might have caused difficulty with infants, weeks when infants experienced major changes (e.g., the weeks when mothers started to work) were excluded from the analysis. For validity purposes, information from the father was also collected during the weeks when he was the main caretaker. Furthermore, other factors believed to influence the family have also been taken into consideration (e.g., major or minor life events and illnesses). To control for differences in the infants' gestational age, corrections have been made for infants born ± 4 days from the expected date. Infants who were born from 4 to 10 days from the expected date were corrected by 1 week, and infants who were born from 11 to 17 days from the expected date were corrected by 2 weeks.

Analysis of Maternal Reports

Periods lacking or containing regressive behaviors were plotted according to gestational age for every single infant. Thus, the information was analyzed individually over time, comparing the infants' behavior during each week against their usual pattern (the baseline) during the week/s before. For infants in the OG, the interview was regarded as the main source. For infants in the QG, the main source was instead the weekly questionnaire. The following analyses were conducted.

Comparisons with the Hypothesized Periods. First, the frequency of identified periods (per infant) was compared with the expected (hypothesized) frequency of regression periods. The relation between the identified and expected periods was analyzed using Pearson's correlation coefficient. Second, the frequency of identified regressions (per infant) during hypothesized periods compared to nonregression periods was calculated. Third, the percentage of regressive infants during the hypothesized nine periods was calculated, and periods within which at least 60% (60+) of the infants were regressive were identified. Fourth, the percentage of regressive infants/week during hypothesized regression weeks was compared with the percentage of infants showing signs of regression during nonregression weeks. This comparison was analyzed with the use of independent *t* tests.

Inductive Analysis. An inductive analysis was conducted, searching for clusters with a higher proportion of regressive infants during consecutive weeks, compared to the average number of regressions per week. First, nine periods with the highest proportion of regressive infants were identified. Second, the percentage of regressive infants/week during the 60+ periods was compared to the percentage of regressive infants/week during nonregression periods (all the other weeks) with the use of independent *t* tests.

Background Variables. In order to investigate suspected influences due to specific background variables, dependent variables (number of regression weeks, periods etc.) were correlated with all the background data of the sample (e.g., the parent's age, SES, Apgar scores, etc.).

Analysis of Observational Data

Comparisons with Hypothesized Regression Periods. Observational data were analyzed separately for each infant. Using visual inspection, peaks in: (a) time in body contact, (b) time crying, and (c) relative frequency of fretting compared to not fretting, were considered indications of infantile regression. Weeks with peaks in one behavioral item were labeled as "peak weeks." First, the number of observed peak weeks in relation to the number of expected regression weeks was analyzed using Pearson's correlation coefficient. Second, the percentage of peak weeks matching versus not matching the hypothesized regression weeks was calculated.

Observational Data Versus Maternal Reports. Using Pearson's correlation coefficient, the study analyzed whether or not regression weeks identified by maternal reports were significantly related to peak weeks in the observational data.

Reliability Measures

Interobserver reliability was established in collaboration with the Dutch research group. Reliability (coding of a special training video) between the Swedish and the Dutch coders was acceptable. The average agreement for different contact distance categories was from 81% to 99%, and the average agreement for crying was 99%. Reliability for coding fretting was calculated using Cohen's Kappa ($\kappa = .74$). Interrater reliability for coding infants as "difficult/regressive" from the maternal reports was also checked. Independent analyses of maternal reports for two randomly chosen younger infants (from 2 to 40 weeks of age) and three different randomly chosen older infants (from 41 to 65 weeks of age) showed acceptable agreement when calculated with Cohen's Kappa ($\kappa = .78$ and $\kappa = .90$, respectively).

RESULTS

Analysis of Maternal Reports

Due to external confounding factors (i.e., illness), the number of infants included in the analysis varies between weeks, from 13 to 16 infants per week. Descriptive data with means, standard deviations, and range for the analysis of regressions are shown in Table 4.1.

Comparisons with Hypothesized Regression Periods. The relation between number of identified regression periods and number of expected (hypothesized) periods was above chance level (.99), but only 55% of the regression periods were observed within expected weeks. Further

TABLE 4.1

Descriptive Data (Mean, Standard Deviations, and Range) for Measures of Regressive Weeks and Periods ($N = 17$)

Variable	*M*	*SD*	*Min*	*Max*
Regression weeks				
Identified regression weeks (frequency)	10.24	3.13	4.00	15.00
Possible weeks* (frequency)	53.40	12.44	21.00	63.00
Identified regr.weeks./poss. weeks (%)	0.19	0.04	0.10	0.30
Regression periods				
Identified regression periods (frequency)	7.76	2.14	4.00	12.00
Expected regression periods** (frequency)	8.00	1.77	3.00	9.00
Duration of regression periods (weeks)	1.56	0.43	1.00	5.00

*Number of regression weeks, excluding weeks with major or minor life events, or illness.

**Number of regression periods expected in the sample (the variation depends on number of possible weeks/infant).

analyses of the percentage of infants judged as regressive during the expected weeks revealed clear support for three of the hypothesized periods: Over 60% (60+) of the children were identified as regressive during the periods between 14–19 (70+), 32–37 (80+), and 40–46 (80+) weeks. Periods not directly supported by this data were the 4–5 (54%), 7–9 (29%), 11–12 (50%), 22–26 (53%), 49–52 (44%), and 61–64 (36%) weeks periods (see Fig. 4.3).

Infants' reported illnesses may have masked some of the actual regressions (i.e., cases in which a regression was incorrectly interpreted as illness), so an analysis was made investigating the occurrence of illness during expected regression periods. In most cases, this was not a problem, because infants generally were not ill during entire regression periods. However, during the last expected period (61–64 weeks), as many as four infants were reported ill (29%) but not regressive.

As shown in Fig. 4.3, there are weeks with higher proportions of regressive infants compared to the surrounding weeks. There are, however, few

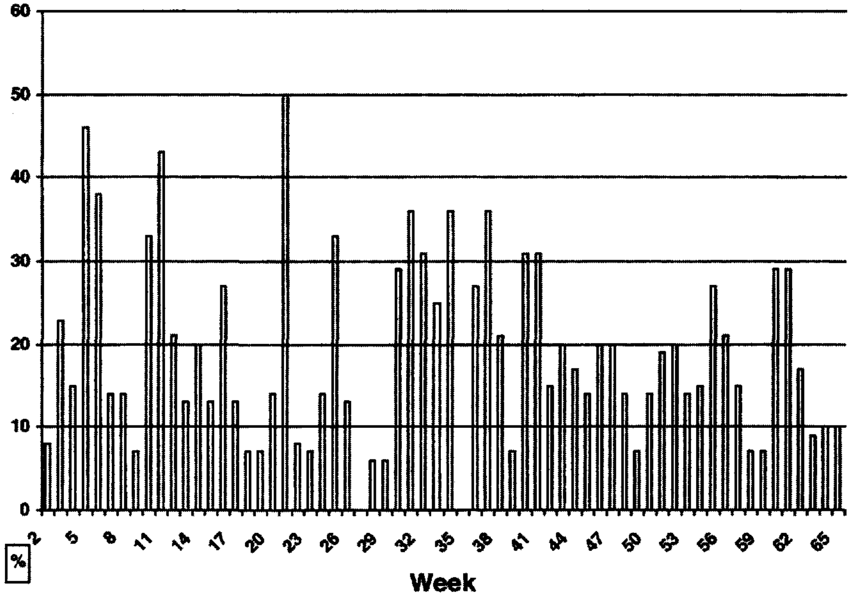

FIG. 4.3. Percentage of regressive infants per week.

weeks in which regressive infants are not found. A comparison between the observed percentage of regressive infants/week during the hypothesized regression (*M* = .20, *SD* = .11) and nonregression periods (*M* = .19; *SD* = .12) came out nonsignificant.

Inductive Analysis. An inductive analysis without restrictions to the hypothesized periods was also conducted, searching for clusters with higher percentage of regressive infants/week compared to the average percentage. The nine periods with the highest proportions appeared at 5–6 (77%), 10–11 (71%), 14–17 (57%), 20–21 (57%), 31–34 (75%), 36–38 (50%), 40–46 (81%), 55–57 (50%), and 60–62 (60%) weeks. During these periods, 27% of the infants were, on average, regressive during each week (*SD* = .10) compared to only 13% (*SD* = .08) during the nonregression periods. The percentage of regressive infants during the five 60+ periods (*M* = .29, *SD* = .10) was significantly higher compared to during nonregression periods (*M* = .16; *SD* = .10; $t(62) = 5.08$, $p < .001$; see also Fig. 4.4).

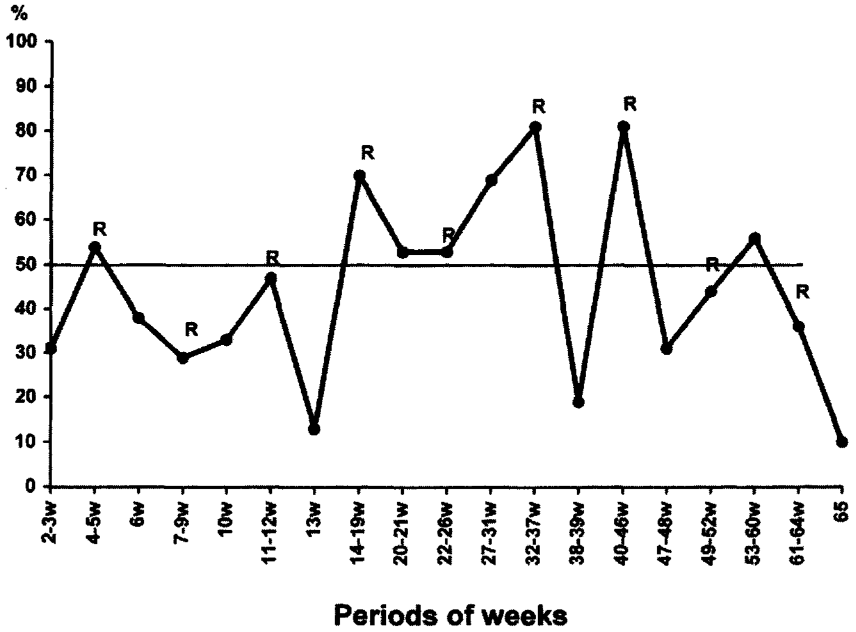

FIG. 4.4. Percentage of regressive infants during regression and nonregression periods. R = expected regression periods according to the periods postulated by van de Rijt-Plooij and Plooij (1992).

Background Variables. An analysis of the data from the OG and the QG did not reveal any significant differences between the groups. Nor did factors like SES, maternal age, or mothers going back to work early (before 49 weeks) seem to have any effect. Also, infant sex did not appear to influence regressions, although boys had slightly more peak weeks than girls.

Analysis of Observational Data

Comparison with Hypothesized Regression Periods. Observed peak weeks (range = 7–15 weeks) were compared with the expected number of regression weeks per infant. The relation between the total amount of observed and expected number of peak weeks was high ($r = .90$, $p < .005$), indicating a stronger connection than expected by chance. The number of peak weeks matching the expected regression weeks was 87 out of 128 (68%).

Comparisons Between Observational and Interview Data. Identified regression weeks determined by interviews were coincident with peaks in observational data during the very same or surrounding weeks (± 1 week; $r = 1.00$). However, comparisons between data from exactly the same weeks did not show a significant relation ($r = .39$, $p < .30$).

CONCLUSIONS

Overall, these findings may be interpreted as supporting the existence of a cyclical pattern of stability–instability during the first 15 months of life, although the observed level of regression periods seem to be lower in this sample than in other comparable samples (see chaps. 2 and 3, this vol.). When compared with van de Rijt-Plooij and Plooij's findings (1992), direct support was evident for three of the hypothesized nine regression periods (using a 60+ criterion), which all appeared between 3 and 10 months of age (at 14–19, 32–37, and 40–46 weeks of age). The percentage of regressive infants during these regression periods were significantly higher compared to during all other weeks. Three additional periods received somewhat lower support: At least 50% of the infants were judged as regressive during 4–5, 11–12, and 22–26 weeks of age.

In agreement with the findings of van de Rijt-Plooij and Plooij (1992), it was assumed that there were nine regression periods to be found from birth to 15 months of age. However, the criteria had to be lowered from 60+ to 50+ in order to find nine periods with high proportions of regressive infants. This inductive analysis provided evidence for five 60+ periods at partly different ages than the first (ad hoc) analysis: at 5–6, 10–11, 31–34, 40–46, and 60–62 weeks. The percentage of regressive infants per week during these 60+ periods were significantly higher compared to during all other weeks. Interestingly, these periods either overlapped or matched the hypothesized weeks. The periods around 5–6, 10–11, and 31–34 weeks observed in the sample, probably correspond to those at 4–5, 11–12, and 32–37 weeks found by van de Rijt-Plooij and Plooij (1992). Furthermore, the 40–46 weeks period matched the hypothesis exactly, and the period found at 60–62 weeks overlapped the hypothesized period at 61–64 weeks.

None of the methods provided any support for three of the expected periods, those at 7–9, 22–26 and 49–52 weeks of age. Because the period around 8 weeks is an accepted transition period in the literature (e.g., Fischer, 1987; van de Rijt-Plooij & Plooij, 1992), and because both van de Rijt-Plooij and Plooij (1992) and Sadurní and Rostan (1997; see also chap. 2, this vol.) found strong indications of a regression period around these weeks, the maternal reports were reanalyzed for this period. This analysis revealed that five more infants, besides the four previously identified, displayed less strong difficult behavior (taken together, 69% of the infants).

The lack of support for a regressive period toward the end of the first year of life might be because the time table for regressions becomes increasingly influenced by contextual factors as the child grows older. The study did try to control for such influences by excluding from the analyses the first week of weaning and the week when the mother started to work again. It is, however, impossible to know whether this was sufficient. Likewise, it is also impossible to know how unforeseen changes in the sample affected the results. It was necessary to add two extra subjects relatively late to compensate for two families leaving the study. Several mothers also did go back to work earlier than planned. This also meant that many fathers became active as primary caretakers during part of the time period in focus for this study. Thus, the fact that the number of regressive weeks was more evenly distributed after 9 months of age (resulting in less time-scheduled regressions in data) might be due to cultural phenomena. Strong cultural influences between countries supposedly close in overall culture have been demonstrated, but are often overlooked (Posner, Rothbart, Farah, & Bruer, 2001). There might be subtle differences in how parents organize their everyday life and how they interpret their infants' signals. These differences probably interact with intrinsic developmental forces at a microlevel and the result might be differences in how parents from various cultures respond to similar changes in their young infant. This new awareness of the intricate interplay between culture, brain development, and child development is summed up by the new scientific branch, cultural neuroscience, and is an aspect that has to be incorporated in any further investigation of the regressive phenomena discussed here.

The observational data revealed that the observed number of peaks of "time spent in body contact," "crying," or "fretting/fussing" corresponded highly with the expected number of peak weeks. If accepting peaks surrounding the expected ones (± one week), then a perfect match was noted. However, if only including those weeks that matched exactly, then a match was found for 68% of the observed peak weeks.

In sum, the Swedish infants in the study did show regressive/difficult periods during their first 15 months of life. However, these periods were fewer and did not occur during exactly the same weeks as proposed by van de Rijt-Plooij and Plooij (1992). Three explanations may be proposed for this nonidentical pattern: (a) less homogenous development after 9 months of age, (b) cultural differences in parenting between the Netherlands and Sweden, and (c) individual variability between infants due to factors not controlled for (e.g., temperament). All of these factors need to be addressed in future studies.

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The Effects of Sources of "Noise" on Direct Observation Measures of Regression Periods: Case Studies of Four Infants' Adaptations to Special Parental Conditions

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Horwich (1974) already concluded that "although the precise occurrence of regressive periods may be determined by individual genetic variations, it is obvious that species and subspecies genetic variation, gender, and environmental conditions have an effect on the emotional state of the individual and presumably also on these regressive periods" (p. 146).

In the original study, 10 regression periods were reported in the first 20 months of human babies (van de Rijt-Plooij & Plooij, 1992, 1993). The point was to understand normal development before venturing into understanding pathology. The group was very homogeneous. This may have helped to find the regression periods where others failed. A very strict selection procedure was followed to find absolutely problem-free and healthy families where father and mother were married and both parents looked forward to having the baby. The mothers had no previous medical or psychological problems, intended to look after the baby themselves, were financially secure, and had an extended support system (family living in the same part of town) and free-of-charge access to the baby "consultation bureau" (a kind of child guidance clinic). A very low incidence of major life events and other stressors were found to prevail during the study (only three major life events were found toward the end of the study).

The purpose of a follow-up study, where Plooij was the principle investigator, was to see if the regression periods as reported by Van de Rijt-Plooij and Plooij (1992) were reflected in weekly direct observation measures concerning proximity and distance regulation, crying, fretting, and smiling. Four mother–infant pairs were observed weekly from birth to age 15 months. In the original study (van de Rijt-Plooij & Plooij, 1992), monthly observations were made in the homes of two mother–infant pairs on the percentage of time mother and infant spent in body contact. These observations corroborated the questionnaire and interview data.

De Weerth and Van Geert (1998) published on the same weekly direct observation measures of this follow-up study and reported the age-related regression periods for only one of the four mother–infant pairs. Consequently, they reached the conclusion that the phenomenon of nine age-related regression periods does not exist.

Woolmore and Richer (chap. 3, this vol.) argue that "studies that fail to find regression periods must be carefully scrutinized to ensure they have not simply failed to see through the 'noise' in their data, such that they have mistaken their own failure to find the phenomenon for the phenomenon's nonexistence." The sources of noise they discuss are poor relationship with participants, insensitive data collection, regressive behavior caused by other factors (e.g., illness, separation), and failure to ensure sufficient homogeneity in the sample, especially failure to exclude depressed mothers.

De Weerth and Van Geert (1998) failed to report important sources of noise, which are elaborated on in a later section.

The purpose of this chapter is to study the effects of these sources of noise on the same direct observation measures of the regression periods and show that such special circumstances cannot be neglected. Since Plooij was principal investigator and second author of a preliminary draft of the paper published by De Weerth and Van Geert (1998), large parts of the "Methods" section of their paper also apply to the "Methods" section of this chapter.[1] For the sake of the reader's convenience it was the inten-

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[1] Obviously, Plooij did not agree with De Weerth and Van Geert on the approach followed in the 1998 paper and withdrew his name. All parties involved agreed that, as principle investigator, Plooij kept the right to publish on the same data independently.

tion to place these parts between double quotes to enable the reader to know the exact similarities and, more important, the exact differences between the "Methods" sections of both papers. Permission to use lengthy quotes in the Methods section was denied by De Weerth and Van Geert. Therefore, the gist of their wording shall be summarized and the differences between the "Methods" sections shall be stressed. Unfortunately the reader shall have to get hold of the paper published by De Weerth and Van Geert (1998) to learn more details of the methods used.

METHODS

Subjects

Four Caucasian mother–infant dyads were recruited from intact middle-class families. Two of the babies were male (E and F) and two female (J and S). All infants experienced an uneventful prenatal period. Three infants had a vaginal delivery and one a Caesarean. The infants were healthy, full-term firstborns with Apgar scores of 8 and 9 at one minute and of 9 and 10 at five minutes. Seven days after birth the neurological examination performed by a physician did not show any abnormalities. Around the age of 15 months application of the Bayley Scales of Infant Development (BOS 2-30) resulted in Mental/Nonverbal/Motoric scores of 117/89/45, 114/87/47, 115/87/57, and 115/88/49, indicating normal development. Because of the replicative nature of the study, the mothers should have been selected on mental and physical health, but this is not mentioned in the publication of De Weerth & Van Geert (1998).

During the course of the study, some environmental, parental conditions came to light that were not foreseen.

First of all, the mothers of Infants F and J turned out to follow a very strict sleeping, contact, and feeding schedule. Such rigid schedules of the kind advocated in the 1920s and 1930s influence the direct observation measures of body contact, crying, and fretting-fussing by definition. Such schedules in combination with extensive use of a playpen disturb a spontaneous contact and proximity regulation between mother and infant. Only when the mother is "child-following" and feeds and provides contact "on demand," can direct observation measures of body contact reflect the "contact-wish" of the baby and thus the regression periods. The mothers of Infants F and J explicitly and recurrently state in their questionnaires and interviews from the beginning to the end that they have decided to apply such rigid schedules and they placed their baby in the playpen for hours on end. The administration of rigid sleeping, contact, and feeding schedules may seem outdated and extreme, but Harkness and Super (1993; Super et al., 1996) reported on a rural area in the Netherlands and affirmed that the custom of maintaining a consciously "regular" schedule still occurs and leads to a greater distance and less body contact between mother and infant.

Second, Infant J and her mother were separated for 10 days after birth. The mother did not object to this because she was "not yet up to it anyway." Next, Infant J was overstretched and received physiotherapy for at least 8 months.

Third, the mother of Infant E started child-minding two other children in her home 34 weeks after the birth. Next, toward the end of his first year of life, she started to bring Infant E to family or friends more often and for longer time spans, including staying overnight.

Fourth, in her weekly interviews halfway through the first year after birth, the mother of Infant S stated that she was depressed from birth onward and had been receiving therapy long before birth. Finally, she felt so troubled that she applied for renewed therapy at the department of psychiatry of the university hospital. In the interviews and the questionnaires, this mother reported to feel depressed, overstrung, and all sorts of phobias (e.g., the fear to be alone, open the door, pick up the phone, and/or go into the street). She had nightmares, sleepwalked, hyperventilated, had various physical complaints, diarrhea, bad appetite for food, and so on. The mother of Infant S realized the effect of all this on her infant and expressed the fear that her infant would be placed out of the home.

The various contributions in Murray and Cooper (1997a) show that there is evidence of major effects of a parent's postpartum depression on the infant and the parent–infant interaction patterns. H. Papoušek & M. Papoušek (1997) described a system of "intuitive parenting" and presented various conditions, including maternal depression, that may jeopardize the balance of the system and lead to vicious cycles of impaired patterns of relating. Their clinical observations indicated a coincidence of infant crying and maternal depression. Tronick and Weinberg (1997) presented their mutual regulation model (MRM), which focuses on the interactive nature of development. Referring to Connolly and Prechtl (1981), they emphasized the mutual influence of maturation of the infant's nervous system and the mothering repertoire of the caregiver. They described how maternal depression disrupts the mutual regulatory process. There are at least two interactive patterns. *Intrusive* mothers engaged in rough handling, spoke in an angry tone of voice, poked at their babies, and actively interfered with their infants' activities. *Withdrawn* mothers, by contrast, were disengaged, unresponsive, and affectively flat, and did little to support their infants' activities. Infants of intrusive mothers spent most of their time looking away from the mother and seldom looked at objects. They cried infrequently. Infants of withdrawn mothers were more likely to protest and to be distressed. Murray and Cooper (1997b) showed that depressed mothers were rated as less sensitively focused on their infants' experience and were found to make more responses that were rejecting or affectively discordant. Even in the absence of depression, women who experienced difficult circumstances and were preoccupied with other problems showed the same patterns of interactive impairment. Murray (1992; Murray & Cooper, 1994) showed that interactions between depressed mothers and their babies have another style to such an extent that these babies are insecurely attached after 1–2 years. This has been confirmed by other researchers. Campbell and Cohn (1997) showed that in their low-risk community sample only those mothers showed impairments in parenting whose depression persisted for at least 6 months. If mothers remain depressed over their infants' first year of life, then their infants not only show behavioral disturbance, but also physiological and biochemical dysregulation (Field, 1997). Depressed mothers are noted to touch their infants less frequently (Field, 1997). Hart, Field, del Valle, and Pelaez-Nogueras (1998) showed that, during toy-play interactions, 1-year-old infants of depressed mothers engaged in less object examination, daughters of depressed mothers showed less positive and more negative affect, and depressed mothers were more intrusive with sons. Donovan, Leavitt, and Walsh (1998) found that maternal depression, but also home–work conflict or marital happiness, influenced mother's actual sensitivity to infant distress (crying). And finally, Woolmore and Richer (chap. 3, this vol.) have shown that maternal postnatal depression affected the length and timing of regression periods.

The previous evidence shows that maternal depression should have an effect on the direct observation measures collected in the study, the more so since Campbell and Cohn (1997) showed that, even in a low-risk community, depression was followed by impairments in parenting if the depression lasted longer than 6 months. This condition applied to the mother of Infant S.

Materials

Ethological observations of mother and infant were carried out in the home environment with the help of a laptop computer. The mother and her infant were followed around the house.

Weekly questionnaire and interview data were collected. The questionnaire was derived from the one used by Van de Rijt-Plooij & Plooij (1992, 1993) and based on the results of their data analysis. In the interview the observer asked the mother for additional information, clarification, and examples concerning the questionnaire.

Procedure

Weekly Data Collection. Each mother–infant pair was observed weekly in its own home environment by a student, de Weerth. The (corrected) ages at which each mother–infant pair was observed according to our calculations differ slightly from the ones as reported by De Weerth and Van Geert (1998). The first observation took place in the second week of life for Infant E, the third week for Infant F, and the fourth week for Infants S and J. The last observation took place in the 64th week of Infant J, the 65th week of Infants E and F, and in the 66th week of Infant S (for further explanation see "Age correction").

The observations always began around 9:00 in the morning and continued until three hours of "good observation" had been completed. "Good observation" meant the child was not asleep and mother and infant could be seen. The observations mostly ended between 12 and 14 hours. On three occasions, it was necessary to end an observation before the 3 hours had been completed; however, because only 35 minutes or less were missing in these cases, they were included in the analysis.

In unexpected eventualities, such as a spontaneous visitor or the mother having to run an urgent errand, observations were stopped until the standard conditions had been reached again. Three fathers were occasionally present during (part of) an observation and the fourth father was regularly home during the weekly visits. In all cases, they were asked to interact as little as possible with the infant. De Weerth claimed they complied, and their presence had no visible influence on the mother–infant interaction or on the infant's behavior.

Upon arrival at a family's home, the observer engaged in conversation with the mother while preparing the equipment for the observation. During this brief period, both the mother and the infant were able to get used to the observer again and relax in her presence, continuing to do whatever they were doing.

The interview took place after the observation was completed or when the infant was sleeping. Because the mothers spoke largely about their infants during the observation, they were often spontaneously giving information that they had (consciously or unconsciously) omitted writing in their questionnaires.

A parenting book had been published in the Netherlands before the start of this project (Van de Rijt & Plooij, 1992). This book describes the 10 regression periods in the first 20 months of the babies' life, the ages at which these regression periods occur, how they are followed by a leap in their mental development, and suggestions for how to react. The book was a best-seller and, consequently, the mothers could not be expected to be naïve to the object studied. To keep the study group as homogeneous as possible, each mother was given a copy of the book.

Ethogram. The ethogram is derived from the one used in the original study by van de Rijt-Plooij and Plooij (1992). The following behavioral elements were recorded during the observations:

Vocalizations

- **Crying**
- **Fretting/fussing**

Facial expressions

- **Smile**

Contact/distance

- **Body contact**

Body contact and **crying** were scored by continuous coding of events.

Smiling and **fretting/fussing** were recorded by means of interval coding with intervals of 60 seconds. If during longer than ± 5 seconds the infant's face was not visible, then smiling was not scored during that particular interval.

Reliability. De Weerth was trained intensively by H. H. C. van de Rijt-Plooij during live home observations. Training was continued until the inter-observer reliability scores were satisfactory. The mean percentage agreements for contact/distance and crying was 82.6%, and Cohen's kappa for smiling-fretting was .88.

Intra-observer reliability was established after 7 months from the start of the observation period by scoring a videotape twice, with an interval of a month between both occasions. The mean percentage agreements for the body contact categories was 89.3% and for crying 86.6% and the kappa for smiling-fretting was .71 (De Weerth and Van Geert, 1998), which indicate little observer drift.

Analysis

Age Correction. Infant J was born 13 days later than expected. Because age from the moment of conception is considered more important for the phenomena studied than that following the moment of birth (van de Rijt-Plooij & Plooij, 1992), the age of the infant was corrected by using the date it was expected to be born instead of the actual birth date.[2]

Illness. The infants were observed every week notwithstanding illnesses. The weeks in which the infant's behavior was clearly affected by a physical affection were included in the analysis, but have been treated with caution and marked with the letter Z in the graphs as weeks in which the infant was ill. In the original study, the definition of a regression period was such that any obvious external reason for being difficult, such as the infant being ill, was excluded.

Graphical Inspection of the Data. The percentage of time spent in fretting-fussing was positively correlated to the percentage of time spent crying. Pearson's r values were .50 for Infant E, $p < .001$; .25 for Infant J, $p < .05$; .45 for Infant S, $p < .001$; and .32 for Infant F, $p < .01$. Therefore, the percentage of time spent in fretting-fussing is omitted from the graphs depicting the direct observation measures (Figs. 5.2–5.5).

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[2] The expected birth dates were used as reported by the mother and as checked by the neurologist 7 days after birth. When Infant S was 31 weeks, the ages indicated on the weekly questionnaires all of a sudden were reduced with 2 weeks. De Weerth and Van Geert (1998) reported on Weeks 2–64, whereas this study reports on Weeks 4–66.

RESULTS

Looking at the behavioral measures obtained through direct observation in the homes (Figs. 5.2–5.5), it is immediately clear that three out of the four mother–infant pairs do not show the expected age-linked peaks in body contact at all ages. With the help of an extensive set of statistical tests, this conclusion was confirmed by De Weerth and Van Geert (1998). To be able to explain these results properly, the interplay between the special parental conditions mentioned in the section Subjects (e.g., a rigid sleeping, contact, and feeding schedule, or being depressed and phobic), and the observation measures body contact, crying, and smiling are described. The graphs of the four mother–infant pairs are analyzed separately. For each mother–infant pair, the graphs for body contact, crying, and smiling are described in that order.

Mother–Infant Dyad E: Child-Minding Other Children Beyond 34 Weeks

The body contact measure of one mother–infant pair (E) confirms eight of the nine regression periods of the original study (see Fig. 5.1) at 5, 8, 11–12, 16–17, 25 (30 weeks is not a regression period but the period of the "checking back pattern" as described by Mahler, Pine, & Bergman, 1975, p. 55), 37, 42 or 46, and 62 weeks. Notwithstanding the one missing peak around 52 weeks, it is fair to say that the findings as reported by van de Rijt-Plooij and Plooij (1992) are reflected in temporary increases in direct observation measures of body contact.

The 10 peaks in Fig. 5.1, which are marked, were selected as the most important peaks in the same way as used by De Weerth and Van Geert (1998). They calculated the difference between the value of any point in the graph and the values of the four neighboring points according to the formula:

$$R_t = x_t - (x_{t-2} + 2x_{t-1} + 2x_{t+1} + x_{t+2})/6$$

where a high R value refers to a single "spike" in the observed behaviors. When two neighboring weeks were selected in this way, they were considered to be representing the same regression period. Then the highest value was selected and its neighbor was replaced by the week with the next highest R value. This selection process was done separately for Weeks 1–20 and weeks 21-65, because the values of the data of the first 20

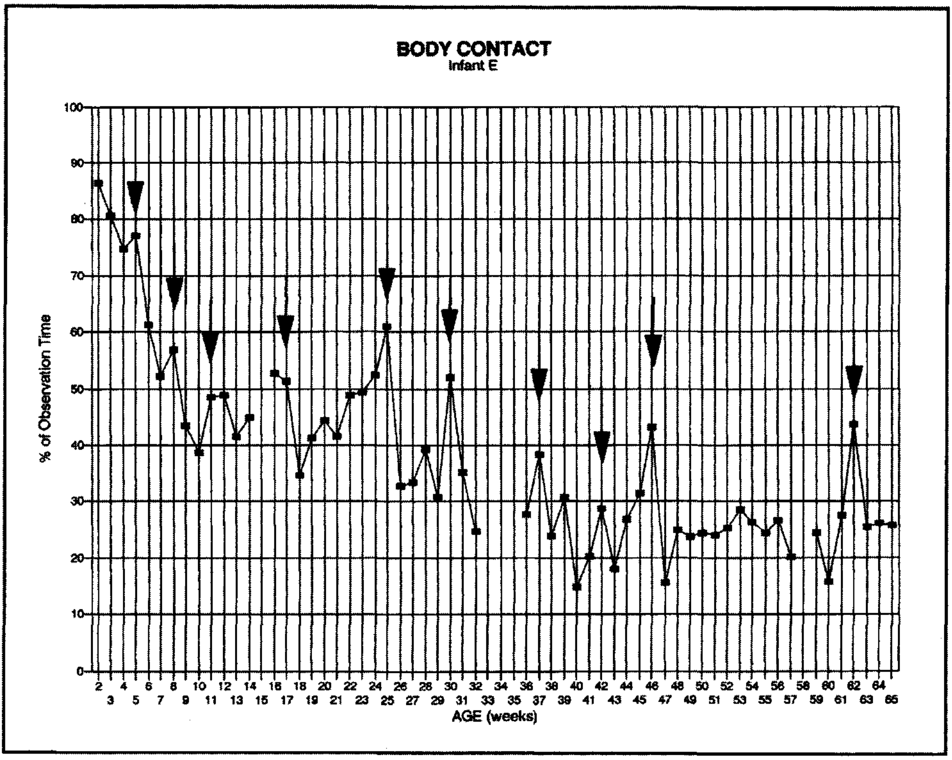

FIG. 5.1 The 10 most important peaks in the body contact data of Infant E. These were obtained by selecting the four highest *R*'s from Weeks 1–20 and the six highest *R*'s from Weeks 21–65, where *R* was calculated according to the formula presented in the text. Due to missing data, the *R* values for Weeks 14–16, 32–36, and 57–59 could not be calculated. The peak at 30 weeks concerns no regression period but the "checking back pattern" (Mahler, Pine, & Bergman, 1975). Of the other nine peaks, eight fall within the regression periods as reported by van de Rijt-Plooij and Plooij (1992).

weeks were often much higher and showed important downward trends with relatively small reversals, as compared to those of Weeks 21–65.

The frequency of crying of Infant E (not shown in Fig. 5.2) is positively correlated with the percentage of time spent in body contact (Pearson's $r = .22$; $p < .05$). Comparing the percentages of time spent on crying in Figs. 5.2–5.5, it is striking that beyond the first 13–17 weeks Infants F, J, and S hardly cry anymore, whereas Infant E still does from time to time.

The percentage of time spent on smiling during the first 32 weeks is much lower in Infant E as compared with the other three infants (see Figs. 5.2–5.5).

The only regression period that is not covered by the peaks in body contact of Infant E is the one around 52 weeks. The body contact graph shows a slight peak in both body contact and crying at Week 53 (see Fig. 5.2), but then Infant E was ill the week thereafter and it is impossible to know what the graph would have been without the illness.

Infant E's mother started child-minding two additional children in her own home from the age of 34 weeks onward (see letter K in Fig. 5.2). Furthermore, she started to bring Infant E to family or friends more often, including nights, toward the end of his first year of life (see Fig. 5.2). These two environmental conditions may have had an influence on the mother–infant interaction from 34 weeks onward.

As Infant E's graph shows, the phenomenon of age-linked regression periods can be reflected in a direct observation measure of body contact.

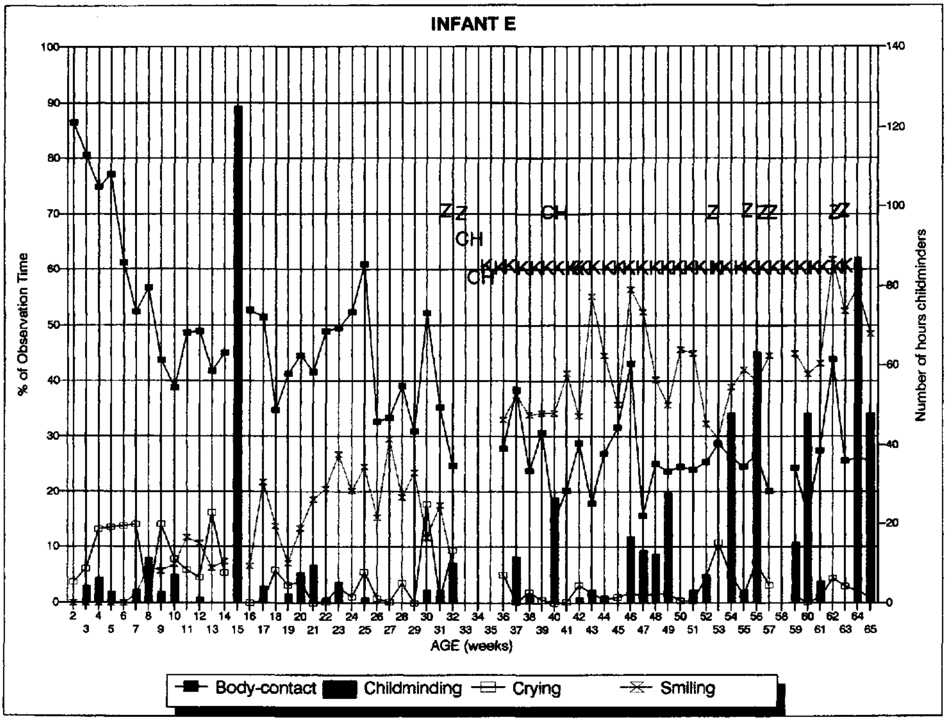

FIG. 5.2. The percentage of observation time Infant E spent in body contact, crying, and smiling, and the number of hours other people than the mother were looking after (child-minding) Infant E. Z = child ill; CH = chaotic week; K = mother is child-minding two additional children in her own home.

Mother–Infant Dyad F: Rigid Sleeping, Contact, and Feeding Schedules

The mother of Infant F was the most extreme in following schema care and letting her baby cry "in order not to spoil it." If the infant was sleeping, it was woken up if the feeding time came up. Vice versa, if the infant woke up and started crying, the mother left it crying in bed if it was not yet the schema time to feed. At the age of 6 weeks, the mother described at length how she decided to stop any "spoiling" activities and adhere rigidly to schema sleeping, schema contact, and schema feeding by letting her infant cry it out on its own (i.e., if the infant cried, it was *less* likely to be held). This attitude of the mother showed in the negative correlations found between the percentage of time spent crying and the percentage of time spent in body contact ($r = -.46$; $p < .001$) and between the frequency of crying and the percentage of time spent in body contact ($r = -.24$; $p < .05$).

Another way in which this rigid regime shows is the low mean percentage of time spent in body contact after the age of 26 weeks (see Fig. 5.3). This is more than 10% lower than the mean of Infant E. Infant F spent a considerable amount of its time in the playpen during the first 9 months of its life. Being in the playpen played a daily recurrent part in the rigid schema.

One would expect this rigid regime to change the predicted age-linked peaks in body contact and so it did (see Fig. 5.3). At 4 weeks, during the first regression period, the crying graph shows a peak and the body contact graph decreases dramatically from 85% to 33%. The combination of a dip in body contact and a peak in crying is shown again at 11 weeks.

Apart from the effect of a rigid schedule on the contact measure, there are other environmental circumstances that influence the percentage of time spent in body contact. First of all, according to the mother, Week 14 was very chaotic (see letter CH in Fig. 5.3) with the first programed injection cocktail (see letter I in Fig. 5.3), lots of travel by car, staying the night in several places, and meeting many new people. Body contact shows a sharp peak in this week. Furthermore, the peak at 39 weeks has to do with the start of crawling and the mother starting to train for this activity (e.g., "come up to mammy").

Beyond the age of 14 weeks, however, the body contact graph shows clear-cut peaks and dips and the peaks coincide with the regression periods (except for the one that has to do with the training of crawling). In particular, this coincidence may have contributed to the significant tem-

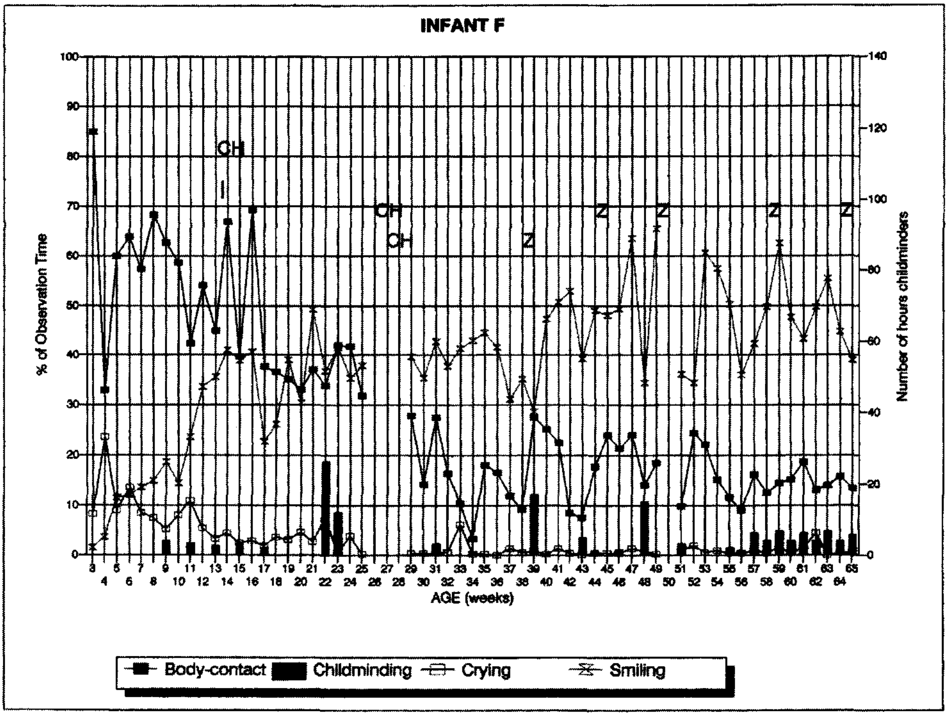

FIG. 5.3. The percentage of observation time Infant F spent in body contact, crying, and smiling, and the number of hours other people than the mother were looking after (child-minding) Infant F. Z = child ill; CH = chaotic week; I = programed injection cocktail.

poral correlation between the body contact measure and the regression periods (Fisher Exact Test, $p = .001$).

Crying decreased rather quickly in the first 13 weeks after birth apart from the two peaks at 4 and 11 weeks; and, beyond 24 weeks, it is zero most of the time.

It is striking that Infant F starts smiling much earlier than the other infants and it did so for a considerable percentage of the time (> 10%): at 5 weeks (instead of approximately 10 weeks), smiling becomes more prominent than crying, as if it takes over as a means to get attention. At 12 weeks, the week after the second combination of a dip in body contact and a peak in crying, the percentage of time spent in smiling has again increased sharply to a level of approximately 35%. This is very high for that age, compared with the other three infants.

Mother–Infant Dyad J: Rigid Sleeping, Contact, and Feeding Schedules

This is the second of the two mothers who adhered to schema care. She was advised by the Child Guidance Centre to let Infant J cry in order not to spoil the child. Again, this implies that, if the infant cried, it was *less* likely to be held. This approach is reflected in the graphs at 8 and 16 weeks, for instance, where the body contact graph shows a dip and the crying graph a peak (see Fig. 5.4). At later ages, beyond 28 weeks of age, the most prominent dips in body contact are found at 30, 35, 42, 52, and 62 weeks. Apart from the "checking-back-pattern" at 30 weeks (Mahler, Pine, & Bergman, 1975), this coincides with the regression periods around 36, 44, 51–53, and 61–62 weeks (van de Rijt-Plooij & Plooij, 1992). This is in accord with the notion that one might spoil children and this mother

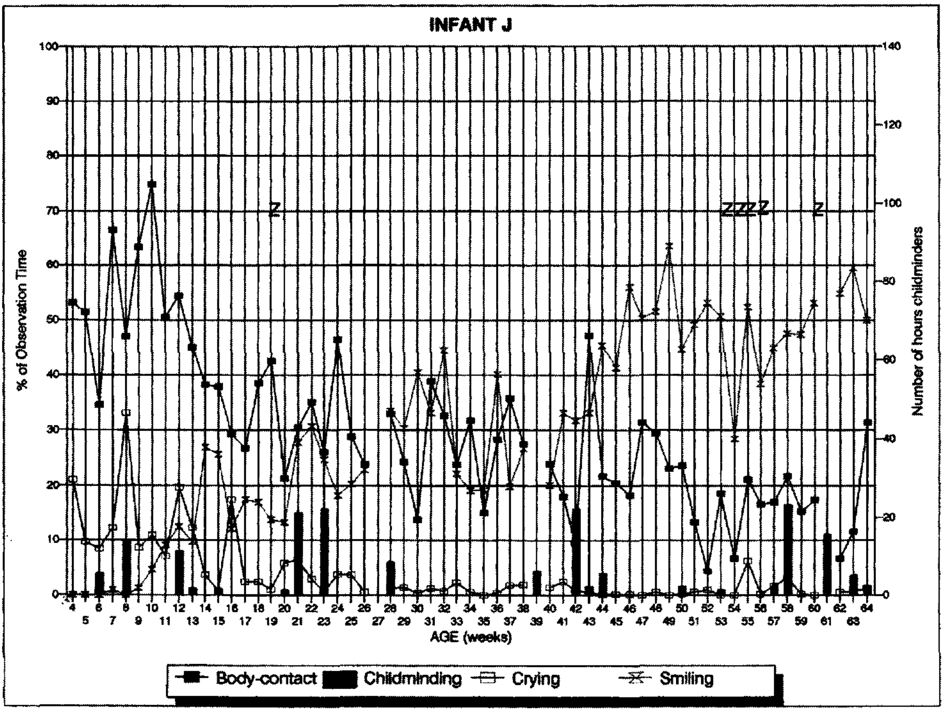

FIG. 5.4. The percentage of observation time Infant J spent in body contact, crying, and smiling, and the number of hours other people than the mother were looking after (child-minding) Infant J. Z = child ill.

said she disliked body contact. Daily, Infant J was placed in the playpen for a scheduled amount of time and could not make contact.

Apart from the effect of a rigid schedule on the contact measure, there are other environmental circumstances that influence the percentage of time spent in body contact. For the two largest increases in body contact at 43 and 64 weeks, there is a very simple explanation: They coincide with the infant walking bipedally for the first time at 43 weeks while being held at the hands, and the infant starting to crawl at 62 weeks followed by beginning to walk bipedally for the second time at the age of 64 weeks while holding hands.

The crying graph of Infant J shows four peaks at 4, 8, 12, and 16 weeks that coincide with the first four regression periods (see Fig. 5.4). Thereafter, however, the percentage of time the infant spends in crying is reduced to (nearly) zero and crying can no longer be used as an indicator of regression periods.

The smile graph of Infant J shows interesting patterns over age, which coincide with the regression periods (see Fig. 5.4). The first increase in smiling at 10–12 weeks is followed by a peak at 14–15 weeks. The peak in crying at 16 weeks coincides with the beginning of a dip in the smiling graph. In the following two regression periods, the smiling graph shows a dip as well at 24 and 34–35 weeks. Beyond the age of 39 weeks, these dips during regression periods cannot be found anymore. The smiling graph rises to another level of approximately 50%. This rise crosses both a regression period and an easy period, and the ultimate peak lies at 49 weeks. The following most pronounced dip lies at 54 weeks, 1 week after the end of the regression period around 52 weeks. This strongly suggests that there has been a qualitative change here where the regression periods coincide with peaks in smiling and not dips. At the age of 41 weeks, the observer reported that the mother told her for the first time that Infant J was smiling in a striking way that seemed “slimy,” as if it was trying to get on good terms with her, while (still according to the mother) it had never been particularly sweet with mother before. Seen at a larger scale, the next peak in this new way of smiling at 49 weeks coincides with the very beginning of the next regression period around 52 weeks. Thereafter, it comes down toward 54 weeks, only to rise again to a peak at 63 weeks. In the regression period around 61–62 weeks, Infant J changed tactics in order to get contact. Apart from the “slimy” smiling to mother, Infant J was very much hugging, kissing, and embracing, especially with father and grandmother. Infant J would not get such contact from mother. Furthermore, Infant J was very babyish again.

Mother–Infant Dyad S: Depression, Phobias, and So On

Looking at the graphs of the mother–infant dyad S in Fig. 5.5, the regression periods do not coincide with peaks in the body contact, as was expected, but just the opposite: They coincide with the dips. This is very clear at age 5 weeks, where the percentage of time spent in body contact decreased dramatically from more than 70% to less than 30%. Further sharp decreases are found at 8, 12–13, 17, 25, 31–32, and 36–37 weeks.

In the interviews and questionnaires, the mother reported the baby's wish for more contact very clearly, but, as soon as she felt that a regression period started, she often became more "ill" herself. Next, from the questionnaires, it became clear that she had difficulty coping with any changes in the behavior of her baby, be it regressive behavior or progress such as the emergence of new abilities. In both circumstances, she was preoccupied with her own worries. The result was a decreased body contact with her baby.

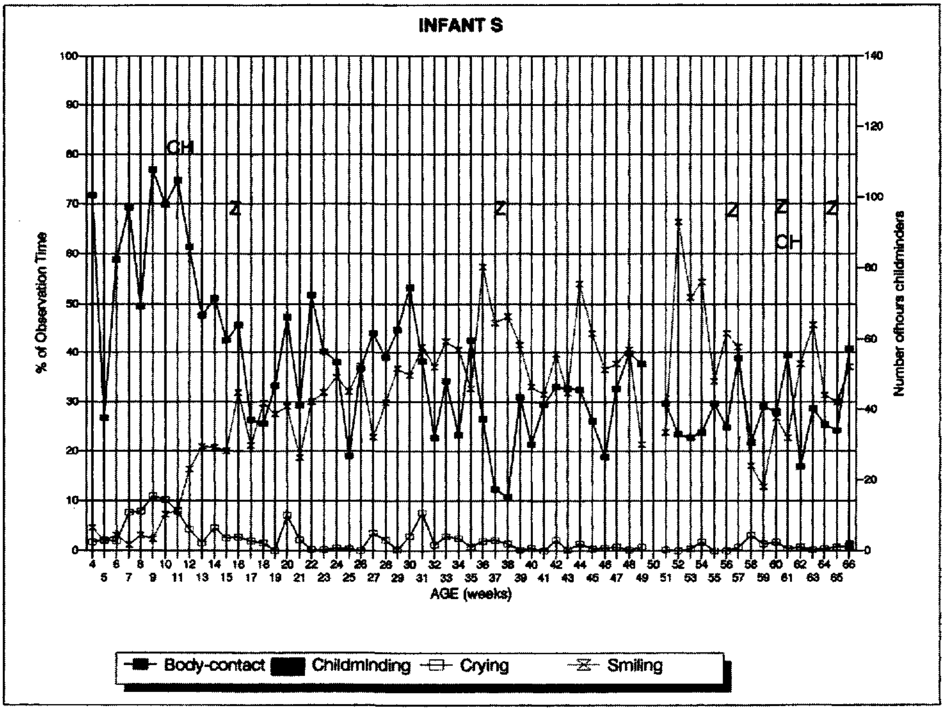

FIG. 5.5. The percentage of observation time Infant S spent in body contact, crying, and smiling, and the number of hours other people than the mother were looking after (child-minding) Infant S. Z = child ill; CH = chaotic week.

It is striking that Infant S hardly cried, apart from the first 13 weeks where a small "mountain" can be found around 9 weeks. The percentage of time spent in crying or fretting-fussing and the frequency of crying all correlated significantly with body contact ($r = .39, p < .001$; $r = .32, p < .01$; $r = .30, p < .01$; respectively). This clearly results from both crying and body contact showing a maximum around 9 weeks.

The smiling graph shows a dramatic nonlinear timing. Around 11 weeks there is a sharp rise in smiling where smiling "takes over" from crying. Beyond that it is striking that Infant S was smiling much more than Infant E. Then, beyond 34 weeks, smiling in Infant S shows very prominent peaks that coincide with the regression periods around 36, 44, 52, and 61–62 weeks, as reported by van de Rijt-Plooij and Plooij (1992).

Summarizing, Table 5.1 shows the results in a schematic way.

CONCLUSIONS

The following conclusions can be drawn from these data:

1. The phenomenon of age-linked regression periods as reported by van de Rijt-Plooij and Plooij (1992) is reflected in peaks in direct observation measures of body contact under normal circumstances. Thereby, the phenomenon is once again validated by direct observations.
2. Under special parental conditions, such as rigid schedule care or depression and phobias, direct observation measures are not simply chaotic and do reflect the age-linked regression periods, albeit in another way. Dips instead of peaks on body contact have been found at the regression periods. Peaks in crying could be found only in the first few months after birth, because the crying is practically nonexistent thereafter and cannot be used anymore as a measure reflecting regression periods. Infants smile more under these special circumstances and smiling appears to take over from crying as a means to try and get mother's attention. Large peaks in smiling have been found to co-occur with regression periods at later ages.
3. It has proven important to filter out (large) peaks in body contact that can be explained by obvious external circumstances such as chaos, travel, and training crawling or bipedal walking.
4. The context, the parenting regime and attitude, and the age of the child cannot be ignored and have to be taken into account in any analysis.
5. Data of individual mother–infant pairs have to be analyzed separately and cannot be lumped.

TABLE 5.1

Summary of the Effects of Special Circumstances on Direct Observation Measures of Body Contact, Crying, and Smiling for Four Individual Mother–Infant Pairs

	Special	*Effects on Direct Observations of:*		
Infant	*Circumstances*	*Body Contact*	*Crying*	*Smiling*
E	None < 34 weeks	Peaks at regression	More than other infants	Less than all other infants
	Child-minding > 34 weeks	No peak at 52 weeks		
F	Rigid schedules	Low mean % time	Quick decrease after birth	More and earlier than all other infants
		Negative correlation with crying	Negative correlation with body contact	
	< 14 weeks	Dips at regression	Peaks at regression	
	> 14 weeks	Peaks at regression		
	Chaos and travel	Peaks at 14 weeks		
	Training first crawling	Peaks at 39 weeks		
J	Rigid schedules, maternal aversion of contact, overextended		Quick decrease after birth	More than E
				Dips 4–9 months at regression
	< 28 weeks	Some dips at regression	Peaks at regression high	
	> 28 weeks	Dips at regression		Peaks at last 2 regression periods
	Training biped, walking	Peaks at 43 and 64 weeks		
S	Depression, phobias	Dips at regression	Hardly any > 13 weeks	More than E
				First sharp increase around 11 weeks
				Peaks at regression > 34 weeks

DISCUSSION

Woolmore and Richer (chap. 3, this vol.) were right. De Weerth and Van Geert (1998) failed to report and take into account a number of environmental, parental circumstances, or sources of noise and, consequently, have "failed to see through the 'noise' in their data, such that they have mistaken their own failure to find the phenomenon for the phenomenon's non existence" (p. 34). Notwithstanding much oral and written debate since 1995 (Plooij, 1998a, 1998b; Van Geert & De Weerth, 1998), in which the sources of noise were clearly spelled out, De Weerth and Van Geert (De Weerth, 1998, chap. 2) kept insisting that "the differences in results are most unlikely to lie with the subjects which participated in the study" and that "strict selection procedures ... should guarantee that the infants are an adequate representation of a normal population" (p. 34). However small the chances are that three out of four families live under special circumstances, the fact is they did. This can not only be shown to be true with the help of the weekly questionnaire and interview data. Also De Weerth and Van Geert's own analyses of the observational data support it. For instance, the rigid sleeping, contact, and feeding schedules of mother–infant dyads F and J show up in the fact that Infants F and J spent significantly less time in physical contact with their mothers than Infants E and S (De Weerth, 1998, chap. 7).

Of course, this insistence on four representative mother–infant pairs is necessary for those engaged in quantitative falsification research, who are attempting to deduce the laws by which brains learn by studying samples of the classified behaviors of large numbers of them, then averaging within and across the samples in order to predict and/or understand the behavior of any single one (Taylor, 1958). According to this author, one should not expect this kind of research to provide much lawful explanations of behavior. And, indeed, Runkel (1990) showed the pitfalls of this approach with many examples.

Furthermore, De Weerth and Van Geert (1998) heavily made use of null hypothesis significance testing (NHST). Loftus (1996) articulated six major problems with NHST and suggested alternatives such as plotting the data and planned comparisons. And Sternberg (1997) reflected on the strong emphasis in the training of psychology students on considerations of research design and analysis at the expense of questions of substance: "We could teach more about scientific creativity—what it is, what leads to it, and how it can be developed. Unfortunately, very few psychology departments now even have courses on creativity."

The discussion needs now to move on from the phenomenon of age-linked regression periods to exist or not, to looking at how an infant adapts to special parental conditions. In what follows, it is striking that conclusions are supported by the analysis results of De Weerth and Van Geert themselves.

The maternal environment of Infant E did not show any special circumstances up to the age of 34 weeks. The mother of Infant E was sensitive to the contact wishes of her infant and the regression periods are expressed clearly in peaks in body contact. Of all four infants, Infant E had the strongest relation between negative vocalizations and body contact with the mother, especially ventral contact (De Weerth, 1998). This is in accord with the original findings of van de Rijt-Plooij and Plooij (1992). Infant E showed more negative vocalizations than Infants S and F, and Infant E smiled less than any of the other three infants (De Weerth, 1998). This accrued because Infant E did not need smiling as an alternative to negative vocalizations to get into contact with mother.

The maternal environment of Infant S was clearly special and this mother–infant pair showed dips in body contact during regression periods instead of peaks. At later ages, beyond 34 weeks, after crying had all but vanished, Infant S started to show large peaks in smiling during regression periods. One may consider this an effort on the infant's part to get mother's attention by using smiling as a new means to an old end. This effort had not the desired result, because there were still dips in body contact during the regression periods. Consequently, it is no wonder that De Weerth (1998) reported that smiling was negatively related to "total contact" in Infant S. The peak in smiling around 63 weeks (see Fig. 5.5) is lower than the foregoing three peaks and it might well be that the peaks in smiling have faded out at later ages where crying faded out earlier.

Infant S was not the only one to try out smiling as an alternative means to get mother's attention in a maternal environment that was clearly special. The mother of Infant F had decided to let her baby "cry it out" and administered the most extreme form of schedule care. During the first 3 months, there were dips in body contact combined with peaks in crying and sharp increases in smiling to a level that is higher than that of any of the other three infants. The crying quickly faded out to a very low level (see Fig. 5.3). Together with Infant S, Infant F showed less negative vocalizations than the other two infants and Infant F smiled more than any of the other three infants. This resulted in a strong association between smiling and body contact (De Weerth, 1998), and it is interesting to note that the regression periods tended to be associated with peaks in body contact after the smiling had increased to this high level. This successful, positive association between smiling and body contact may have been the reason why the level of smiling did not decrease toward older ages in Infant F.

Infant J is the most complex. The maternal environment was special in the sense that Infant J was separated from mother during the first 10 days after birth, the mother stated herself that she disliked body contact, and the mother administered rigid schedule care. In addition to that, Infant J was overstretched and received physiotherapy for at least 8 months after birth. Like Infant F, Infant J spent significantly less time in body contact than Infants E or S (De Weerth, 1998). The initial level of time spent in body contact is much lower than in the other infants. This may have to do with the mother–infant separation during the first 10 days after birth. This, in its turn, may have disturbed the mother–infant contact regulation. In the majority of the regression periods, there was a dip in body contact instead of a peak (see Fig. 5.4). But, like Infant E, Infant J showed more negative vocalizations than Infants S or F (De Weerth, 1998). Infant J showed very clear and high peaks in crying during the first four regression periods. The height of the crying peaks decreased and crying faded out soon thereafter (see Fig. 5.4). Whereas Infant J smiled less than Infant F, like Infant S it smiled more than Infant E (De Weerth, 1998). During the last two regression periods around 52 and 61–62 weeks, Infant J showed a peak in smiling. However, the smiling had a peculiar, "slimy" quality according to the mother. It may be that this peculiar smiling was a mix of a smile and a fear-grin, witnessing an approach-avoidance conflict in the infant wanting body contact and knowing the mother disliked body contact. Richer (1979) reported a similar discrepant form of smiling in autistic and very disturbed children that looks as follows: The mouth corners are drawn back and slightly up, the upper lip is pulled up to straighten its line. Both rows of teeth are usually shown and are together. This is often seen when a child is in conflict.

It is interesting that all three infants, for whom the regression periods were not invariably expressed in peaks in body contact, turned to an increased level of smiling as an alternative to negative vocalizations. This implies that the use of smiling is not an idiosyncratic solution but an option available to any infant. It also shows that infants will do anything as long as they reach their goal, which is a certain amount and kind of body contact in this case. If crying is ineffective, then the infants stop doing it and try another behavior that is available in their repertoire, such as smiling. In this context, it is worth noting that Woolmore (1998) found that mothers with a postnatal depression showed a more regulatory style of mothering. In that respect, they have something in common with mothers adhering to rigid schedule care.

Finally, a reflection of a more general nature. In analyses of directly observed behavior categories such as those already discussed, context is very important. Without it, analyses become meaningless. Either one tries to control for the context, or, if this proves impossible, one analyzes the interplay between context and observational measures. Otherwise, the results are biased or even nonsense. However impressive the statistical analysis, if the prestatistical data gathering on behavior and context is incomplete, then the analysis collapses like a house of cards.

This enormous flexibility and context contingency of human behavior is not to say that there is no "human nature" and there are no built-in mechanisms or motives to guide action, as is expressed in the age-linked regression periods. The central message of evolutionary psychology is that "without those mechanisms to guide action, the islands of adaptive solutions could never be discovered amid the expansive oceans of maladaptive possibilities" (DeKay & Buss, 1992, p. 186).

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6

Illness Peaks During Infancy and Regression Periods

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As long ago as 1935, Walter Cannon suggested that the normal experiences of life—such as the onset of puberty, fatigue, and everyday worry—all make a physical impression on the body. He observed that "the whole gamut of human diseases might be studied from this point of view" (p. 14). Since then, researchers have learned that ill-health is preceded by a high level of psychosocial transitions, or "life events," especially if these events are perceived as "negative" (Helman, 1990, p. 252). The psychosocial transitions most likely to cause stress are those that take place over a relatively short period of time, are lasting in their effects, and affect many of the assumptions that people make about their worlds (Parkes, 1971). Considerable evidence is accumulating that demonstrates a relation between immune function and behavioral states, such as object loss or depression in adults (Schleifer, Scott, Stein, & Keller, 1986). Investigations on the immune system in young children regarding the possible effects of deficiencies or losses in the area of bonding to caretakers are scarce (Mattsson, 1986).

Early life experiences in humans and in animals have been shown to have both immediate and long-term effects on behavior and health plus the immune system (Schleifer et al., 1986). The early interruption of mother–infant interaction has significant, specific biochemical and physiological consequences in mammalian species. This is consistent with clinical findings of impaired growth hormone secretion and tissue responsivity to growth hormone in nonorganic failure-to-thrive children, or children with maternal deprivation syndrome, reactive attachment disorder, or psychosocial dwarfism (Schanberg & Field, 1988). Many pediatricians serving disadvantaged clinic populations note a high incidence of respiratory and gastrointestinal infections, along with the general signs of retarded growth and development (Mattsson, 1986). Children with chronic psychosomatic illness are at risk for development of "inverted" attachment (Bowlby, 1973), and are likely as a group to show measurable growth hormone deficiency, and reduced slow-wave sleep, as are physically abused children (Moore, 1989). It is becoming evident that modulators of immune responses may also be important in the regulation of slow-wave sleep (Karnovsky, 1986).

Little is known concerning the nature of behavioral–CNS–immune interactions during early life, when developmental processes within the immune system and the CNS may amplify or diminish the impact of behavioral and CNS effects (Schleifer et al., 1986). It is clear that progress in the discipline of psychoneuroimmunology over the last 25 years concerning adult organisms has shown that complex interactions do exist between overt behavior, the central nervous system (CNS), the endocrine system, and the immune system (Ader, Felten, & Cohen, 2001). There are two bodies of evidence for a linkage between the brain and the immune system (Locke & Colligan, 1986, pp. 56–57). The first is largely inferential and concerns the findings that it is possible to influence the immune system by conditioning behavior (Ader & Cohen, 2001); that damage to the neocortex and the hypothalamus cause changes in the immune system; and that alleged structural differences in the brain (dyslexia) are connected with higher than average incidence of autoimmune disease. The second contains more direct evidence, such as anatomic nerve-mapping that shows infiltration of the nervous system into the immune system (the bone marrow, the thymus, the spleen, and the lymph nodes); the immunosuppressive or immunoenhancing effects of the endorphins secreted by the brain; and findings showing active lines of communication between the brain and the immune system. Another important line of research concerns the effects of immune processes on emotional states and other behaviors such as activity, sleep, and appetite (Ader, 2001).

In light of (a) these complex behavior–CNS–immune interactions, (b) the 10 infantile regression plus conflict periods (around Weeks 5, 8, 12, 17, 26, 36, 44, 53, 61–62, and 72–73) during the first 20 months of life as reported by van de Rijt-Plooij and Plooij (1992, 1993), Plooij and van de Rijt-Plooij (1994), and Heimann (chap. 1, this vol.), and confirmed and discussed in the contributions to this volume, and (c) the suggested link between the regression periods and changes in the CNS (Trevarthen & Aitken, chap. 8, this vol.), it does not seems too far fetched to go one step further and assume these changes in behavior and the CNS somehow are reflected in changes in health and the immune system as well.

This notion implies that the distribution of illnesses over development should be nonlinear and show a multimodal distribution during the first 20 months of life. This hypothesis is tested in this article.

METHODS

Subjects

Twenty-six subjects, 15 girls and 11 boys, from two independent studies (van de Rijt-Plooij & Plooij, 1992, 1993; Koopmans-van Beinum, Jansonius-Schultheiss, & Van der Stelt, 1990) contributed data for the present analysis. All subjects but one were healthy, full-term newborns without any complications during pregnancy or at birth. Their Apgar scores were 8–10 after 1 and 5 minutes. The single exception (a girl) was born spontaneously 4 weeks early, just like her older sister. She spent 3 days in an incubator because of possible signs of prematurity of the lungs. No postnatal problems were found. The median maternal age at childbirth was 29 years (range 22–37 years). The babies came from working- (5), middle- (11), and upper-class (10) Dutch Caucasian families. Twelve babies were firstborns, 8 had one older sibling, 6 had two older siblings.

Procedure

A mixed (prospective multiple case study) time series design was used. The mothers were asked for approximately 24 months after birth to complete a questionnaire once a week and to return the forms immediately.

Compliance was 100%. The mothers were not informed the exact purpose of the study, but were told that the interest was in the baby's progress, new skills, new interests, and new fears.

In the questionnaire, part of the questions concerned the baby's health during the last week. If the baby had been ill, then the mother was asked to write down the kind of disease and the date the illness had started and/or ended. Thus, longitudinal data on onset and duration of diseases was obtained.

Analysis Methods

A statistical technique was used as proposed by Silverman (1981),[1] using the kernel density estimator

$$f_h(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right) \tag{1}$$

(where K = φ where φ denotes the standard normal density) together with a "smooth bootstrap," to investigate the number of modes in the frequency distribution of illnesses over age. His method (S-method for short) can be described as follows: Define, for each natural number j,

$$h_{crit,j} = \textit{the smallest value of the bandwidth } h$$

$$\textit{such that } f_h \textit{ has at most } j \textit{ modes} \tag{2}$$

To compute $h_{crit,j}$, one can make use of the following property of f_h (cf. Silverman, 1981): f_h has more than j modes if and only if $h < h_{crit,j}$. So, $h_{crit,j}$ is easily found, because for each value of h it is possible to check whether or not $h < h_{crit,j}$, simply by counting the number of modes in f_h.

Silverman's idea now is to reject the hypothesis

$$H_{0j} : \textit{the number } M \textit{ of modes of } f \textit{ is at most } j \tag{3}$$

in favor of the alternative

$$\mathbf{H_{1j}} : \textbf{the number of M of modes of f is bigger than j} \tag{4}$$

---

[1] The statistical analysis, based on Silverman (1981), was carried out in 1991–1992. Between then and the publication of this chapter, a number of works on "bump-hunting" have appeared in the statistical literature. We have not looked into these more recent developments.

whenever the observed value of $h_{crit,j}$ (cf. Equation 2) is "too large." A smooth bootstrap can now be used to assess the significance of the observed $h_{crit,j}$. A "bootstrap sample" $y_1^*, \ldots, y_n^*$ can be drawn as follows:

$$y_i^* = R_S(X_i^* + h_{crit,j} Z_i) \qquad (5)$$

for $i = 1, \ldots, n$. Here, $X_1^*, \ldots, X_n^*$ is a bootstrap sample drawn with replacement from the original observations $X_1, \ldots, X_n$; that is, each of the n data points $X_1, \ldots, X_n$ gets equal probability mass $1/n$, whereas $Z_1, \ldots, Z_n$ are independent standard normal random variables. The value of $h_{crit,j}$ is computed from the data set $X_1, \ldots, X_n$ with the aid of Equation 2 and the argument following it, and the "scaling" factor R_S is given by

$$R_S = \left(\frac{s^2 + h^2_{crit,j}}{s^2} \right)^{-1/2} \qquad (6)$$

where

$$s^2 = n^{-1} \sum_{i=1}^{n} \left(X_i - \overline{X_n} \right)^2$$

with

$$\overline{X_n} = n^{-1} \sum_{i=1}^{n} X_i.$$

By means of a Monte-Carlo simulation, one now generates a large number—say B—of artificial pseudo-bootstrap samples

$$y^*_{1b}, \ldots, y^*_{nb} \ (b = 1, \ldots, B) \qquad (7)$$

of size n according to Equations 5 and 6. For each bootstrap sample, it is necessary to compute $h^*_{crit,j}$, the smallest bandwidth h such that $f^*_{h,b}$—the kernel density estimator of f_h with the X_i's replaced by the $y^*_{i,b}$'s—has at most j modes. Finally, $p^*(h^*_{crit,j} > h_{crit,j})$ may be estimated by the number of times that $h^*_{crit,j} > h_{crit,j}$, divided by B, the total number of bootstrap samples in the simulation. As pointed out by Silverman (1981), there is in fact no need to compute $h^*_{crit,j}$ for each bootstrap re-sample: It suffices to count the number of modes in $f^*_{hcrit,j}(.)$ for each of the B bootstrap based density estimates. The relation

$$p^*(h^*_{crit,j} > h_{crit,j}) = p^*(f^*_{hcrit,j}(\cdot) \text{ has more than } j \text{ modes})$$

$$\approx B^{-1}.[\text{number of bootstrap based density estimates}$$

$$f^*_{hcrit,j}(\cdot) \text{ which have more than } j \text{ modes}] \quad (8)$$

yields a Monte-Carlo estimate of $p^*(h^*_{crit,j} > h_{crit,j})$. In other words, by means of smooth bootstrapping, the probability that the kernel density estimate f^*_h (cf. Equation 1), with bandwidth $h = h_{crit,j}$ (cf. Equation 2), the observed value of Equation 2, will have *more* than j modes. If the probability in Equation 8 is "too small," then $h_{crit,j}$ is viewed as being "too large," under the hypothesis H_{0j}, and H_{0j} is rejected in favor of H_{1j}: The number M of modes of the density f is bigger than j.

In judging the results, bear in mind that, under the null hypothesis H_{0j}, the bootstrap estimates $p^*(h^*_{crit,j} > h_{crit,j})$ tend to be considerably bigger than the quantity it is trying to estimate, namely, the probability that $h_{crit,j}$ is larger than its observed value. Although a complete mathematical analysis confirming this is still lacking, Mammen, Marron, and Fisher (1992) gave compelling heuristic evidence. In other words, the bootstrap based *S* test is likely to be conservative (i.e., a nominal level of significance of .10 will probably correspond to a much smaller true level of significance). So, it is justifiable to consider a p^* probability in the range of .10–.20 as rather small.

RESULTS

A total of 183 illnesses were reported. The great majority (92%) of the diseases consisted of a common cold/cough or diarrhea. The other diseases were rash (3 ×), otitis (2 ×), pneumonia (2 ×), rubella (2 ×), varicella (2 ×), laryngitis subglottica (1 ×), measles (1 ×), scarlet fever (1 ×), and spasmodic croup (1 ×).

The frequency distribution of the duration of the diseases is presented in Fig. 6.1. The mean duration is 13.35 days.

The percentage of the number of days per week the babies could maximally be reported to *be* ill (7 days × total number of babies participating in the study during that week) is plotted against age in Fig. 6.2. A number of peaks are superimposed on an inverted U-shaped curve. The question that arises, however, is what peaks are to be considered real local maxima, and what peaks are merely noise in the data. At face value, there seem to be at least nine peaks—if one not only considers the height of the local

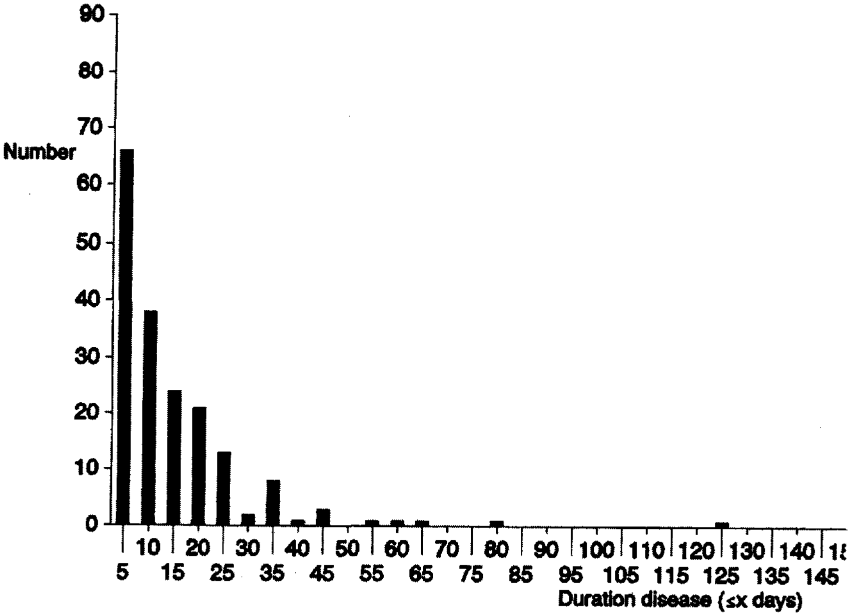

FIG. 6.1. The frequency of distribution of the durations of the diseases. The mean duration is 13.35 days.

maxima, but also the depth of the local minima. These peaks are centered around 6, 15, 21, 31, 40, 51, 65, 85, 95, and 99 weeks.

To test statistically whether there exist a number of illness peaks during infancy, the days at which infants *become* ill had to be used instead of the durations of the illnesses. The observations—denoted by $X_1, \ldots, X_n$—are the observed moments at which infants got ill. The common density of X_i's ($i = 1, \ldots, n$; $n = 183$) is completely unknown (i.e., there are not a priori assumptions of a (semi) parametric nature that could be imposed). In such a nonparametric framework, the aim is to make statistical inference about the number of the modi of f. More precisely, the unknown number of modes M is at least k, with high confidence. Throughout, it is assumed that the observed X_i's are independent realizations of the same random variable.

Given the fact that the 183 measurements of moments at which an infant became ill all originate from the same group of 26 infants, one might doubt the assumption of independence. The assumption is reasonable for a first study, provided it is assumed that each infant is fully recovered after each illness period and the length of illness periods is small compared

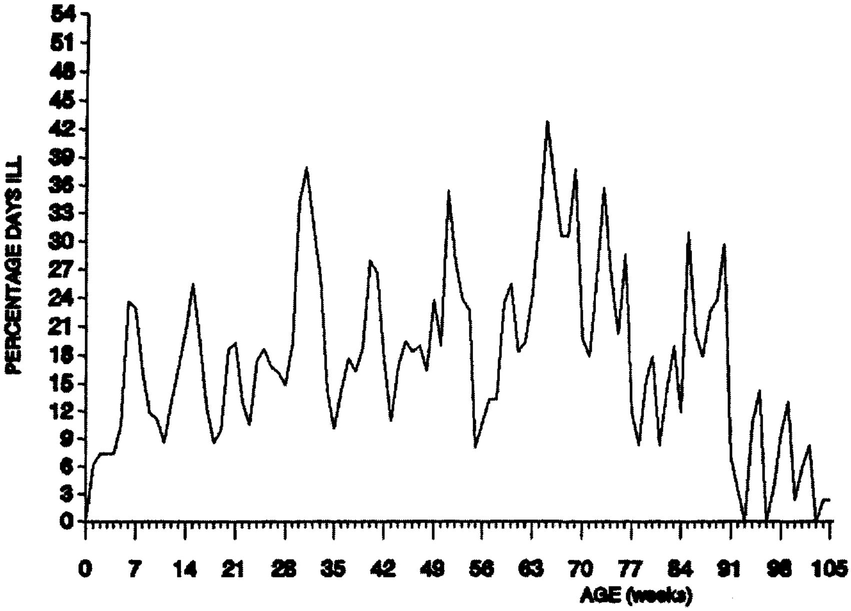

FIG. 6.2. The percentage of the total number of baby days per week (7 days × total number of babies participating in the study during that week) the babies were reported to *be* ill, as plotted against age.

to the median time between clusters of illness episodes. The distribution of the duration of the illnesses has been investigated and it turns out that the average is 13.35 days with a standard deviation of 15.72 days.

Another point that should be mentioned is the fact that the measurements are treated as continuous data, whereas in fact they are daily, and thus grouped, measurements. Extra smoothing is applied at instances where the discreteness might actually influence the performance of the statistical procedure.

In Table 6.1, the results are summarized as obtained by application of Silverman's method. In the third column, p^* becomes as low as .15 for eight modes. From this it may be concluded that the true unknown number of modes of f is likely to be *at least* eight, or more.

Figure 6.3 presents the Kernel density estimator (1) of the unknown density f for bandwidth $h_{\text{crit}} = 18.5$. Eight tops can be seen at the ages of 5, 15, 30, 40, 51, 62, 86, and 99 weeks. The same ages were obtained for $h = 18$, or $h = 19$.

TABLE 6.1
Silverman's (1981) Density Analysis

	$N = 183$	
Number of Modes	h_{crit}	p^*
1	42	.87
2	34	.83
3	30	.68
4	28	.45
5	22.5	.70
6	22	.38
7	20	.24
8	18.5	.15
9	15.5	.28

Note: Calculations of $p^*(h^*_{crit,j} > h_{crit,j})$ with Bootstrap, B = 500.

CONCLUSIONS

First of all, the total number of observations $n = 183$ appears to be rather limited for the purposes here. It is well known that the statistical variability of kernel density estimates and even more so of qualitative smoothness measures of these density estimates, such as the number of modes, is generally quite large in not very large samples. This, of course, is also reflected in the relatively large p^* values in Table 6.1. It may be concluded that the problem of making a really trustful assertion about the number of modes in the density f would require a considerably larger number of observations. However, the present statistical analysis seems to suggest that this is indeed a multimodal density.

This multimodal density contains at least 8 modes, or more. It is important to realize that the multimodal density cannot consist of less than 8 modes, but 9 or 10 modes are certainly not refuted by the present analysis. This statement is based on the following considerations. Only lower confidence bounds for M, the number of modi of f, are possible. Statements like "the number of modes of f is at most 10, with 90% confidence" are impossible to validate. The mathematical theory supporting this was given by Donoho (1988). It turns out that because $M = M(f)$ is a lower

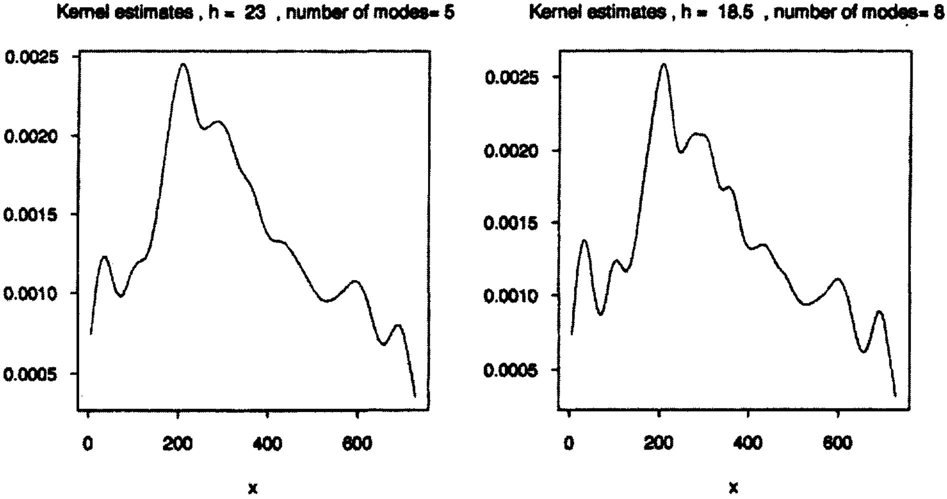

FIG. 6.3. Kernel density estimator.

semi-continuous functional one-sided inference about M is possible. By small perturbations of f, it is easy to end up with densities with 9, 10, or even more modes. Looking at Fig. 6.2, it is easy to understand how the peaks at Weeks 21 and 73, for instance, may become more prominent with a larger number of observations.

So, six and possibly eight illness peaks fall within the first 20 months (85 weeks) of life.

Comparing the age ranges in which the regression periods start and end with the ages around which the illnesses start, the temporal relation is striking. The first column below rank orders the 10 regression periods found earlier (see Fig. 6.1 in Heimann, chap. 1, this vol.). The second column presents the age ranges in which the regression periods start. The fourth column presents the age ranges in which the regression periods end. The third column presents the ages around which the illnesses start. The ages between the { }-brackets are tentative. In regression periods 2 and 7, no illnesses were reported (–).

1.	4–5	(6)	5–6
2.	7–8	(–)	8–9
3.	11–12	(15)	12–13

4.	14–17	{21}	16–20
5.	22–26	(30)	25–27
6.	32–37	(40)	36–40
7.	40–44	(–)	43–48
8.	49–53	(51)	52–57
9.	60–61	(62)	62–65
10.	71–72	{73}	73–78

It is striking that, during the first 9 months (regression periods 1–6), the start of an illness falls in between two regression periods or follows the (end of) previous regression periods. Toward one year and beyond, the illnesses start already during a regression period toward the end. The argument that regression periods result from an illness can be ruled out. The definition of a regression period was such that any obvious external reasons for being difficult, such as the infant being ill, were excluded. The exact temporal relation between regression periods and illness only shows up clearly in sequential analysis of individual data. This goes beyond the scope and limits of this chapter and is a topic for further research.

DISCUSSION

The aforementioned temporal relation between the nonlinear distribution of illnesses and the nonlinear distribution of regression periods is the result of the same process underlying both phenomena. This underlying process may be age-linked brain changes that both affect behavior and the immune system, the consequence of the latter being illness. But, before dwelling a little more on this speculation, more parsimonious explanations need to be explored.

The inverted U-shaped curve, on which the multimodal density is superimposed, was reported in other studies as well. The risk of experiencing an episode of acute otitis media increases at the age of 6–12 months and decreases slowly during the second year of life (Alho, Koivu, Sorri, & Rantakallio, 1991; Pestalozza, Romagnoli, & Tessitore, 1988). Diarrhea shows a higher incidence in the first 3 years of life, especially in the age group 6–12 months (Ford-Jones, Mindorff, Gold, & Petric, 1990). The incidence of acute respiratory tract infection is highest in the first 2 years of life and decreases with increasing age (Oyejide & Osinusi, 1990). Of 111 children under 10 years and admitted to a hospital with gastroenteritis, 89.7% were less than 2 years of age (Moodley, Jackson, Gathiram, & Van den Ende, 1991). A total of 188 patients out of all children born in Göteborg, Sweden, between 1970 and 1980, were found to have coeliac disease. Of these, 83% were less than 2 years old at the time of their first duodenal biopsy (Ascher, Krantz, & Kristiansson, 1991).

This inverted U-shaped curve is understandable from knowledge about the ontogeny of the immune response. With Solomon's age equivalence theory, it is possible to combine growth rate characteristics and predict stages of immunologic competence. A curve can be constructed that generally applies to all mammalian species so far examined, including man (Solomon, 1978a, 1978b). This curve concerns the life span until adulthood. During infancy and early childhood, distinct periods of susceptibility to certain diseases were found (Pabst & Kreth, 1980). These periods are 1–6 months, 7–18 months, and over 18 months. The period of 7–18 months can be recognized in Fig. 6.3: After the age of 6 months (182 days), there is a steep rise in getting ill and between 7–18 months the chance of becoming ill goes down to the level of before the age of 6 months. After 18 months, there is another, relatively large rise in the chance of becoming ill (after 78 weeks in Fig. 6.2; also the one but last bump after 546 days in Fig. 6.3). By age 2, the immune system is functioning at a mature level.

The multimodal density superimposed onto the inverted U-shaped curve has never been reported so far. A thorough computer search of literature stored in the Index Medicus from 1966 to 1991 and in the *Sociofile* from 1974 to 1991 did not uncover any report of multiple illness peaks over age during infancy. Nor did a recent search from 1988 until 2001 in the citation databases of the Institute for Scientific Information (ISI). Only two articles report comparable results with regard to the number of illness peaks.

A prospective study of diarrheal illness was conducted for 2 years in 309 families who were part of an epidemiologic research center population in rural Egypt. The rates of illness peaked in the first year of life with between five and six episodes per person per year at risk (Alamy, Thacker, Arafat, Wright, & Zaki, 1986). This is in accord with the six modi found in the study in the first year.

A longitudinal, community-based study of the epidemiology of acute respiratory tract infection (ARI) in children less than 5 years old was carried out in a community of low socioeconomic level in Ibadan, Nigeria. The annual incidence of ARI ranged from 6.1 to 8.1 episodes per child per year (Oyejide & Osinusi, 1990). The number 6.1 is in accord with the six illness modi found in the first year. The number 8.1 is possibly related to the number of eight regression periods in the first year.

The multimodal density cannot be explained parsimoniously. Admittedly, there have been reports on some (but not all) isolated peaks. For instance, a heightened susceptibility to disease has been reported for the age of 3 months. The explanation given is that the "antibodies" present in the baby's blood from birth have been exhausted and that the baby's own immune system is not yet fully functioning: The gamma immunoglobulin (IgG) levels in serum of infants falls to a minimum by about 2 months of age, with a subsequent rise to those levels that characterize older children and adults (Mussi-Pinhata & Gonçalves, 1989). And antibodies of the major bloodgroup (ABO) system usually appear by the second month of life (Kempe, Silver, & O'Brien, 1978; Nelson, 1979). Furthermore, for every single disease there may also be literature supporting a nonuniform distribution over age of the likelihood of occurrence of that disease. For example, sudden infant death syndrome (SIDS) occurs almost entirely in the second through the fifth month of life; the peak is at some midpoint (Helweg-Larsen, Bay, & Mac, 1985). Such deaths at earlier or later ages are quite rare (Nelson, 1979, p. 1980). However, all this knowledge does not fully explain the multimodal distribution of illnesses found during infancy over age. Without questioning the validity of the kind of explanations given so far, they are only part of the picture. Not all illness peaks are covered. Additional information is needed for explaining the modi found.

Confounding factors such as breastfeeding or not, group day care or not, parity, a correlation between illness and return of the questionnaires, month of the year the baby was born, and birth order were all considered and could be ruled out.

The most parsimonious explanations do not hold, so it is legitimate to search for more complex explanations such as the hypothesis that brain changes underly both regressive behavior and illness.

Summarizing, at least 8 and possibly 10 illness peaks are found in the first 2 years of life. Six and possibly 8 illness peaks occur in the first 20 months and fall in between or shortly follow regression periods. Such a multimodal distribution of illnesses was never reported in the literature. A temporal link between illness peaks and regression periods was suggested. Apart from replicating this multimodal distribution of illnesses in a larger sample, directions for future research might involve the mechanisms underlying these illness peaks cum regression periods.

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7

Multimodal Distribution of SIDS and Regression Periods

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Galef (1981) predicted periods of vulnerability based on his comparative evolutionary perspective on mammalian parent-infant relationships. He compared mammalian infants with parasites, who lose some structural and functional integrity once attached to a host. For human infants, this implies that once they begin to engage, or rather, re-engage with their mother, they also lose some of their structural and physiological integrity because they become increasingly dependent on the nature and timing of her care (see Field, 1985; Trevarthen & Aitken, chap. 8, this vol.) while simultaneously losing reflexive behaviors to higher brain (labile) behaviors as their development proceeds. So, they become vulnerable to neurological control system errors, especially during early, critical transitions or developmental shifts.

McKenna (1990b) argued that the shift from reflexive to speech breathing is such a vulnerable period and there is some connection with the sudden infant death syndrome (SIDS). At around 2 months of age, the infant begins to be able to switch back and forth between voluntary and involuntary, or automatic, breathing (McKenna, 1990b). Between 2 and 4 months after birth, a shared brain stem–cortical breathing control necessary for speech breathing vis-á-vis crying emerges. Whereas the medulla oblongata and the pons region of the brain stem's reticular formation (the primary respiratory or "pneumotaxic" control center) are primarily involved in the involuntary breathing, the motor area of the neocortex is involved in the voluntary breathing through corticobulbar and corticospinal pathways (McKenna, 1986).

Such developmental shifts are not limited to breathing per se. Also at 8 weeks, babies show regression in the way they vocalize cry and noncry sounds. At that age, human infants "produce a special sound which is called 'cerebral peep'" (Mende, Wermke, Schindler, Wilzopolski, & Höck, 1990, p. 106). According to Wermke and Mende (1993):

> The spectogram and the melody reveal a kind of monotony/rigidity of the sound (which is also audible). All the well performed complex melody patterns seem to be forgotten, and a simple rising-falling melody with slight modulations of low modulation depth appears. The perturbation residuals reflect the rigidity by its very constant and low value over the whole cry (PNG: 1.73 ‰). These cries remember to cries of the very first weeks (PNG: 2.12 ‰), although they are not identical to them.... These periods of regression seem to be external signs of reorganization processes in the brain and of inauguration of new controls of superimposed centers. Caused by a disturbed neurological control the sounds also reflect aerodynamical instabilities in form of noise bands during these phases. Those bands seem to occur frequently during such "regression" periods. (p. 187)

Such regressive, vulnerable periods are not limited to the age of 8 weeks either. Wermke and Mende (1993) studied the first half year of life and found their vocalizing regressions at the same ages as van de Rijt-Plooij and Plooij (1992) found their regression periods.

If there is some connection between SIDS and the regression period at 8 weeks, then there might be some connection between SIDS and the other regression periods as well. If this is true, then it would be expected that the frequency distribution of the number of SIDS victims over age would show a multimodal instead of a monomodal distribution. This hypothesis is tested here.

METHODS AND SUBJECTS

Subjects

All children in the Netherlands who died of SIDS (definition according to International Classification of Diseases version 9 [ICD-9]) in the first year of life during the years 1979–1993 participated in this study. The variables recorded were age (days after birth) at which the baby died and sex. These data were obtained from Statistics Netherlands in Voorburg. It was not possible to link these data to the length of gestation or to correct the ages into "age since conception." In total, the ages of 1,322 boys and 892 girls were studied.

Analysis Methods

A statistical technique was used as proposed by Silverman (1981),[1] using the kernel density estimator together with a "smooth bootstrap," to investigate the number of modes in the frequency distribution of SIDS victims over age (for a description of this technique, see Plooij, van de Rijt-Plooij, van der Stelt, van Es, & Helmers, chap. 6, this vol.).

RESULTS

Figures 7.1 and 7.2 present the frequency distribution over age of the number of deaths per week for girls and boys, respectively. The data for girls and boys are given separately, because there are clear differences between them. Apart from the well-known fact that many more boys die of SIDS than girls (Hatton et al., 1995), the highest peak comes 4 weeks earlier in girls than in boys (the 10th vs. the 14th week), and the small cycles superposed on the one big cycle are much more clear in girls than in boys. In girls, there seem to be small peaks at Weeks 7, 10–12, 17, 25, and between Weeks 29–35, 38–42, and around Week 51.

In Table 7.1, the results are summarized as obtained by application of Silverman's method. The p^* values for boys and girls + boys are not statistically significant. This means that the null hypothesis of a unimodal distribution cannot be rejected for boys or for boys and girls taken together. In the column for girls, p^* becomes as low as .085 and .156 for three or four modes, respectively. From this, it may be concluded that the true unknown number of modes of f is likely to be *at least* three or four for girls.

Figure 7.3 presents the Kernel density estimator (Equation 1 in Plooij, van de Rijt-Plooij, van der Stelt, van Es, & Helmers, chap. 6, this vol.) of the unknown density f for bandwidth $h_{\text{crit}} = 11.55$ for girls. Four tops can be seen at Weeks 10, 33, 39, and 51, where an increase reverses into a de-

---

[1] The statistical analysis, based on Silverman (1981), was carried out in 1995. Between then and the publication of this chapter, a number of papers on "bump-hunting" have appeared in the statistical literature. We have not looked into these more recent developments.

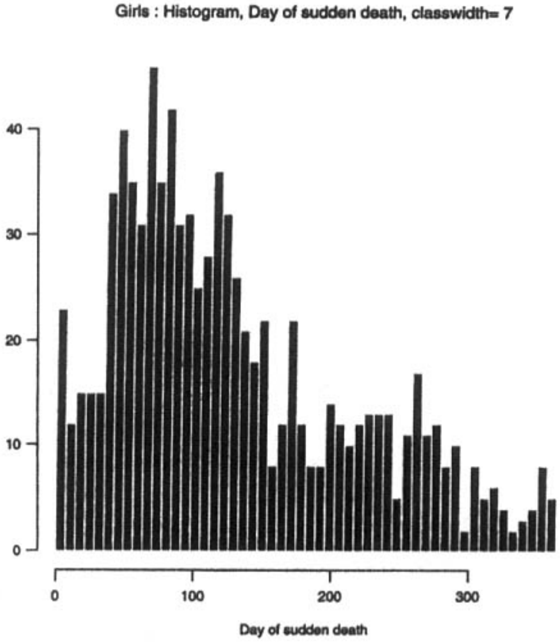

FIG. 7.1. Frequency distribution of age (days) at SIDS for girls. Classwidth = 7.

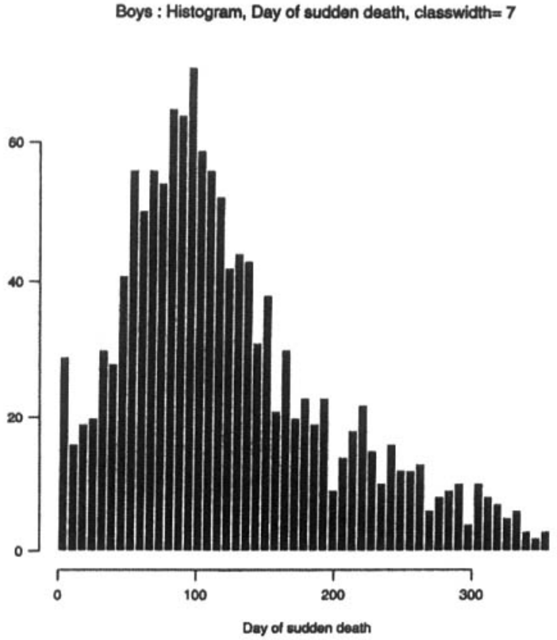

FIG. 7.2. Frequency distribution of age (days) at SIDS for boys. Classwidth = 7.

TABLE 7.1
Silverman's (1981) Density Analysis

	Girls $n = 892$		*Boys* $n = 1322$		*Girls + Boys* $n = 2214$	
Number of Modes	*hcrit*	p^*	*hcrit*	p^*	*hcrit*	p^*
1	19.93	.523	14.36	.461	15.47	.243
2	15.52	.211	10.01	.730	9.21	.786
3	14.00	.085	7.64	.901	8.65	.547
4	11.55	.156	6.99	.825	7.28	.701
5	9.57	.275	5.98	.938	7.11	.469

Note: Calculations of $p^*(h_{crit,j} > h_{crit,j})$ with Bootstrap, B = 1,000.

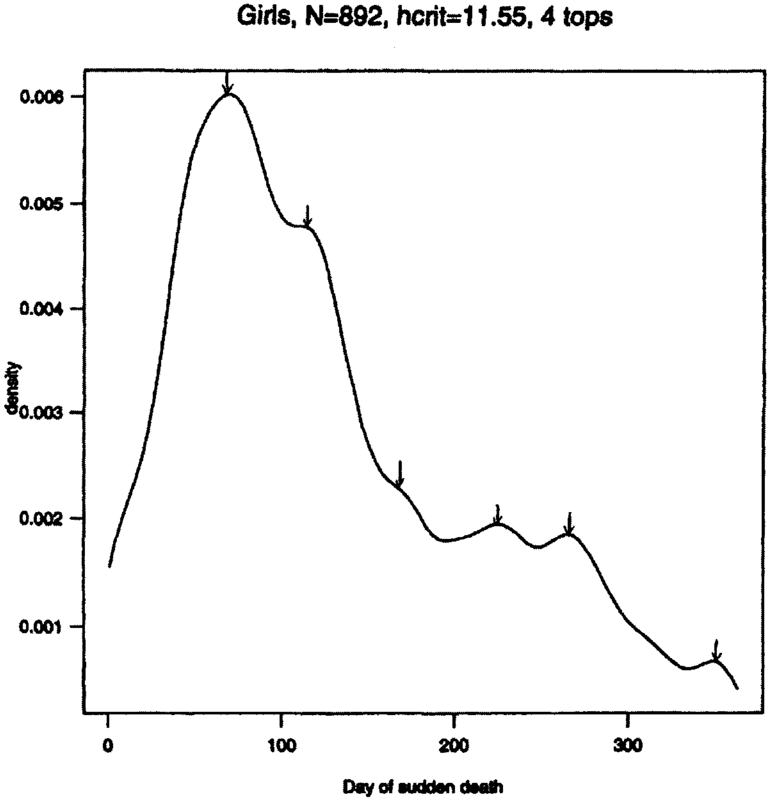

FIG. 7.3. Kernel density estimator.

crease. At two more ages, Weeks 17 and 25, there is a change in the slope of the curve, which might indicate the existence of two more tops.

CONCLUSIONS

There is an effect of sex. The frequency distribution of the number of SIDS victims over age shows a multimodal distribution for girls, but not for boys. At present, there is no explanation for this effect. Perhaps the extra large population of male SIDS victims consists of at least two subpopulations for various reasons such as seasonality (Douglas, Helms, & Jolliffe, 1998). One subpopulation may show a multimodal distribution, which is covered up by the other subpopulation being equally distributed over age or multimodal and shifted. Finding the reason for the extra large population of male SIDS victims might also produce criteria for distinguishing between such male subpopulations. Part of the explanation might be that the population consists of both term and preterm births, and the length of gestation is unknown. So, the age at death is the age since birth and not the age since conception. This implies that the data are "polluted" with a number of cases that are "too old." Because it is known that preterm infants are at higher risk for SIDS than term infants (Malloy & Hoffman, 1995), the proportion of shifted, "too old" cases might be substantial. On top of that, an excess of males was found among preterm births (Cooperstock & Campbell, 1996). This might explain why the multimodal distribution was not found in boys. To make things even more complicated, the postconceptional age of peak vulnerability for SIDS in preterm infants is shifted 4–6 weeks in the younger direction (Malloy & Hoffman, 1995). For instance, an infant born at 24 weeks postconceptional age in the population is 16 weeks too old. The peak vulnerability for SIDS may be shifted 6 weeks in the younger direction. Such an infant ends up in the research population still being 10 weeks too old. Of course, many combinations are possible, but in general there should be a shift of peak vulnerability toward older ages. This is reflected in Figs. 7.1 and 7.2 where the age of peak vulnerability for SIDS for males is 14 weeks as compared with 10 weeks for girls. Clearly, it is better to work with age since conception instead of age since birth. This is an issue for future research.

As for the multimodal distribution in girls, this is clearly composed of a number of small peaks superposed on one large peak around Week 10.

DISCUSSION

This chapter could end here. The proposed hypothesis that there might be a multimodal distribution in the frequency distribution of SIDS over age has been confirmed and finding out more about the underlying mechanisms is something for future research. But, discussions allow speculation on these underlying processes, if only to stimulate further research.

One of the explanations for the large peak is the shift from reflexive to speech breathing, as suggested by McKenna (1990b). During the first few weeks of life (five in the Dutch population), the newborn seems to have a natural immunity to SIDS (Spiers, 2000), possibly because of the gasping reflex. Thereafter, the infant loses this reflex, becoming more vulnerable to breathing control errors (apneas, or breathing pauses). This coincides with the sharp increase in SIDS victims (Figs. 7.1 and 7.2). The decline in SIDS victims is explained by the development of speech breathing, which is complete at age 7 months.

The small peaks that are superposed on the large peak are not accounted for by McKenna's suggestion per se and are in need of a complementary explanation.

There is a striking overlap in ages at which these small SIDS peaks occur and the ages at which regression periods occur: the first column below rank orders the eight regression periods found in the first year of life (compare with Fig. 1.1 in Heimann, chap. 1, this vol.). The second column presents the age ranges in which the regression periods start. The fourth column presents the age ranges in which the regression periods end. The third column presents the ages around which sudden infant deaths in girls peak statistically significantly (see Fig. 7.3). The age between the {} brackets is tentative, but cannot be ignored in light of the enormous increase in Week 6 (see Fig. 7.1). No SIDS peak was found in regression period 1 (–). This is understandable in light of the aforementioned natural immunity in newborns.

1.	4–5	(–)	5-6
2.	7–8	{6}	8–9
3.	11–12	(10)	12–13
4.	14–17	(17)	16–20
5.	22–26	(25)	25–27
6.	32–37	(33)	36–40
7.	40–44	(38)	43–48
8.	49–53	(51)	52–57

The polyvagal theory of emotion of Porges (1997) may be helpful in understanding what might happen during the regression periods that coincide with temporary increases in the incidence of SIDS. Three important scientific propositions provide the basis for this theory: Darwin's concept of evolution and the processes that contribute to phylogenetic variation, Jackson's concept of dissolution as a viable explanation for diseases of brain function, and MacLean's concept that the human brain retains structures associated with phylogenetically more primitive organisms such as reptiles.

The theory emphasizes the phylogenetic dependence of the structure and function of the vagus, the primary nerve of the parasympathetic nervous system. Three phylogenetic stages of neural development are described. The first stage is characterized by a primitive unmyelinated vegative vagal system that fosters digestion and responds to novelty or threat by reducing cardiac output to protect metabolic resources. Behaviorally, this first stage is associated with immobilization behaviors. The second stage is characterized by a spinal sympathetic nervous system that can increase metabolic output and inhibit the primitive vagal system's influence on the gut to foster mobilization behaviors necessary for "fight or flight." The third stage, which is unique to mammals, is characterized by a myelinated vagal system that can rapidly regulate cardiac output to foster engagement and disengagement with the environment. The myelinated vagus originates in a brainstem area that evolved from the primitive gill arches and in mammals controls facial expression, sucking, swallowing, breathing, and vocalization.

It is hypothesized by Porges that the mammalian vagal system fosters early mother–infant interactions and serves as the substrate for the development of complex social behaviors. In addition, the mammalian vagal system has an inhibitory effect on sympathetic pathways to the heart and thus promotes calm behavior and prosocial behavior. In mammals, according to Porges, the autonomic nervous system response strategy to challenge follows this phylogenetic hierarchy, starting with the newest structures of stage three, the ventral vagal complex (VVC). When this fails, a disinhibition of the sympathetic control of the heart results (Stage 2). And finally, withdrawal of sympathetic tone results in a disinhibition of the dorsal vagal complex (DVC), the most primitive structural system of Stage 1. This most conservative strategy may be adaptive for primitive vertebrates, but it is lethal to mammals. Hypoxia appears to be the main stimulus that triggers the DVC. Once triggered, severe bradycardia and apnea are observed, often combined with defecation. This response strategy is observed in the hypoxic human fetus.

In light of all this, the connection between regression periods and the temporary increase in the incidence of SIDS may be the following. During regression periods, a disinhibition of the sympathetic control of the heart and a switching back to Stage 2 may have occurred. If, on top of this, additional major stressors are present such that the Stage 2 system cannot cope anymore, then the autonomous nervous system might revert to the most primitive stage one dorsal vagal complex with the lethal consequences as described earlier. Outside the regression periods, the additional major stressors alone are not enough challenge to the system to switch all the way back to the dorsal vagal complex.

One major stressor may be illness due to respiratory tract infections. Significant markers of illness were found to precede sudden infant death (Jonville-Bera, Autret-Leca, Barbeillon, & Paris-Llado, 2001; Platt et al., 2000). Toxigenic bacteria were found significantly more in SIDS infants than in healthy peers under 3 months of age (Blackwell et al., 1999).

McKenna (1990a) and McKenna and Mosko (1990) argued that the young infant is far less physiologically autonomous than Western culture has come to presume, and they are in need of and adapted to physiological regulation by, and responsivity to, a caregiver. Lack of such co-regulation through breastfeeding and body contact is likely to be a risk factor for SIDS. It was found that fully breastfed babies in all economic groups had the lowest illness rates (Raisler, Alexander, & O'Campo, 1999) and the shortest illness duration, as well as reduced severity of illness (Cushing et al., 1998). Apparently, co-regulation helps defend the baby against major stressors, explaining why breastfeeding and body contact are the very conditions that infants during regression periods crave.

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8

Regulation of Brain Development and Age-Related Changes in Infants' Motives: The Developmental Function of Regressive Periods

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> The doctrine which I am maintaining is that the whole concept of materialism only applies to very abstract entities, the products of logical discernment. The concrete enduring entities are organisms, so that the plan of the whole influences the very characters of the various subordinate organisms which enter into it. In the case of an animal, the mental states enter into the plan of the total organism and thus modify the plans of successive subordinate organisms until the ultimate smallest organism, such as electrons, are reached.
>
> There are thus two sides to the machinery involved in the development of nature. On the one side there is a given environment with organisms adapting themselves to it.... The other side of the evolutionary machinery, the neglected side, is expressed by the word creativeness. The organisms can create their own environment. For this purpose the single organism is almost helpless. The adequate forces require societies of cooperating organisms. But with such cooperation and in proportion to the effort put forward, the environment has a plasticity which alters the whole ethical aspect of evolution.
>
> —A. N. Whitehead, *Science and the Modern World* (1925)

Asking if there are "age-related events" in an infant's psychology—specific ages when the interests, actions, and emotions of most healthy infants change significantly in a short time—acknowledges advances in dynamic systems theory. This theory, which overcomes the limitations of simplistic linear causal explanations and allows formal analysis of emergent order in multicomponent systems, is attractive to scientists attempting to model the brain and its functions in artificial mechanisms or formulations. It proposes that psychological functions "emerge" within "complex dynamic systems" of cells, brain networks, body parts, cognitive representations, pattern-recognizing and problem-solving modules, object-directed behaviors, and social relationships, all of which are inherently plastic in response to their environments, interacting with one another, and variable in their development (de Weerth & van Geert, 2000; Fogel & Thelen, 1987; Hopkins, 2001; Kauffman, 1993; M. D. Lewis & Granic, 2000a, 2000b; Pantoja, Nelson-Goens, & Fogel, 2001; Thelen, 1995; Van Geert, 1994).

This way of conceiving the developing child is contrasted with the traditional biological notion of intrinsically regulated development in an organism. An organism is defined as a "well-formed" and coherent outcome of life processes that grow intricate adaptive anatomy prefunctionally, the form and functions of which progress along a predictable or "determined" course and with regulated timing. Furthermore, an animal organism's anatomy, its bodily organization, anticipates environment-sensing and environment-using behaviors that are capable of changing their environments, as well as changing in response to them in adaptive ways (Grenough & Black, 1992). In short, what kind of biological theory is needed, and what level of organismic self-regulation must be assumed if we are to understand what infants do, how they conceive and care about their world, and how they change themselves and their world? It appears that Whitehead was right. Understanding "concrete enduring organisms" and their "creativity" requires more than the formulation of abstract processes or functions that might put back together the dismembered "products of logical discernment."

A review of data on the embryology of the human brain and its genetics finds abundant evidence that cell systems that later become essential motivating factors to the top levels of the hierarchy in psychological functioning, guiding dynamic interactive response to the environment and all learning, have a history of gene-regulated, prenatal, spatiotemporal form construction before birth in the body and brain of embryo and fetus. Indeed, integrated and counterbalanced emotion systems (Table 8.1) that

TABLE 8.1

Affective Neuroscience: Brain Stem Motive Regulators

Affective Behavior	*Principal Neural Systems*	*Main Neuromodulators*
	ERGOTROPIC	
Seeking and Exploring	Ventral tegmental area (VTA), dorsolateral hypothalamus, periaqueductal grey (PAG), nucleus accumbens, projecting to mesolimbic and mesocortical areas	Dopamine (DA), glutamate, neuropeptides
Play/Joy and Social Affection	Centromedian and dorsomedial thalamus, posterior thalamus, projecting to dorsomedial PAG	Glutamate, opioids, acetyl choline (ACh) (muscarinic)
Rage—Social Attack	Medial amygdala, bed nucleus of stria terminalis (BNST), anterior and ventromedial hypothalamus to dorsal PAG	Substance P, ACh, glutamate
Fear	Central and lateral amygdala, anterior and medial hypothalamus, dorsal PAG, nucleus reticularis pontine caudalis	Glutamate, ACTH, neuropeptides
	TROPHOTROPIC	
Sexuality	BNST, corticomedial amygdala, preoptic and ventromedial hypothalamus, lateral and more ventral PAG	Steroids, vasopressin, and oxytocin
Nurturance and Maternal Care	Anterior cingulate to bed nucleus of stria terminalis (BNST), preoptic hypothalamus, VTA, ventral PAG	Oxytocin, prolactin Dopamine, opioids
Separation Distress, Social Bonding	Anterior cingulate/ anterior thalamus to BNST, ventral septum to midline & dorsomedial thalamus, dorasal preoptic hypothalamic, dorsal PAG	Opioids, oxytocin, prolactin, CRF, ACh

Note: Buck, 1999; Gray, 1990; Hess, 1954; Lane and Nadel, 2000; Luciana, 2001; MacLean, 1990; Panksepp, 1998.

powerfully direct spontaneously generated neural activity in the brain of the newborn, and that will, as the months go by, guide the infant's experience by orienting senses and effectors, anticipating behavioral encounters with the environment, are identifiable in the embryo brain before the cerebral cortex exists (O'Rahilly & Müller, 1994). Rudiments of the cortex tissue that will assimilate the fruits of experience after birth differentiate in the fetal telencephalon around month two of gestation. Neocortical circuits, with the cerebellum, continue to develop long after birth. The self-organizing systems of the embryogenic Intrinsic Motive Formation (IMF) in brain stem and limbic cortex are of key importance in regulation of postnatal cognitive growth (Trevarthen & Aitken, 1994). They create the infant's curiosity, and above all they control and express sympathetic and mimetic awareness of attendant persons and their human responses. Infants' motives and emotions powerfully attract, respond to, and evaluate other persons in communication (Trevarthen, 2001b). They continue to attract and transform relationships and collaborative awareness throughout childhood. Some motives are formed to recollect experiences and predict the advantages and risks of life in the physical world. Others seek intimate acquaintances in fellowship with intentional and emotional human beings. It is the latter that animate the peculiarly human cultural learning (Trevarthen, 2001a).

Evidence from developmental research for age-related difficult periods in the first year of infancy, lead to the observation that, despite the fact that longitudinal data is scant and patchy, there is actually considerable support for Periods of Rapid Change (PRCs) in positively motivated, purposeful behaviors of infants, in addition to troublesome or challenging "regressions"—periods of retreat into organismic regulation and self-maintenance. Changes in curiosity and desires affecting purposeful outgoing action are reflected in data on the development of the mediating behaviors of vision, prehension, body support, and locomotion. That is, brain developments and motives are coupled to increases of efficiency in peripheral body components that engage with the environment. Brain developments initiate especially important advances in the perception of and engagement with persons by all modalities, in ways that further communication and cooperation in active experience-seeking life. In consequence, they transform those object-discriminating, memorizing, and categorizing skills that are measured by laboratory experiments with infants' preferential orienting and habituation to artificially structured sound or light displays, or with their searching for and recognizing objects that have become goals for visual inspection or manipulation. All the latter cognitive skills are dependent on learning. Their development in different individuals may or may not give clear indication of underlying age-related changes in intrinsic life and experience regulating motives.

Some PRCs appear to follow, or lead to, times when mothers report infants to be more "difficult" in temper, more demanding of maternal attentions, more contrary, and irritating. Evidently emotional states, and changes in emotional tendencies in the child, are part of the regulatory process motivating development of cognitions and skills and also the vital state of the body. This suggests that, in children developing normally with adequate intuitive parental support, the balance between life-preserving and environment-challenging functions shifts spontaneously at certain ages, in response to internally generated events. The neurohumoral mechanisms of the developing child that maintain this balance appear to animate a succession of spontaneous self-regulated transformations in creative brain activity. They set up a developmental project for the child's acquisitive consciousness, and use of the body to gain experience.

Attempts were made to relate identified PRCs to developmental events in infant brain anatomy and physiology, but there is limited information available. Nevertheless, rapid transitions in behavior do appear to match with at least two periods in the first year when brain anatomy and physiology are known to undergo extensive elaborations or reorganizations in a relatively short time.

It is hypothesized that intrinsic motive regulations of body and brain trigger accelerated changes in action and understanding at specific ages, greatly affecting communication with the mother and other persons, as well as consciousness of what the infant perceives as the attractive and "usable" world. Changes in perception, cognition, and action are, in this view, secondary to changes in "innate" brain-generated motives, notwithstanding the evident fact that both knowledge of what the world affords and motor skill will depend on each individual child learning different things from their different experience and practicing, and on their doing so at different stages of their readiness to learn such things.

Oscillations in interaction with the environment may come about through the equilibration of opposing regulatory states (including autonomic states) that are concerned, respectively, with "ergotropic" assertive action that provokes experience, and "trophotropic" retreat into nurturance and self-protection (Hess, 1954). The trophotropic state of psychological motivation in an infant is associated with increased demands for maternal care, and these are more intense at certain ages, separating epochs of active cognitive and behavioral advance. The ergotropic phases are characterized by a "disposition to learn": alertness, investigative curiosity, eager playfulness and an enthusiasm for sharing of actions, expressive states, and experiences in active companionship with familiar partners. Learning is easy in these times of self-confident agency and sociability.

Clearly, more information is needed about the adventurous mechanisms of purpose, and about those emotional systems that determine the self-defending but other-sensitive concerns of young children, and how both are inclined to change at certain ages, with great effect on the impressions retained in the plastic cerebral responses of experience and learning.

PSYCHOBIOLOGICAL REGULATION OF THE INFANT MIND AND ITS COMMUNICATION

Evidence for age-related changes of behavior in infancy is compared with data from research on developments in the infant's brain, where all of the intrinsic factors being proposed must originate. Recent findings on the genetic and epigenetic regulations of brain formation in the human embryo and fetus explain how the complex initial state of the newborn infant's brain, with its specific adaptations anticipating intersubjective psychological functions, comes about as a process tightly regulated in time and space.

Knowledge of the original psychological state that controls infant behaviors leads researchers to look for neural mechanisms and developments that motivate a selective awareness, and to note the appearance of systems that produce the coordinated purposeful actions by which infants seek and evaluate the objects that they perceive, even before they have sufficient control of the biomechanics of their bodies to enable them to execute fully effective actions to complete their purposes. Most remarkably, before babies have competence for handling and exploring nonliving objects, they show sensitive awareness of the motive states and feelings of other persons who offer to interact in well-timed contingency with what the infants express, and the babies react in intricately adaptive interpersonal ways to human expressions, often imitating, but not just by imitating (Aitken & Trevarthen, 1997; Als, 1995; Bateson, 1979; Beebe & Lachmann, 1988; Beebe, Jaffe, Feldstein, Mays, & Alson, 1985; Bråten, 1988; Brazelton et al., 1975; Condon & Sander, 1974; DeCasper & Carstens, 1981; Fiamenghi, 1987; Fifer & Moon, 1995; Heimann, 2001;

Jaffe, Felstein, Crown, & Jasnow, 2001; Legerstee, 1992; Murray & Trevarthen, 1985, 1986; Newson, 1977; H. Papousek & M. Papousek, 1987; Stern, 1985/2000; Stern, Beebe, Jaffe, & Bennett, 1977; Trevarthen, 1979, 1993b, 1998a, 1999b; Trevarthen & Aitken, 2001; Trevarthen, Kokkinaki, & Fiamenghi, 1999; Trevarthen, Murray, & Hubley, 1981; Tronick, Als, & Brazelton, 1980; Weinberg & Tronick, 1994).

The evidence renewed here confirms the view that developments in both subjective and intersubjective intelligence of infants are not adequately described as an accumulative or constructive process driven by circumstantial events, and, further, that intrinsic adaptive regulations of the brain and body of a baby will inevitably trigger accelerated change and response to the environment at specified ages. Of course, an appropriate environment at these stages of accelerated change is essential if the innate potential of the infant's mind is to develop normally, and it is in that nature of a living brain to become part of a dynamic system of exchanges of energy and substance within a body and in engagement with the environment. Nevertheless, it is necessary to understand the factors of self-regulation that make an infant's brain and body capable of developing that kind of human-responsive intelligence that is expected of the "meaning-hungry," imaginative, theatrical, and creative toddler.

Age-related changes vary the aim and strategy of purposeful actions and the emotional evaluations of "objects of interest," especially through the infants' consciousness resonance with the mind of a responsive and known caregiver (i.e., that person who is the source of external regulation and added efficacy to the infant's developing physiological and psychological states). Age-related developments in infant perceptions, cognitions, and adaptive actions are accompanied by, or follow, marked changes in communication with the mother. These critical events in postnatal life of the "parent–child system" (Aitken & Trevarthen, 1997; Beebe & Lachmann, 1988; Papousek & Papousek, 1987; Sander, 1997a, 1997b; Stern, 1985/2000; Tronick & Weinberg, 1997) are evidently initiated, in considerable part, in the infant, by the same kind of morphogenetic "autopoetic" factors as are responsible for the stepwise prenatal differentiation of psychological mechanisms in the human brain in utero. These factors will significantly affect or "direct" the dynamic "co-regulation" of development by engagement of the sensitive body with the world (Thelen & Smith, 1994), and especially in dynamic "co-conscious" and emotional communication with parents, and eventually with many other persons (Fogel, 1993; Kaye, 1982; M. D. Lewis & Granic, 2000b; Pantoja et al., 2001; Tronick, 1989).

Newborn humans express needs for communication of motive states and consciousness unlike those of the young of any other species of bird or mammal. Their unique imitative capacities are adapted for a new, more psychological or "intersubjective" kind of self–other regulation (Als, 1995; Blass, 1996; Brazelton et al., 1975; DeCasper & Carstens, 1981; DeCasper & Fifer, 1980; Field, Woodson, Greenberg, & Cohen, 1982; Heimann, 1989, 2001; Kugiumutzakis, 1993, 1998; Meltzoff & Moore, 1977; Nagy & Molnár, 1994; Reissland, 1988; Trevarthen, 1997; Trevarthen et al., 1999). Thus, infant intelligence is adapted to motivate not only maternal physical care and autonomic regulation of the infant's internal states, but also cooperative cultural learning—the acquisition of socially or interpersonally contrived meaning for interpreting the world as the community does with its historical beliefs, traditions, conventions, technologies, and so forth (Bateson, 1979; Dore, 1983; Halliday, 1975; Hubley & Trevarthen, 1979; Newson, 1979; H. Papousek & M. Papousek, 1977; Ratner & Bruner, 1978; Ryan, 1974; Tomasello, Kruger, & Ratner, 1993; Trevarthen, 1980, 1987b, 1988, 1992, 1994, 1998a; Trevarthen & Hubley, 1978; Trevarthen & Marwick, 1986). These inborn communicative or "intersubjective" abilities develop far more rapidly, and with far more effect, than either behavioristic or cognitive psychologies have expected. This explains their relative neglect by those developmental psychologists who prefer hypothesis-driven and data-selective experimental approaches.

Two-month-olds enjoy participating in rhythmic face-to-face protoconversations regulated by expressive and receptive processes engaging simultaneously many modalities (Bateson, 1979; Trevarthen, 1979). By 1 year a baby can, without language, energetically share complex arbitrary experiences with familiar persons, displaying boldly an individual, socially adapted personality while attending to and imitating conventional gestures, emotional attitudes, and activities (Akhtar & Tomasello, 1998; Bates, 1979; Bretherton, McKnew, & Beeghly-Smith, 1981; Forman & Kochanska, 2001; Hubley & Trevarthen, 1979; Tomasello, 1988; Tomasello et al., 1993; Trevarthen, 1990, 2001a; Trevarthen & Hubley, 1978; Trevarthen et al., 1981; Uzgiris, 1981, 1991). The baby can also demonstrate considerable sociability in communication with peers with no adult assistance (Hay, Nash, & Pederson, 1983; Selby & Sylvester-Bradley, 2003). In the second year, a young toddler will enjoy imitative and creative mimetic "fantasy" play with peers (Nadel & Pezé, 1993), is comprehending language well, and is beginning to use a few words correctly to specify ideas and actions and name familiar persons and things (Bruner, 1983; Jusczyk, 1997; Locke, 1993).

The inherent intersubjective motives and person-related, or "moral," emotions (Trevarthen, 1993a) that drive this growth of self–other conscious social behavior and highly selective curiosity about shareable meaning in engagement with a social and cultural context are additional to the "attachment" needs infants express for parental protection, comforting, and care. On the other hand, and in contrast, the state-regulating attachment behaviors and reactions of infants resemble the signals of needs shown by the helpless young of many other species (Blass, 1996; Carter, Lederhendler, & Kirkpatrick, 1997; McKenna & Mosko, 1994; Panksepp, Nelson, & Bekkedal, 1997; Panksepp, Nelson, & Siviy, 1994; Rosenblatt, 1994; Schore, 1994; Suomi, 1997).

It is certain that the unique complexity of motives for cultural learning in *companionship* (Trevarthen, 2001a) has imposed new demands on the mammalian developmental strategy, and extensive elaboration of the biological mechanisms by which the newborn human organism is prepared to grow and organize brain and body while benefiting from an intelligent parenting that educates the infant's consciousness and appetite for learning. No general "plasticity" of the brain, or enlarged cortical cognitive and memory capacity, as hypothesised currently in developmental cognitive neuroscience (Johnson, 1997; Nelson & Luciana, 2001), is sufficient to explain how an infant and toddler learns so fast to realize its potential as a purposeful, self-conscious individual with a human sense of actions, manners, and concerns (Donaldson, 1978).

In any attempt to explain early human development and its special intersubjective features, it is necessary, therefore, to recognize that the infant depends on communication with caregivers, not only to service the baby's needs for external regulation of organic or physiological processes, but also to maintain and develop an intimate emotionally expressed companionship in changing purposes and conscious experiences. The infant's mind and body has many special structures and functions adapted to anticipate this species-specific psychological existence, which motivates the intensive learning and teaching that is cultivated as education (Bruner, 1996; Rogoff, 1990, 1998). Self-regulatory brain mechanisms of ancient phylogenetic origin (MacLean, 1990; Panksepp, 1998), which evolved to signal bodily needs and to attract appropriate parental ministrations for physiological states (Table 8.1), have been augmented by, or transformed into, mechanisms of sympathetic mind engagement for more creative cognitive purposes (Porges, 1997; Schore, 1994, 1998, 2001). In humans, they link the time changes of imagination and memory so the intelligent flow of experience can be shared intersubjectively. Even a 2-month premature infant can share dynamic motives in purposeful movement and focused attention, exchanging facial expressions, vocalizations, and gestures of the hands in intimate contact with a sympathetic partner (Trevarthen et al., 1999; van Rees & de Leeuw, 1993). No other species can do the like.

Representation of the states of mind of a partner in psychological life, being central to the human species' strategy for development, will be rooted in innate brain systems. Learning tests prove that perceiving the mother's rhythmic vocal expressions of motive state from her speech can begin in utero, weeks before birth (DeCasper & Spence, 1986; Fifer & Moon, 1995; Hepper, 1995; Mehler et al., 1988). Her characteristic patterns of speech can be identified by her newborn immediately. Recognition of the visible appearance of her face is acquired within hours of birth (Bushnell, Sai, & Mullin, 1989; Field, Garcia, & Greenberg, 1984, Pascalis, de Schonen, Morton, & Deruelle, 1995), aided by the newborn's capacity for interest in imitation of, and interaction with, facial expressions (Field et al., 1982; Heimann, 2001; Heimann & Schaller, 1985; Kugiumutzakis, 1993, 1998; Meltzoff & Moore, 1977, 1983; Nagy & Molnár, 1994; Reissland, 1988; Zeifman, Delaney, & Blass, 1996). The adaptive motive structure of a newborn human brain, and all the neuromotor organs that specify timing and emotional tone in dynamic signals of social interest and expression, not just the static anatomical form of the face at any moment, determine directions and limits to any future acquisition of skills or knowledge by a child.

MOTIVE THEORY: PURPOSES OF PSYCHOLOGICAL CAUSES

The first events that set behavior and learning in action at any stage of development are *attentional* (stimulus seeking) and *intentional* (motor action forming) states, generated by *motives,* which arise spontaneously in anatomically organized brain systems[1] (Fig. 8.1). Motives coordinate and integrate the perceptions and movements of the animal in one subjective time and space: a kinematic movement time that progresses according to the rhythms and energy budget synthesized by the neuronal assemblies that have grown in the brain, and a single behavior space centered on the head that is mapped in the brain somatotopically (i.e., in many neuronal

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[1] For a fuller explanation of the concept of motives as applied to explain infant behaviors, and comparison with other explanations of animal psychological action, see Trevarthen (1982b, 1984, and 1998b).

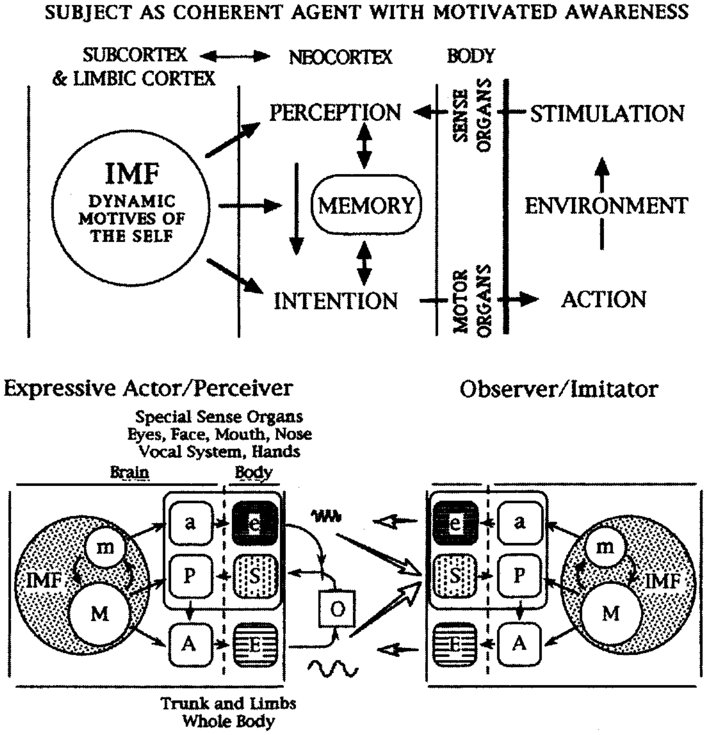

FIG. 8.1. Motives are generated in the core of the brain in an interneuronal system, the intrinsic motive formation (IMF), that coordinates all neural centers in one generative space–time field of behaviors.

arrays collectively representing the bilateral symmetry, dorsoventral differentiation and polarity of the body; Trevarthen, 1985). No matter what partial times or partial spaces may be differentiated temporarily in the diversification of states of motivation and behavior (Trevarthen, 1978), this unity of a total behavioral time–space complex remains the origin and foundation of behavior, and it is formulated in brain growth antenatally (Trevarthen, 1985). That is, motives integrate a "self as conscious agent."

Motives to move the body (M) integrate mechanisms of perception (P) and action (A) in cycles of perceptuomotor activity that are performed by effectors (E) and monitored by receptors (S). A subset of the motor system (a + e) is motivated (m) to regulate the orientation and focusing of special sense organs. Effector activity may make use of objects (o) and at the same time transmit rhythmically coherent effects that may inform the motives of an observer or imitator, who has similar (sympathetic) motive principles, about the purposes, interests, and feelings of the actor.

Motives are prospective, anticipating the *experience*[2] they will generate. Ultimately, motives influence plastic neuronal nets to retain impressions that may be retrieved or reactivated as memories, to modify future intentions, and to attain more elaborate purposes. They shape dynamic systems of brain and body in interaction with an environment, in which experiences emerge and are consolidated as knowledge and skills that have useful meaning for the subject.

Motives estimate their fate with emotion. *Emotional states* govern the energetics of motives and are reflected in the kinematics of motivated movements (Trevarthen, 1999b), and they give evaluation to the semantic space of meanings (Trevarthen, 1994). Thus, motives make psychobiological information for life activities, and the perceptions that guide them do not simply process input from the environment. Every perception, cognition, concept, or motor skill—however dependent on input of circumstantial information from the senses—is also a consequence of inner aspects of motive states, such as arousal, attention, emotional evaluation, and strategic anticipation of the consequences of acting (Panksepp, 2001).

In the longer term, motives generate narratives of experience that carry the history of investigative and personal involvement of the subject. Because motive systems self-regulate their own development and primary motives are relatively stable through an individual's life, the perceptions and memories that a subject retains also develop in predictable directions—effects caused by stimuli in impressionable components of the brain are connected in motivated themes. This process creates age-related stages or steps in progressive life cycles of psychological preference and ability, and each individual keeps memories of an unfolding life drama.

Intersubjective motives between individuals of intelligent social species operate by sympathy (i.e., by subjects sharing regulations of interest and intention, as well as emotional feelings about intentional commitments and the values of ideas and objectives). Movements that are rich in information about the prospective control of one subject's experience and recollections become information that another subject can sympathize with and incorporate in their motives and emotions, imitatively and in play. This companionship results in communal learning about the constraints and affordances or resources of a shared social and geographic world. In human beings, intersubjective motives generate that powerful cultural learning by which artificial knowledge and skills are transmitted from

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[2] Experience comes from Latin meaning "from trying." Properly understood, it means satisfaction of actively seeking or investigating, not passively being changed by information.

generation to generation and accumulated in ever more complex cultural systems of custom, belief, education, technique, commerce, and social politics. Attachment relations formed in childhood within families and social groups constitute crucial foundations for development of each individual's emotional health and well-being, and they generate transgenerational effects in self-conception, temperament, and motivation, affecting the stability of mature relationships, group affiliation and social identity, and the capacity to acquire knowledge and skills (Fonagy & Target, 1997; Murray & Cooper, 1997; Murray, Woolgar & Cooper, 2001; Schore, 1997, 2001; Van Ijzendorn, 1995).

EMOTIONAL EVALUATIONS OF PROSPECTS IN RELATIONSHIPS

Impulses that commit the subject to new engagements with the environment, with those that regulate a continuing state of well-being, must attach values to the probable risks to the organism of any action, and they must estimate future energy costs. Measures of risk and the energy balance are mediated as emotional states in interneuronal neurochemical systems of the core and limbus of the brain, which modulate or prime the perceptuomotor and cognitive processes, and activate and validate executive strategies and the making and retrieval of memories, including attachment relations (Holstege, Bandler, & Saper, 1996; Tucker, 1992, 2001; Tucker, Derryberry, & Luu, 2000; Panksepp, 1998, 2001; Schore, 2001). Emotions operate both in short term, triggering quick adjustments of behavior and autonomic state, and as slowly transforming arousal changes or moods. The rates of these changes, like the motor images behind intention and attention, are regulated by time-making mechanisms of the brain that initiate both rhythmic sequences of behaviors and qualitative modulations of energy profile in gestures of action or expression (Clynes & Nettheim, 1982; Trevarthen, 1986b, 1999b).

Emotions generated in social encounters and relationships have a special power and complexity. They must be reflective in the sense that their usefulness for each individual depends on what emotional signals come back from other individuals. Motivated actions can be responded to by similar dimensions of motive in the minds of other individuals. Different individuals can mirror one another's actions, imitating or complementing both the timing and subjective aim or direction of each other's movements. They are sensitive to the emotions of other subjects. Social "relational emotions" (Stern, 1993) arise and function in the dynamic space between mutually aware subjects who are in communication, with the exception of those undisclosed emotions of liking or disliking that either leave a relationship unrequited, serve to prevent one forming. In relationships, emotions are as mercurial as intentions and movements. Their moment to moment changes in a dialogue are generated in the time sensed by the two participants. Social engagement of motives depends on a fine sense of contingent responsiveness in all parties to relationship.

THE TWO KINDS OF MOTIVE EDUCATING EARLY HUMAN PSYCHOLOGICAL TALENTS

The fate of an animal's behavior in an environment where there are both benefits and challenges will depend on the dynamic balance maintained between commitment of energy-spending behaviors of seeking and taking, and self-protective energy-conserving behaviors that satisfy consummatory needs of life in the whole organism. In the terms of Hess (1954), ergotropic and trophotropic behaviors will be needed at different times, and they will have to be kept in balance over time (Fig. 8.2).

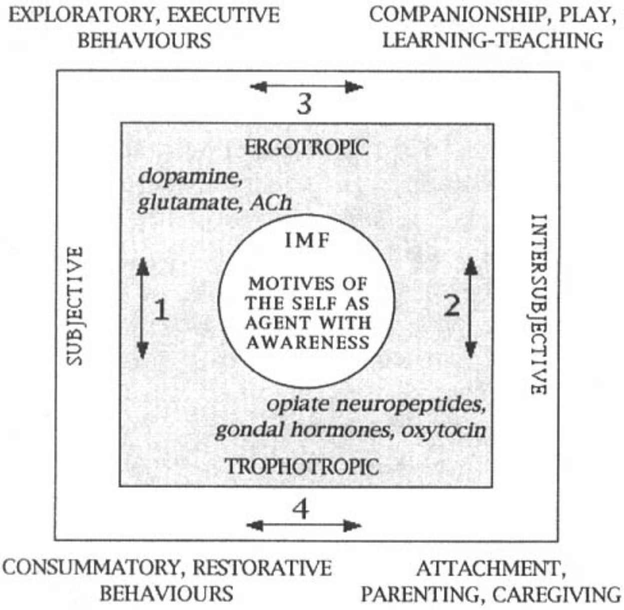

FIG. 8.2. Motive principles, self-regulating neurochemical systems, and relations between the subject and different objectives of behavior.

In infancy, an evolving dynamic balance is established between these two kinds of motive and autonomic regulation: *ergotropic* (and parasympathetic) states govern active cognitive mastery of the objective and socially constructed environment and learning of culture-specific shared meanings and cooperative skills; *trophotropic* states supply essential support for autonomic (sympathetic) self-regulation of inner physiology. Both tropic functions or guidance mechanisms require parental support, and close engagement of the infant with motives for what H. Papousek and M. Papousek (1987) called "intuitive parenting," but they differ greatly in their requirements and potentialities. This discussion is concerned with evidence on how these two complementary regulatory states are generated and elaborated in the infant mind, and whether a process of alternation between them can explain age-related regressive periods.

Postnatal age-related changes in the physiological ergotropic–trophotropic balance (between energy expending action on the environment and nurturing, energy-conserving and protective self-maintenance) will continue to be regulated inside the infant and young child by factors that guided the genesis and design of parallel, coordinated somatic and visceral sensory and motor systems of the brain in the embryo and fetus (Trevarthen, 1985, 2001b). Evidently, the genetically and epigenetically regulated process of brain–body development entails periodic crises of adjustment or equilibration between different intrinsic neural regulations or emergent functional states (Brazelton, 1993; van de Rijt-Plooij & Plooij, 1992, 1993). These may be described as stages in the emergence of cognitive mechanisms and behavioral skills (Fischer & Rose, 1994, 1997; Herschkowitz, Kagan, & Zilles, 1997; Piaget, 1954; Rose & Fischer, 1998). However, world knowledge and skills for acting on knowledge are *learned* in experience. They will consequently show individual chance differences, which may be large. The intrinsic regulations of the developing brain that are likely to appear in similar form and at the same ages in most children are motivational in nature. Changes in cognition and skill will be secondary to the common driving principles that set goals and search for appropriate environmental experience or information, and they will be far more at the mercy of sensory stimulation and exercise. Indeed, attempts to chart the emergence of the infant's perceptual, cognitive, motoric, and communicative abilities day by day or week by week reveal nonlinear, age-related transformations, not in particular perceptual processing modules, but in quality of whole-subject interest, leading inevitably to changes in cognitive or executive ability, and also in affections of intersubjectivity—motives for recognizing and responding to "live company."

Accordingly, it may be proposed that these transitions between periods of enterprise and dependency are caused by changes in the intrinsic, self-determined regulations of brain activity; brain activity that directs movements and attention and stirs the dynamic systems of brain and body in action emotionally. Intrinsic motives and emotions become the predictors and creators of an environment of experiences with value, experiences selected by what the children like, and by what they do in response to the world and to other persons. Furthermore, developments in perceptuomotor skills and cognition will correlate with, or depend on, changes in the quality and intensity of emotional dynamics in communication, changes linked to reorganizations in the infant's autonomic and neurohumoral state and self-maintenance of energy balance, as well as dependent on the quality of responses from a caregiver, who also has motives that guide awareness of and responses to the child (Schore, 1994, 2001).

The infant is not a passive emotional reactor to adequate parental care, but a proactive solicitor of particular kinds of intersubjective engagement in ways that powerfully influence the behavior of the parent, making transformations in their dynamic relationship at particular ages. Learned experiences give more precise and effective adaptive shape to behavior in forms that reflect the dynamic intricacies of individual experience, but every behavior is also an expression of the time, form, and emotions of intrinsic states of cerebral activity, states that draw their vitality and directions of interest from anatomical principles of sensorimotor integration that were set out prefunctionally in the growth of body and brain before birth. Some of these intrinsic states undergo self-regulated developmental change at specific times in the life of the child.

In fact, little detail is known about internally generated transformation of human brain anatomy and function in infancy. Research on rodents, cats, and primates shows that the period of early postnatal mammalian life is one of great changes in brain structure, neurochemistry, and function (Bayer, Altman, Russo, & Zhang, 1993; Bourgeois, 2001; D. A. Lewis, 1997; Takahashi, Nowakowski, & Caviness, 2001; Trevarthen, 1985), changes that are critically dependent on parental support (Blass, 1996; McKenna & Mosko, 1994; Panksepp et al., 1997; Rosenblatt, 1994; Schore, 1994; Zeifman et al., 1996). Knowledge of genes that regulate prenatal brain elaboration is advancing rapidly. The picture is increasingly complex, indicating that key functions depend on the activity of constellations of genes and gene products regulating expression of other genes (Keverne, 2001; Pennington, 2001; Vicente & Kennedy, 1997). At the same time, the traditional assumption that the neonate has little psychological coherence, needing integrative and representational functions of the cerebral cortex, and consequently that it is at the mercy of primitive reflexes for survival mediated by sensorimotor links in brain stem and spinal cord and directed by a simple bodily pleasure–pain system, has lost credibility as accurate observations are made of the intricate whole body coordinations of activity and responses to stimuli of newborns, both premature and full term (Trevarthen, 1997). Now integrated and intricately complementary hormonal, brain stem, subcortical and limbic systems and their motivating and emotional functions should be viewed as actively shaping neocortical circuits at all stages of development, in their initial formation and subsequent functioning (Benes, 1994, 2001; Berger, Verney, & Goldman-Rakic, 1992; McEwen, 1997; Panksepp, 2001; Tucker, 1992, 2001; Tucker et al., 2000).

Developmental psychologists may have difficulty in accepting the biological evidence of an inborn substrate for intentions and consciousness. This is not helped by information generated by an explosive development of scientific technologies for examination of details in brain genetics, anatomy, and physiological activity and for brain scanning to pick up foci of neuronal response in experimental tests that aim to locate modular cognitive processors in cortical or subcortical structures. Modeling the construction of cognitive processes in terms of selective differentiation and association of perceptions and motor skills by learning in highly plastic cortical neural nets has favored, and been favored by, laboratory experiments that measure how infants as observers or listeners exhibit stimulus discrimination and categorization, then attentional exploration and consolidation of preferences for geometrically defined forms of stimuli, and finally episodic memory and strategies for problem solving or executive functioning. Experiments to measure construction of hypothetical cognitive systems for representation of objects or events commonly make comparison of infants' performance with few age groups spaced several months apart. Research on the formation of emotional awareness and temperamental control of children's behavior by cognitive definition of the objects of emotion and by socialization learning have sampled even less closely (Derryberry & Rothbart, 1997). Data from such work requires complementary longitudinal data that enables much more frequent sampling of concurrent age-related changes in many systems of spontaneous behavior (i.e., behavior motivated by the subjects when they are in control of alert and active states and free to choose experiences in rich circumstances, especially as concerns possible developmental events triggered by changes in motives that originate within the child). Only this kind of research will give the data needed to distinguish effects of adaptive environment-dependent learning from the innate patterns of environment-expectant and experience-seeking processes that may grow in the brain (Greenough & Black, 1992; Luciana, 2001).

Medical studies on physical development of the infant (Falkner & Tanner, 1986), and psychologists' research on stages of emergence of motor skills (McGraw, 1945; Touwen, 1976), give very detailed age-related biometrical information, but in general findings are not related to motivational and socioemotional developments and the growth measurements usually show high variance (Thelen, 1995). The same goes for longitudinal studies of intelligence (usually conceived as information-processing cognition, either in a general system, or in different special purpose computing modules) and the factors that affect learning of visuospatial, mathematical, and linguistic skills.

Advances in brain science and in cognitive psychology, supported by the psychobiological study of infant intersubjectivity can, however, lead to a new conception of infants' needs and adaptive abilities, and to new questions about the intricate controls and needs of early brain development (Schore, 1994, 1998, 2001; Trevarthen, 1987b, 1997). At the same time, attention is being directed by research on the emotional systems of mammals, and a new perspective on the neuropsychology of human emotions, to the role of intrinsic emotional processes in the emergence and development of consciousness and cognitive functions (Panksepp, 2001; Tucker et al., 2000; Watt, 1998) The discipline of affective neuroscience (Panksepp, 1998) gives new perspective on the causal processes of both intentional behavior and conscious awareness, and how they may effect cognitive change (Luciana, 2001).

DIFFICULT OR TRANSITIONAL PHASES AND THEIR FUNCTIONS

It is folk wisdom, and clinical experience (Brazelton, 1993), that at certain ages infants and young children show periods of increased timidity, irritation, and instability of mood. An intrinsic life-regulating process may generate many such episodes at particular points in early life. Van de Rijt-Plooij and Plooij (1988), observing mother–offspring relations in free-ranging chimpanzees, reported what they called regression periods before each leap in the young ape's attempts to increase independence from maternal holding. Regression was expressed as the nursling animal's need for staying closer to the mother, and for ventro-ventral contact. Following a similar naturalistic study of the human infant, van de Rijt-Plooij and Plooij (1992) reported 10 regression periods in the first 20 months (see van de Rijt-Plooij & Plooij, chap. 5, this vol.). The babies showed more expressions of need for comfort and care and were experienced as more difficult around Weeks 5, 8, 12, 17, 26, 36, 44, 51–53, 61–62, and 72–73. As with the chimpanzees, increases in expression of mother–infant conflict shortly followed the regression periods (van de Rijt-Plooij & Plooij, 1993).

These studies direct attention to the possible relation between regulation of the dynamic motive states and emotions in the mother–infant system and the intrinsic regulations within the infant that lead to developments in psychological functions and behavior. In this volume, Sadurní and Rostan (chap. 2) in Spain, Lindahl, Heimann, and Ullstadius (chap. 4) in Sweden, and Woolmore and Richer (chap. 3) in England confirm cycles of stability/instability, many of which appear to coincide with ages at which van de Rijt-Plooij and Plooij recorded regressions and periods of conflict. Van de Rijt-Plooij and Plooij proposed that each episode of regression and conflict, as part of normal development, may both indicate a critical event in the maturation of intrinsic brain functions and their maternal regulation, and provoke opportunities for learning and progress. Mother and child must renegotiate their habits of interaction as the infant's interests and abilities change. Regression periods may also signal increases in vulnerability for disorder in development, or illness of whatever cause (see Plooij et al., chap. 5, this vol.).

In order to understand these as events of the developmental process, it is necessary to gain knowledge of the intrinsic regulations of developments in the infant's brain, as well as their dependence on affective support and engagement of attentions and intentions with the mother. Within the framework discussed briefly earlier, such periods of apparent regression are interpreted as periods of transition from ergotropic to trophotropic phases, the latter being as essential to development as the former.

THE EARLY DEVELOPMENT OF THE HUMAN BRAIN

Knowledge of the timetable of events in histogenesis and morphogenesis of the CNS in some animals is now quite precise. There would appear to be a universal process that gives rise to close similarities of temporal sequencing of events in developing brains of humans and other mammalian species, even though the time to attain maturity varies greatly (Bayer et al., 1993; Takahashi et al., 2001). There is no evidence of development of one homogeneous system emerging by a continuous proliferative process, but parallel development of multiple systems along semi-independent, discontinuous pathways in which particular events, such as cell multiplication cycles, synaptogenesis, or cell death, may occur in regular succession at different times. Cell proliferation may occur in one area at the same time as dendritic arborization in another and as selective cell death (apoptosis) in a third. Timing of phases in cell multiplication, migration, and integration into systems is regulated to generate species- and individual-specific characteristics in cerebral systems (Takahashi et al., 2001). Patterns and systems develop in the brain—in part driven by genetic factors, in part guided by intra-organismic constraints, and in part transformed by the impact of the environment. Large transformations in function may appear when one developing system replaces another. A clear example is the transitory deafness of amphibian tadpoles when they undergo metamorphosis and develop new structures appropriate for terrestrial audition (Boatright-Horowitz & Simmons, 1997).

The Embryology of the Human Brain Forecasts Regulation of Cognition by Motives

Human brain development is exceptionally elaborate in prenatal stages, and exceptionally long and complex through postnatal life. In the "initial state" at birth, all major systems are present in various states of completion. This innate complexity constrains all subsequent dynamic emergent events. Age-related events in early childhood reflect the prenatal determination of intrinsic mechanisms that have evolved to generate adaptive body–brain relations in this period of accelerating growth, and development and adaptive response to the environment.

In the human embryo, core regulatory mechanisms of the autonomic nervous system, hypothalamus, reticular formation, basal ganglia, and limbic system are laid down before the rudiments of cognitive structures of the cerebral cortex appear (O'Rahilly & Müller, 1994). Developments of the cerebellum, especially of the vermis, through childhood, beginning in infancy, transform the coordinative action-timing mechanisms of the subcortex in close coupling with emerging cerebral cortex systems for processing reafferent information from vision and hearing and for generating executive programs of moving and attending (Bourgeois, 2001; Gillies, Shankle, &

Dooling, 1983; Sidman & Rakic, 1973; Yakovlev & Lecours, 1967). The communicative precocity of human newborns indicates that emotional expressions and emotional responses to caregivers play a crucial role in brain development (Schore, 1994). Prefrontal, temporal, and limbic cortices, regulated by the core of the brain stem and the cerebellum, form a link between gene instructions for brain and body systems and the developing integrative mind (Trevarthen & Aitken, 1994). When they, or their subcortical regulators, go wrong, they give rise to, or contribute to, communicative or empathy disorders such as autism or schizophrenia (Aitken & Trevarthen, 1997; Panksepp, 1981; Royston & Roberts, 1995; Trevarthen & Aitken, 1994; Trevarthen et al., 1998). Gene factors in the earliest stages of brain morphogenesis appear to offer indicators of the processes of gene expression in later stages of development, such as might determine emergence of new psychological functions in infancy (Keverne, 2001; Pennington, 2001).

The Determination of Prenatal Brain Development

Genetics of the Embryo—Organism Mapping Before the Nerve Net Is Formed. Genesis of the human body and of neural systems within the brain is intricately determined in space and time. Events that organize the embryonic anatomy are constrained by the structure of molecular and cellular elements, and by processes and reactions that proceed at rates fixed by the biophysical potentialities of these elements (Kauffman, 1993). There is, of course, vast scope for chance and emergent patterns when enormous populations of nerve cells and their contacts are proliferated to excess and constrained by emergent relations between them, but these complex dynamic system consequences are also channeled, or "attracted," by structure and signals formed or activated previously—in the ovum and sperm, the zygote, the embryo, the fetus, the infant, and so on. Acquired form and function, although inherently progressive, generative, and anticipatory or prospect-creating, remains dependent on these antecedent states, which are far from random in their organization or potentialities for change.

The fertilized human ovum divides to form a three-layered, bilaterally symmetrical embryo with broader anterior "head" end. When cells of body and brain are still indistinguishable, the polarity and symmetry of the integrated individual life form that they will share is determined. A group of mesoderm cells (the organizer "node") induce the ectoderm cell layer above them to become neurectoderm of a neural plate that mirrors the anteroposterior polarity and left–right symmetry of the embryo body

(Ruiz i Altaba, 1994). As the embryo elongates during the next week, midline mesoderm cells, proliferating and migrating back in a strip, continue to influence the cells of the neural plate, which elongates and rolls up to form a neural tube, the beginning of the central nervous system.

Regulator substances produced by genes in the mesoderm around the border of the neural plate induce differentiation of the dorsal sensory part of the CNS; at the same time, the "sonic hedgehog" gene (Shh) induces the ventral or basal motor component in which motor neurone systems will differentiate. Regulator genes encode protein transcription factors that bind to the DNA, turning genes on and off, and the regional expression of these regulatory proteins in a temporal sequence down the embryo body reflects cascades of homeobox (Hox) gene activation that define pattern formation in segments of the embryo and its brain, at least posteriorwise from the hind brain (Ruiz i Altaba, 1994; Krumlauf, 1994). An ordered anteroposterior sequence of transcription regulators control differentiation of nerve cell groups in the future forebrain, midbrain, hindbrain, and spinal cord, and they continue to pattern neuromorphogenesis throughout development of the brain (Vicente & Kennedy, 1997).

Division of the skeletomuscular mesoderm of the embryo into segments in the third and fourth weeks triggers segmentation of the neural tube into compartments or neuromeres. In these, gene transcription factors produce cell adhesion molecules (CAMs), effectors of intercellular activity that create forces of adhesion between cells and set up barriers to cell movement at neuromere boundaries. Inside each neuromere, the proliferation, differentiation, and grouping of neural cells is regulated by combinations of Hox genes that are ordered, as a consequence of tandem duplication, in a body-representing chain down the chromosomes, and expressed in a regular sequence posterior-wards, from the forebrain/midbrain boundary through the hindbrain and spinal cord (Joyner et al., 1991; Krumlauf, 1994). Three critical morphogenetic zones are formed across the anteroposterior axis of the CNS: at the junction of the hindbrain with the midbrain, at the midbrain/forebrain junction, and along the anterior border of the forebrain.

When primitive vertebrates evolved as active predators, presegmental tissues that were at the anterior, or front, end became elaborate organs of an independently mobile head: receptors for sensing the external world, jaws for controlling food intake, and gill arches for gas exchange. Simultaneously, a forebrain was developed to coordinate a more vigorous life with more foresightful intelligence (Gans & Northcutt, 1983). In socially intelligent higher vertebrates, the head additions, and the autonomic systems linked to them, have become elaborated as the expressive/receptive systems of the face, throat, eyes and ears, to which, in humans, the hands have been recruited. The communication of psychological events between subjects by expressive movements constitutes a function that integrates internal organismic or visceral regulations with environment-directed or somatic ones (Porges, 1997; Schore, 2001; Trevarthen, 1989).

In the head, the differentiations of face tissues and brain cell populations of the telencephalon (cerebral cortex, olfactory lobe, basal ganglia, hippocampal formation, and amygdala) and diencephalon (thalamus, subthalamus, hypothalamus, and optic cup) are determined by Pax genes and CAMs that control cell grouping and migration, determine the segregation of cell types according to their functions in relation to the body, and assist the mapping of the body in the brain (Edelman, 1988). CAMs interact with intercellular signaling structures—transmembrane proteins, cadherins, and others. These form linkages with other cells outside and regulate gene transcription inside each cell.

Throughout the embryo CNS, CAMs are expressed in spatial and temporal patterns that determine future affinities of cells and the formation of nuclei, axonal tracts, and synaptic arrays (E. Davidson, 1993). Affinities between cell groups in segments of the early embryo later direct formation of integrated systems that will perform functions for the whole body—internal sensorimotor and neuroendocrine regulations of the viscera and the physiological state of the organism on the one hand, and environment-directed movements, psychological cognition, and learning on the other. Thus, visceral and somatic sensory and motor components are mapped, in highly predictable arrangements, into the CNS.

How Neurons Wire Up to Form Functional Systems. The neural net must become an integrated system capable of synchronizing momentary states of activity throughout the body in very short time spans, much faster than behavioral moves and sensory feedback. The CNS is never a random array of cells, fibers, and connections, but is imprinted with the gene-regulated somatotopy (body mapping) as described earlier. The nervous system exhibits an adaptive morphology produced by guided negotiations between molecular and tissue components that have specified affinities as reagents. The many types of cells that differentiate in each segment of the embryo CNS gain distinctive affinities for molecular elements in their environment—complex physicochemical patterns of the extracellular matrix (ECM), on the surface of glia cells, and on other neurons (Goodman & Shatz, 1993). Forces of attraction and repulsion direct cell migration as well as the paths that axons and dendrites follow when they sprout from the neurons in the late embryo (Weeks 5 and 6) (O'Rahilly & Müller, 1994; Windle, 1970). Neuroblasts divide around the ventricle of the neural tube, migrate out along radial glia fibers, and form layered arrangements in the hippocampus, cerebral cortex, and cerebellum (Hynes & Lander, 1992).

Axons and dendrites are guided by the molecular machinery of "growth cones" at the tips of all nerve cell outgrowths (neurites) (Suter & Forscher, 1998). Growth cones are mini sensorimotor organisms that actively explore the intercellular terrain, sensing different molecular environments and laying down the path of the nerve cell extension growing behind them (Magge & Madsen, 1997). Finally, nerve terminals form intricate arrays of synaptic contacts on other nerve cells, with hundreds of contacts per cell. Many CAMs and substrate adhesion molecules (SAMs) effect selective adhesions between cells and movement of growth cones (Suter & Forscher, 1998). The ECM, synthesized by embryonic glia, has dynamic populations of molecules with distinct temporal and spatial expression, which are especially abundant when differentiation and migration of neurons is occurring. At the end of embryonic development, the ECM, its regulatory job done, is reduced, but it may be reactivated at later periods of renewed growth and differentiation (Vicente & Kennedy, 1997).

Growing axons follow molecular contact forces at the surfaces they meet and are affected by repulsion or attraction between growth cones, which react to diffusable molecules that either encourage extension of their activity or cause their projections to collapse and withdraw (Haydon & Drapeau, 1995; Vicente & Kennedy, 1997). A large variety of synaptic vesicle proteins (SNAPs) control the formation of specific patterns of connection in synapse development, and maintenance and replacement of synapses is responsible for anatomico-functional plasticity of nerve nets throughout life. SNAPs play a role in the changes of brain circuitry that store and access memories (Benowitz & Routtenberg, 1997; Söllner & Rothman, 1994). The formation and maintenance of effective synapses is, of course, also affected by the excitations received from other neurons, as well as by growth factors and steroid hormones produced by endocrine glands (McEwen, 1989, 1997; Xiao & Link, 1998).

Selective Cell Death. Building of brain systems involves programed loss of elements from a population excess. At certain periods, large proportions of specific nerve cell populations die, a selection that is significant in both normal cerebral development and pathology (Vicente & Kennedy, 1997). Survival of nerve cells depends on genes that promote or inhibit cell death, and on growth factors, including neurotropin molecules (NTs) produced by target cells, such as nerve growth factor (NGF) and brain-derived neurotrophic factor (BDNF) (Davies, 1994). BDNF increases in postnatal development and has a role in survival of monaminergic neurons, including those in the substantia nigra and hippocampus. It is thus implicated in motivational processes and learning and their changes with age. The cell-death promoting protein Bak has high expression in fetuses and old age, but is low in young adults, which indicates that this product of the Bak gene is important in both development and aging (Obonai, Mizuguchi, & Takashima, 1998). Generation of cells in the developing nervous system is also affected by a wide range of extrinsic growth factors and neurotransmitters. Growth factors and monoamine transmitters increase cell proliferation in the immature nervous system, whereas glutamate, gamma-amino butyric acid (GABA), and opioid peptides may down regulate it (Cameron, Hazel, & McKey, 1998).

After birth, the environment has an increasing role in regulation of the survival of selected connections to form functional nerve circuits. Psychological functions of the mature brain depend on activity-dependent patterning or plasticity of synapses, shaped by stimuli from the world and from the body, and the greatest plasticity will be in early childhood. Even in the fetus, electrical impulse traffic triggered by excitation of receptors modifies the structures formed by spontaneous developmental processes. Nevertheless, as is explained later, the brain is never a passive receiver of stimulus input, and major structural responses to epigenetic factors or the environment occur at certain ages in critical periods (Cynader, Shaw, Prusky, & van Huizen, 1990).

Brain Stem State-Regulating and Motive Systems Develop Early. In the second half of the embryo period (Weeks 5 –8), the main components of the brain have been formed, and the eyes, vestibular canals and cochlear, nose, and mouth, and hands are rapidly differentiating their distinctive forms, each dedicated to the picking up of a particular forms of physical information from the environment. However, for most of this period, the nervous system has no electrical activity and it generates no movements. The cerebral hemispheres and cerebellum are rudimentary. In comparison, the brain stem cell groups and tracts are well-formed (O'Rahilly & Müller, 1994).

Core regulatory mechanisms of the central nervous system—the peri-aqueductal grey of the midbrain, the hypothalamus, reticular formation, basal ganglia, and limbic system—are laid down in the first trimester. The cognitive systems of the cerebral cortex do not appear until the second trimester, and continue to develop after birth. The former motivating and life-maintaining structures form a link between regulation of gene instructions in prenatal brain morphogenesis and the acquired adaptations of the developing mind (Trevarthen & Aitken, 1994). Defects in this link are implicated in disorders of empathy and cognition such as autism and schizophrenia (Aitken & Trevarthen, 1997; Keshavan & Murray, 1997; Keverne, 2001; Panksepp, 1981).

Regulation of Emergent Structure in the Foetal Cerebral Cortex. Modern psychology has tended, rather cavalierly, to assume the cerebral cortex to be the sole tissue of higher cognitive processes, consciousness, memory, and skills. The underlying coordinative mechanisms of the subcortex have been conceived as organic, physiological, and unconscious. Now developmental psychology and brain science show that this view requires radical revision. Significant information comes from analysis of the processes by which the cerebral cortex is formed in the fetus (D. A. Lewis, 1997; Lund, 1997; Rakic, 1991; Takahashi et al., 2001), and from postnatal development of higher intelligence, and refined perception functions, in the cerebral hemispheres (Bourgeois, 2001; Hebb, 1949; Singer, 1986; Trevarthen, 1990; Trevarthen & Aitken, 1994).

Throughout its development, the neocortex is intimately and reciprocally connected with the nerve systems of the brain stem and cerebellum that give coherence to actions of the body, provide an essential spatial and temporal frame for consciousness, and also generate autonomic self-regulations and the emotions of social signaling (Holstege et al., 1996; Panksepp, 1998). Asymmetries of brain function that emerge through childhood (Trevarthen, 1990) depend on asymmetries in these self-regulatory mechanisms of the brain stem, including sympathetic and parasympathetic regulation of the heart (R. J. Davidson & Hugdahl, 1995; Wittling, Block, Genzel, & Shweiger, 1998). Left–right asymmetry of such higher cortical processes as language are now seen to be expressions of anatomical and neurochemical asymmetries to be found in all levels of the human brain (Cynader, Lepore, & Guillemot, 1981; Trevarthen, 1996). In the embryo, human brain postural and gestural movements show asymmetries, and the manual preference observed in self-stimulatory activity of thumb-sucking in individual fetuses of 15 weeks gestational age correlate with hand preferences seen in the second year after birth (Hepper, 1995).

The rudimentary cerebral cortex is visible in the late embryo, at about Week 6. Cortical cells proliferate in the ventricular generative zone of the hemispheres and migrate to form a narrow cortical plate that soon splits into the outer layer I of the future cortex and a subplate region. Later, generated cells migrate in waves to their assigned layers, most moving from Week 7 in a radial direction along glia strands, to form intermediate layers VI to II in inside-out order (Rakic, 1991). The process of neurogenesis depends on the repetition of a neurogenic cycle, between a phase of cell multiplication next to the wall of the ventricle (the cavity of the hemisphere) and a phase of migration into the cortex. Variation in number of cycles and the length of the migration phase generates differences in neocortical structure (architectonic fields, maps with different connective affinities, and layering of cell classes through depth of the cortex) and these are associated with different cognitive and adaptive behaviors across and within mammalian species (Takahashi et al., 2001).

Early primordial brain cells are genetically different, and the fate of their progeny are already determined as glia or neurons, and possibly as subtypes of neuron as well (Lund, 1997). Afferent and efferent layers of the cortex are determined and cells are committed to their laminae in the final cycle cell division in the germinal zone, before migration. The age of their division determines this laminar commitment, even in tissue culture. Cell populations of a given kind may be self-regulating by inhibitory effects of diffusable products. Each region of the cortex has its specificity for receiving connections from other parts of the brain imprinted by the local environment very early in development (Barbe & Levitt, 1991, 1995). Cell types in the cerebral cortex are similar in all species of mammal (Lund, Harman, & Beazley, 1994; Takahashi et al., 2001), but local environment and developmental history determine what cells of a given type will produce and do.

Additional crucial information is transmitted to the developing neocortex from the brain stem. In the primordial plexiform layer (PPL) of the hemispheres, the primitive nursery tissue in which the mammalian neocortex emerges, afferents from the brain stem form very early synapses, before the first radially migrating neurons appear, split the PPL, and attach themselves to the outer layer. Afferents entering the cortex are guided by position-specific molecules that are already in place before the afferents arrive, and before the cortical neurons finish migrating.

Migrating cortical cells creep through a dense cellular lattice and the subplate of early neurons, axons, dendrites, and glial fibers. Subplate cells, among the first to develop in the cortex and the earliest to mature, are the target for initial synaptic contacts of afferents growing from brain stem, basal forebrain, thalamus, and ipse- and contralateral cortex. Their axons project into the cortical plate and pioneer paths to thalamus and other subcortical structures (Lewis, 1997). Subplate cells die after the cortex is mature. The subplate of humans is the largest and most persistent, and abnormal genetic instructions there may lead to schizophrenia and other psychiatric disorders (D. A. Lewis, 1997).

Thalamic fibers grow into the cortex, form synapses in the subplate and layer VI, then "wait" there. Target cortical regions, although they receive thalamic independent regional specifications from the germinal layer in the "protomap" of the cortex itself, are subsequently regulated in size and shape by thalamic afferents and the excitation they bring (D. A. Lewis, 1997). Input from subcortical regions has a role in regulating the structure of the neocortex, including the asymmetries of emotional and cognitive function that become elaborated later (Huttenlocher, 1994; Trevarthen, 1996).

There is a critical period of competition in the genesis and segregation of synaptic contacts in the cortex, only reinforced intercellular contacts surviving (Cynader et al., 1990; Hebb, 1949). Timing of critical periods, which extend into postnatal life, differs between areas, laminae, and cellular components, "so it is likely that the neural components have their own internal 'clocks' as well as there being permissive environmental factors such as nerve growth factors available over particular maturational periods" (Lund, 1997, p. 7). Expression of receptors that pick up growth factor molecules change over time, and NMDA receptors, which may help consolidate synaptic connections, change with development and afferent activity.

As with earlier processes of cortical tissue formation, retention and formation of synaptic connections, which follow a similar pattern in all mammals (Bourgeois, 2001), are affected by input from the brain stem: "Neural modulators such as noradrenalin and acetylcholine, serotonin and dopamine also show marked changes in cortical development and are known to influence cortical excitability as well as affecting the nature of interactions during critical periods for cortical neuron development" (Lund, 1997, p. 7). Evidently the monoamine-carrying axons, the first afferent axons to arrive in the cerebral wall and the first to form synapses in the marginal zone and the subplate, set regulations for the formation of cortical connections. Brain stem monoaminergic neurons differentiate in the late embryo stage (Berger et al., 1992), and penetrate the cortical plate at 13 weeks (Zecevic & Verney, 1995). Other (sensory) thalamic axons arrive in subsequent weeks (Kostovic & Goldman-Rakic, 1983). Thus, neural pathways that will act as motive regulators of cortical activity (Singer, 1986) mature ahead of those that are destined to bring environmental information from special receptors. At the midfetal stage (Week 24) dopamine axons, important in coordination of innate motor patterns, are concentrated in the deep parts of the cortical plate and the upper subplate, at the time when thalamic sensory afferents end their waiting in the subplate (Verney et al., 1993).

In subsequent development of the cerebral cortex, earlier maturing deeper cortical layers act as mediators between cognitive and limbic functions (Benes, 1994; Tucker, 2001; Tucker et al., 2000). As in the embryo, self-regulating mechanisms have a guiding role over the formation of systems that will respond to environmental circumstances, and will retain adaptive representations of the objects of behavior, according to their benefits to the fitness of the organism and the life experience of the subject.

Changes in Postnatal Brain and Behavior Development

The Newborn Infant's Brain: Its Motives and Regulation by Maternal Care. The way a newborn infant's brain is endowed with innumerable somatotopic (body-charting) neural maps has been explained. These representations of body functions project a corresponding field of behavior addressing an external world (Trevarthen, 1985). They are interconnected by a system of axons that regulates states of motivation, balancing the energy demands of action on the environment against passive self-maintenance or tentative exploration. Although the synaptic mechanisms in the interconnected maps are later extensively modified and refined by the experience that they seek, their basic layout expresses the gene regulations and epigenetic processes that have been traced from the early embryo.

Research on the behavior, psychology, and physiology of the fetus indicates that in the last trimester functions are established in anticipation of an active postnatal life, and especially for assimilating maternal care (Lecanuet, Fifer, Krasnegor, & Smotherman, 1995). Motor coordinations exist that are obviously adapted for visual exploration, reaching and grasping, walking, and for expressive communication, by facial expression and gesture (de Vries, Visser, & Prechtl, 1984, 1988; Prechtl, 1984). Respiratory movements and amniotic breathing appear several weeks before birth. It is of particular interest that heart rate changes begin to be coordinated with phases of motor activity from 24 weeks (James, Pillai, & Smoleniec, 1995). This is indicative of the formation of a prospective control of autonomic state coupled to readiness for muscular activity on the environment, a feature of brain function, which Jeannerod (1994) cited as evidence for the formation of cerebral motor images underlying conscious awareness and purposeful movement.

The psychological evidence from tests of object awareness and flexibility of intentional behavior in infants, and especially from analysis of neonates' imitative and communicative skills, implies that the neural arrays for self-maintenance and self-coordination (autonomic functions and *proprioception*) and those for regulating transactions with objects (*exteroception*) have evolved in coordination with a third system, which regulates self–other intercoordination and *alteroception* (Aitken & Trevarthen, 1997; Bråten, 1998; Trevarthen, 1993b; Trevarthen et al., 1999).

It has been proposed that the core regulatory systems of interneurons in the brain stem, which in the adult regulate attentional orientations, coordinate purposeful movements of the body and its parts, and mediate the equilibria between autonomic and exploratory or executive states, first emerge in the embryo brain as regulators of morphogenesis in emerging cognitive systems (Trevarthen & Aitken, 1994). An important output from this intrinsic motive formation (IMF; Trevarthen & Aitken, 1994) controls the sensory-accessory motor systems of the special receptors of the head and hands. The eyes, the ears and cochlear, the lips and tongue, and the palms and fingers are separately aimable and tunable. Movements of these structures dynamically and rhythmically direct and censor the uptake of perceptual information in different modalities of high sensitivity and resolution, and these motor adjustments occur in the exploratory and focusing phases of attention to the outside world, before the final commitment of a "consummatory act." They therefore exhibit predictive information to an observer about emerging motor impulses and prospective self-regulations, and they have evolved into specialized expressive movements that signal the subject's awareness and intentions (Holstege et al., 1996; Panksepp, 1998; Trevarthen, 1993a, 1997). All the organs of human linguistic expression are recruited from this accessory motor set (FIG. 8.1). Brain stem efferent nuclei concerned with selectively aiming and focusing the uptake of visual, auditory, and haptic (tactile) information, on the one hand, and those dedicated to the control of visceral functions of body temperature, pain control, heart rate, respiration, vocalization, and biting in lower vertebrates have been adapted in humans to serve social functions of dynamic emotional expression and, eventually, language (Jürgens, 1979; Ploog, 1992; Porges, 1997; see Fig. 8.1).

Newborn infants, like young of other mammalian species, have effective adaptations for integrating their state regulation with maternal care (Carter et al., 1997). Infant's arousal and expressions of distress are immediately responsive to stimulation from breast-feeding, including responses to the sugar and fat content of breast milk (Blass, 1996). Of great interest is the finding that this physiological response is facilitated if the newborn has sight of the mother's eyes (Zeifman et al., 1996). Young infants respond to the touch, movement, smell, temperature, and so on of a mother, and sleeping with the mother may contribute to the development of cardiac and respiratory self-regulations (McKenna & Mosko, 1994). This is considered to be of special importance in the period before the development of cerebral mechanisms, including those for breathing control, that are specialized for future communication by speech, which involves integration between forebrain and brain stem centers. Newborns, and possibly fetuses, react to, and gain regulation from, the rhythms of maternal breathing and heart beat (McKenna & Mosko, 1994), and fetuses and infants are also supremely sensitive to maternal vocal patterns (DeCasper & Fifer, 1980; Fifer & Moon, 1994, 1995; Hepper, 1995). The emotional and communicative precocity of human newborns indicates that emotional responses to caregivers must play a crucial role in the regulation of early brain development (Als, 1995; Fifer & Moon, 1994). They are likely to guide differentiation of perceptual discrimination, cognitive processing, memory, voluntary deployment of attention to environmental objects, and executive functioning or problem solving (Schore, 1994; Trevarthen, 1990).

The regulatory mechanisms of the infant brain are subject to changes by endocrine steroids and other hormones (McEwen, 1989, 1997; Suomi, 1997), but they are ready at birth to formulate and express motivated behaviors, including coherent emotions. An intricate mutual psychobiological dependency is set up between a newborn infant and the care of a mother or mother substitute. Modern perinatal medicine finds evidence that this biological relation cannot be fully replaced by artificial clinical mechanisms (Als, 1995).

In infancy—long before the oral-vocal system is skilled in imitating speech and using it, or the hands can use symbols in a sign language or writing—eyes, hands, face, and voice may move in coordinated exchanges of expressions of feeling with an attentive and sympathetic partner. The mechanisms for vocal expression of emotion and those for speech that develop in the cerebral neocortex are organized around nuclei of the brain stem, and the basal ganglia, thalamus, and limbic cortex (Ploog, 1992; Trevarthen, 1999b). Their coordinated action can be observed in midgestation (de Vries et al., 1988; Piontelli, 1992; Prechtl, 1984). Multimodal brain stem circuits would seem to be crucial to communication with neonates and for their first imitations, which develop into well-controlled protoconversational abilities by 6 weeks, before visual awareness has undergone rapid development in the first 6 postnatal months. Developments in the mesolimbic cortices of the temporal and frontal lobes in infants and toddlers transform autonomic self-regulation, emotions in communication, and the motives for action and experience (Schore, 1994, 1998). At all stages, these later maturing limbic and neocortical circuits emerge in reciprocal, dynamic, and increasing involvement with the multimodal core regulatory systems of the IMF that were formed in utero (O'Rahilly & Müller, 1994; Panksepp, 1998; Robbins, 1992; Trevarthen & Aitken, 1994; Tucker et al., 2000).

Higher Motives and the Prefrontal Cortex (PFC). The prefrontal cortex (PFC), constituting 30% of the total human neocortex, is said to perform, "complex cognitive tasks involving active memory, abstract reasoning and judgement" (D. A. Lewis, 1997, p. 12). It is attributed an essential role in the integration of information in the temporal domain (Fuster, 1989; Goldman-Rakic, 1987a), a function that would explain the close reciprocal anatomical relation between the PFC and the cerebellum. Dorsolateral PFC is believed to retain transient memory traces that link the temporal discontinuities between recent events and future responses.

This conventional picture of PFC functions gives first place to experience-processing cognitive activities, rather than motivational or emotional functions of the mind. However, both phylogenetic and ontogenetic or developmental considerations would lead to the conclusion that this anterior part of the brain has evolved to integrate intrinsic emotional regulations with environmental information (A. R. Damasio, 1994; Luciana, 2001). The PFC has unique importance in the motivation and programing of expressive communication, and in the complex cross-modal, or multisensory, integrations required to recognize underlying intentions and feelings in behaviors of other subjects (Diamond, 1990; Goldman-Rakic, 1987b; Schore, 1994).

Histological areas 9 and 46 of the dorsolateral PFC of monkeys are thought to be homologous with human areas carrying the same Brodmann numbers, and the rostro-ventral premotor area of monkey frontal cortex (area F5), representing movements of hands, face and larynx, is probably homologous with Broca's speech area in humans (Brodmann's area 44). In both species, this region has a key role in the postnatal development of imitated skills. In humans, it mediates in the acquisition of all productive aspects of language, including speech (Rizzolatti & Arbib, 1998). Lateral prefrontal cortex is implicated in speech production and the dynamics of language, whereas understanding of speech involves dorsolateral temporal cortex and areas above the Sylvian sulcus (A. R. Damasio & H. Damasio, 1992). Research in monkeys has shown that the excitation of "mirror" neurons in frontal areas homologous with or adjacent to Broca's area "imitates" hand actions. Activation of these cells can specify either a gesture by the subject or visual perception of the same gesture in another individual (Rizzolatti & Arbib, 1998).

Mirror neurons in the prefrontal cortex of monkeys have been taken as possible candidates for the mechanism that enables infants to imitate, to associate emotion with imitation of other persons expressions and gestures, and to develop language. However, given the relative immaturity of this region of the brain in early infancy, it is more likely that unidentified subcortical components of a mirror system are responsible for imitation in the first year, at least for the many imitations of discrete and arbitrary expressions that neonates may perform (Heimann, 1991; Vinter, 1986). Mirroring actions involves multimodal, or transmodal, sensory recognitions and there are many multimodal neural populations in the brain stem (e.g., in the superior colliculus; Heimann, 1998, 2001; Stein & Meredith, 1993). These are integrated with systems that formulate motor images for action and expression (Holstege et al., 1996; Panksepp, 1998). The delayed response task, which depends on an intact PFC, develops at about 1 year in humans (Diamond, 1985; Overman & Bachevalier, 2001), but the adult functions of this part of the brain do not mature until after puberty (Levin et al., 1991). There are evidently substantial changes in the memory functions involved in strategic planning of actions and thoughts in adolescence, which are different from those occurring in early life (D. A. Lewis, 1997).

The development of cell forms and synaptic arrays in the PFC have been extensively studied in the monkey, demonstrating that this region has a longer and more elaborate developmental profile than other parts of the neocortex (Lewis, 1997). Other structures that have a comparatively long development in humans, mediating elaboration of new functions from fetal stages to adulthood, include the reticular formation, hippocampus, dorsomedial temporal lobe, and parts of the cerebellum (Gilles et al., 1983; Yakovlev & Lecours, 1967). These all mediate collaboration between intrinsic motivating activities and acquisition of new organization under environmental instruction.

Development of language is governed by principles of perception and motor expression that motivate conversational interactions between infants and their parents (Trevarthen, 1987b, 1999a). Preverbal communication involves both limbic and neocortical mechanisms in temporal and prefrontal parts of the hemispheres, as well as many subcortical structures of forebrain, diencephalon, midbrain, and hindbrain. The orbitofrontal cortex, linked to the mediolateral temporal cortex, has a key role in regulation of the balance between psychobiological state and transactions with the environment, including affective transactions with a caregiver, and it undergoes important elaboration in infancy (Schore, 1994, 1998, 2001).

Brain Events in the First Year that Might Signal Causes of Difficult Periods. The information presently available on human brain development is not sufficiently detailed to identify the causes of many periods of regression in infancy, or to verify or refute them. However, there is clear evidence, more or less direct, of massive transformations in brain structure and function during the first year of infancy: in cortical cell anatomy and connections, myelinization, brain metabolism, neurochemistry, synaptogenesis and synaptic activity, receptor site multiplication and activation or deactivation, and electrical activity and EEG coherence (Dawson & Fischer, 1994; Nelson & Luciana, 2001) (Fig. 8.3). There are many reasons why charting of these changes with infants at accurately known ages after birth and with fine enough discrimination of different brain systems is not possible at present, despite spectacular advances of noninvasive techniques that do not require postmortem material. Simple measurement of brain size and relative size of parts of the hemispheres may give evidence of growth spurts. It is obvious that the newborn brain is differently proportioned than the adult one—frontal, parietal, and temporal lobes are relatively small—and superficial observation of the head reveals that there is a marked enlargement

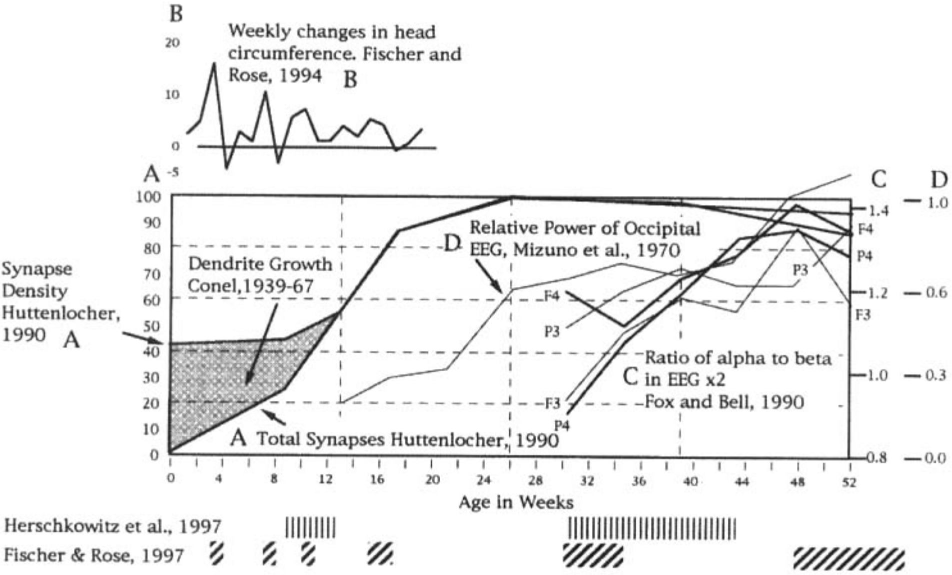

FIG. 8.3. Brain developments in the first year. The ages of "growth spurts" in brain and behavior developments reported by Herschkowitz, Kagan, and Ziles (1997) and Fischer and Rose (1997) are indicated at the bottom of the figure.

of the frontal region in the last part of the first year. Measurements of head circumference apparently demonstrate significant age-related peaks of rate of growth at 3–4, 7–8, 10–11, and 15–18 weeks (Fischer & Rose, 1994). There are no other measurements that discriminate possible transitional events as well as this data appears to do.

Myelinization studies over more than a century show that whereas some cortical and subcortical structures are relatively mature at birth, others undergo extensive functional development. In the first 3 months, the greatest change in myelin density is observed in motor pathways, sensory roots of the spinal cord, and visual projections to the midbrain tectum, thalamus, and cortex (Barkovich, Kjos, Jackson, & Norman, 1988; Gilles et al., 1983; Kinney et al., 1994; Yakovlev & Lecours, 1967). Subthalamic auditory pathways are more mature than visual ones at birth, but postthalamic auditory projections develop much slower than the visual, over the first few years. Thalamocortical tracts for touch also develop slowly.

At birth a rapid proliferation of dendritic branches of cortical cells is in full spate as cortical synaptogenesis increases. After 3 months, growth of major dendritic branches ceases and synapse density continues to increase until 6 months (Bourgeois, 2001; Conel, 1939–1963; Huttenlocher, 1990). In this period, there is a growth spurt in production of interneuronal glia cells in the cortex (Dobbing, 1981). The first three months is a time when sleep regulations and associated processes of respiration and circulatory control, which are set up antenatally, undergo extensive consolidation linked most obviously with developments in the body's motor capacity and in visual alertness and discrimination (Koyama, 1993; Tucker, Grieve, Stark, & Luu 2002, personal communication,"Mechanisms of fetal dreams: Temporal lobe localization of electroencephalographic bursts in the quiet sleep of preterm human infants").

Synaptogenesis occurs at different times in different areas of the human cortex, but is largely complete by the end of the first year. There is no sufficiently discriminating information on the regional differences in cortical maturation and formation and maturation of synapses in different areas of cortex and in different subcortical grey matter to make correlation with periods of significant behavioral change. Concerning the visual cortex, the available evidence is compatible with the theory that synaptic mechanisms of layer 4 neurons there undergo rapid maturation at the same time as binocular stereopsis develops (Held, 1985; Held, Birch, & Gwiazda, 1980). Cortical synaptic density shows a relatively steep developmental curve that is similar to the curve of developing stereopsis but earlier (Wilson, 1993). It is notable that monocular acuity shows a more gradual development over the first year, with no period of rapid change (Gwiazda, Brill, Mohindra, & Held, 1980) (Fig. 8.4).

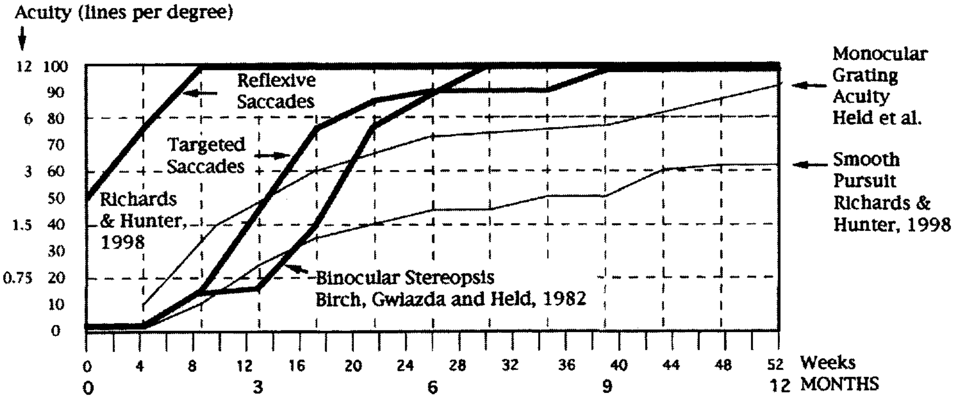

FIG. 8.4. Contrasting rates of development in the first year. Monocular visual acuity and smooth pursuit eye movements (thin lines) develop over many months, continuing to change beyond the first year. Reflexive and targeted saccades and binocular acuity develop within 2 months to mature levels early in infancy.

PET scan evidence on regional glucose utilization in infants' brains has been used to trace synaptogenesis and cerebral plasticity and to make correlations with behavioral maturation (Chugani, 1994, 1998). In the newborn, highest rates of metabolism are found in the primary sensory and motor cortices, thalamus, brain stem, and the vermis of the cerebellum, but the basal ganglia, hippocampus, and cingulate gyrus are also active. Parietal, temporal, and primary visual cortices, basal ganglia and the cerebellar hemispheres are increasingly active during the first 3 months. Lateral and inferior frontal cortex shows increase of glucose consumption after 6 to 8 months and the dorsal and medial frontal cortices show comparable increase only between 8 and 12 months. At 1 year, the infant's pattern of glucose utilization resembles that of an adult.

In the last 3 months of the first year, conspicuous developments in the prefrontal cortex have attracted attention. In this period, the ratio of EEG alpha activity to beta activity increases, coincidentally with the many developments in intelligence and behavior described earlier. Bell and Fox (1996), who used baseline EEG as an indicator of brain development (Bell & Fox, 1992), found that infants that crawl early, and who are proficient crawlers at 8 months, exhibit an earlier decrease in intra-hemispheric EEG coherence, interpreted as evidence of pruning of superabundant intercellular connections, which lead to greater coherence. The same authors (Bell & Fox, 1997) presented evidence that infants who were successful in performing the A-not-B object permanence test exhibited greater frontal EEG power and greater occipital EEG power than unsuccessful infants, and the unsuccessful infants were likely to also be prelocomotor. This supports the conclusion that brain mechanisms for cognitive and locomotor maturation share common regulatory factors, which may or may not be of environmental origin.

Fischer and Rose (1997) published data from Mizuno et al. (1970) showing occipital EEG "spurts" at 3–5, 6–8, and 9–12 months, and they related these to the head circumference measurements showing spurts at 3–4, 7–8, and 10–11 weeks (Fischer & Rose, 1994, see Fig . 8.3). Cortico-cortical connections by long axons within or between the hemispheres have relatively long cycles of maturation throughout childhood (Yakovlev & Lecours, 1967). In the first year, it is likely that a large selective elimination of interhemispheric axons of the corpus callosum takes place during the first 6 months, before the callosal axons start myelinating (Innocenti, 1983). EEG coherence studies show that different cortico-cortical tracts between pairs of locations in the cortex are changing in their efficiency at particular ages, and comparisons between locations in the two hemispheres indicate that cycles of development swing from left to right cortex throughout childhood (Thatcher, 1994). However, these measures of cortical maturation do not distinguish more than one growth event within the first year, and the sample of infants under 18 months was small.

TRANSITIONS IN BEHAVIOR IN INFANCY AND CORRELATIONS WITH REGRESSION PERIODS

A search of the literature and data has been performed in an attempt to find evidence that certain behaviors, in addition to those reported by mothers as "difficult," may undergo periods of rapid change (PRCs). The results are summarized in Fig. 8.5 and Table 8.2. These indicate that, indeed, a variety of measurable features of behavior, including preferences and aversions for particular sorts of experience, and different ways of using the motor and

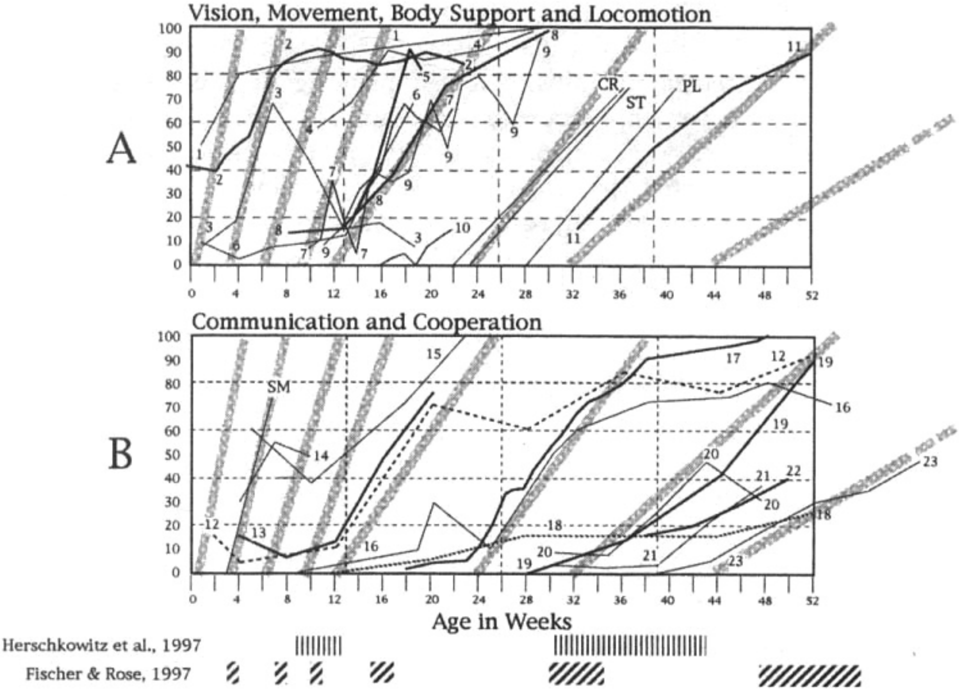

FIG. 8.5. Developmental curves suggestive of Periods of Rapid Change (PRCs) for the first year; in motor activity, vision, and communication. See Tables 8.2 and 8.3 for sources.The shaded bars are approximate regression lines for principle PRCs.

TABLE 8.2

Vision, Movement, Body Support, and Locomotion

Behavior	*Source*	*Parameter*
Coordinated accommodation	Braddick & Atkinson, 1979	Percentage of infants able to focus at 75 cm
Bull's eye preference	Banks, 1985; Fantz & Nevis, 1967	Relative preference for bull's eye relative to grating; Percentage of fixation time
Hand fisted when object fixated	von Hofsten, 1986	Percent of reaching movements with hand fisted when object is fixated
Head/target movement ratio	Daniel & Lee, 1990	Mean head/target movement ratio, percentage of movement
Touches when reaching	Sylvester-Bradley & Trevarthen, 1978	Percentage of total reaching attempts; one infant, 8–20 weeks, observed frame-by-frame on film
Encounters with object when reaching	von Hofsten, 1986	Percent of reaching movements
Controlled reaching	Trevarthen, 1982a	Percentage of "controlled reaching" in all attempts to grasp object; 15 infants, 10–22 weeks of age
Stereopsis, crossed disparity	Birch, Gwiazda, & Held, 1982	Percentage preference for looking at stereo target
Stereopsis	Fox, Aslin, Shea, & Dumais, 1980	Percent of infants showing preferential looking with random dot stereograms
True grasps	Trevarthen, 1982a	Percentage of object supporting grasps as a proportion of all reaches (same data as in "controlled reaching")
"A-not B" delay, or delayed response	Diamond, 1990	Delay at which infants make a correct choice in A-not B or delayed response test; percentage of 12 seconds
Motor developments: CR = Crawling, ST = Sitting, PL = Pulling up to stand	van der Stelt & Koopmans-van Beinum, 1996	Regression lines for percentage of infants, per week; 51 infants

sensory systems of the body, do show particularly rapid developments at identifiable ages. Table 8.3 summarizes other important developments. General conclusions about developments in communication and play, social awareness, cooperative intelligence, and grasp of conventional meanings are summarized in Fig. 8.6A. These relate the findings from many descriptive studies to the curves presented in Fig. 8.5.

Although most of this evidence comes from frequent sampling in small populations, even single subjects, and there is clearly considerable variation, there is indication that a majority of infants are in the process of making these changes at about the same age, and if they develop without complications, complete the transitions in about the same relatively short period (i.e., in a small proportion of the present age of the infant). Clearly, other developments, for example, infants' memory powers (Rovee-Collier & Gerhardstein, 1997), or their monocular visual acuity (Gwiazda et al., 1980; Sireteanu, 2001) and smooth pursuit eye movements (Richards, 2001; Richards & Hunter, 1998) do not show comparable rapid changes, but slowly accumulate a more discriminating level of function (Fig. 8.4).

Figure 8.6 shows that lines corresponding to the most apparent PRCs (B, D, E, and F) also labeled in Table 8.4, correlate well with phenomena discovered by a very different kind of research into maternal perception of infant's state of dependency and self-regulation (Rijt-Plooij & Plooij, 1992, and Fig. 1.1). This indicates that, indeed, regulations in the infant's brain and body trigger changes in both information-seeking psychological functions and self-regulation at certain ages, and these, in turn, affect maternal care and communication.

There is, of course, evidence that the ages of developmental transitions are not fixed to the extent that they are unaffected by environmental factors, abnormal genetics, or prenatal development of the infant, prematurity, or variations in maternal behavior, and so on (Aitken & Trevarthen, 1997). In the first year, as infants become more wakeful, they feed, cry, and fuss less, but there are considerable individual differences, especially in the proportion of time spent sleeping, crying, and fussing (St. James-Roberts & Plewis, 1996). However, it does not seem possible to explain the observed functional or behavioral transitions either by reference to a general dynamic systems model of events in the growing body and brain (Hopkins, 2001; Thelen, 1995) or in temperament and social use of emotions (Fogel & Thelen, 1987; M. D. Lewis & Granic, 2000; Pantoja et al., 2001; Van Geert, 1994), or to plastic response of the cerebral cortex to environmental stimuli. The PRCs appear to indicate regulatory or motivational changes originating in the core of the brain.

TABLE 8.3
Communication and Cooperation

Behavior	*Source*	*Parameter*
SM = Smiling	van der Stelt & Koopmans-van Beinum, 1986	Regression lines for percentage of infants, per week; 51 infants
Not looking at mother	Trevarthen & Marwick, 1986; Trevarthen, 1989	Percentage of time not looking at mother in face-to-face play; 8 boys and 8 girls in 3 overlapping cohorts for ages 4–54 weeks
Not looking at mother	Bundell & Trevarthen, 1983 (new analysis)	Percentage of time not looking at mother in face-to-face play; average of 3 girls and 3 boys; replicates part of population in "not looking at mother"
Looking at eyes	Haith, Bergman, & Moore, 1977	Percentage of time looking at eyes
Right hand gestures, girls (boys, 8 weeks later)	Trevarthen, 1996	Percentages of gestures with right raised higher than left; 3 infants
Supraglottal articulation	Holmgren, Lindblom, Aurelius, Jalling, & Zetterström, 1986	Percentage occurrence of supraglottal articulation in vocalizations; 1 infant
Babbling	van der Stelt & Koopmans-van Beinum, 1986	Percentage onset of babbling; 51 infants
Looking at mother's hands	Trevarthen & Marwick, 1986; Trevarthen, 1989	Percentage of time looking at mother's hands in face-to-face play; 8 boys and 8 girls in 3 overlapping cohorts for ages 4–54 weeks
Cooperation in Truck Test	Trevarthen & Marwick, 1982	Percentage of mother's indications complied with by infant; 5 boys and 5 girls in 2 overlapping cohorts, ages 16–54 weeks
Utterances of Joint Attention and Declarations, one girl	Papaeliou, 1998	Percentage of utterances seeking mother's attention
Utterances of Joint Attention and Declarations, one boy	Papaeliou, 1998	Percentage of utterances seeking mother's attention
Complies with requests	Hubley & Trevarthen, 1979	Percent of mother's requests complied with; 5 girls, ages 34–54 weeks
Self-feeding with hand	Negayama, 1993	Percent of occurrences of taking solids by self-feeding with hand to mouth

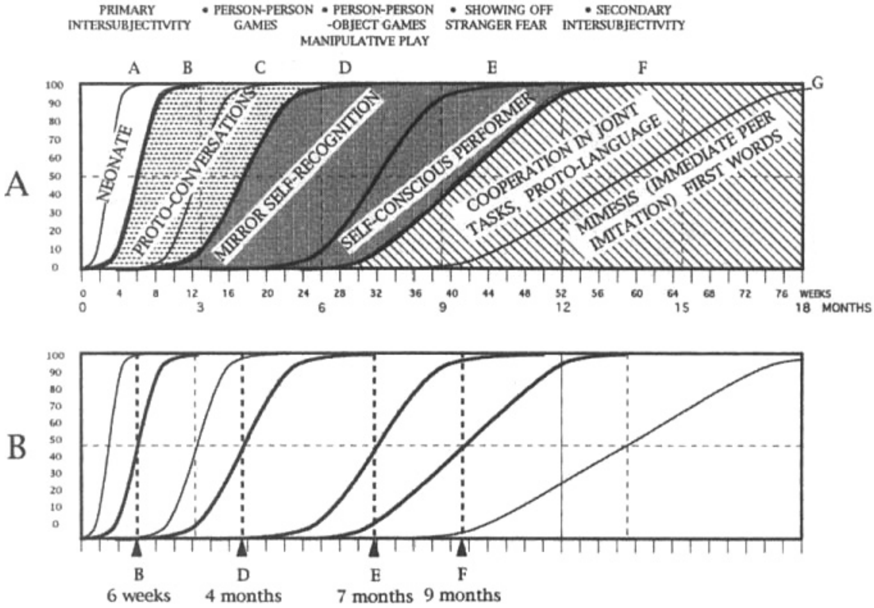

FIG. 8.6. Developmental transitions in the first 18 months, inferred from the data shown in Fig. 8.5. A: Developments in intersubjective functions of communication and cooperative learning. B: Ages of most rapid change in principal developments. See text and Table 8.4.

Development of Movement, Perception, and Cognition in Infants, and Their Dependency on Changes in Motives

Forty years of intense laboratory research to find out what infants perceive and remember at different ages reveals surprising abilities. All the discoveries have depended on granting infants the limited freedom to be selective observers of organized visual displays or operatives in instrumental conditioning systems that record their choices. Experiments generally use displays that limit stimuli to one or two modalities in which the forms are strictly controlled by abstract principles of similarity or difference—of two-dimensional geometry, motion, causality, acoustics, or linguistic semantics. More recently, model animate, gestural, or social actions have been offered as contrasting stimuli, in an attempt to escape the traditional physicalism and individualism of this research (Lacerda, von Hofsten, & Heimann, 2001). The theoretical interpretations of what has been found differ greatly, but the main findings are beyond dispute.

Infants are alert to some of the events around them from birth, and to some of their distinctive features, and they quickly learn to recognize the uses of objects and events to which their motives guide them. They are particularly interested, from birth, in responsive humans as stimuli, and as sources of satisfaction in play. Eventually, they seek familiar companions as partners in joint experiences and collaborative tasks in which interesting spectacles or constructions with manipulable objects are created. The research on perception and cognition needs to be related to developments recorded by clinicians and behavioral scientists in spontaneous motor coordination (von Hofsten, 2001).

To assist comparison with the age-related events, the findings of the experimental research are presented for broad age bands chosen by reference to the times of most rapid change in the S-shaped PRC curves in Fig. 8.6B for which there is strongest evidence in the developmental data reviewed and illustrated in Fig. 8.5, namely, at around 6 weeks, 4 months, 7 months, 9 months, and 18 months, the last being taken as an approximation to an agreed period of developmental change around the middle of the second year. This is simply an attempt to see what kind of relation might be established between achievements recorded in experimental studies of behavior, perception, and cognition with few sample points, and PRCs charted with more frequent sample points.

The First 6 Weeks After Birth. Newborn infants are integrated, or temporospatially coherent, in general motor intentions and awareness, and they have a number of different purposeful movements. They exhibit fluid coordination of spontaneous general movements of the whole body (Prechtl, 1990), which are continuous with the movement patterns of preterm fetuses (Cioni & Prechtl, 1990; Hopkins & Prechtl, 1984). For the first 3 to 6 weeks, the movements have a slow "writhing" character, and asymmetric postures in this period involve the whole body, including the legs. Whereas the turning movement to redirect visual interest to new events has low spatial resolution (Aslin & Hunt, 2001), newborns can orient eyes or head and eyes to a sound, even in the dark (Alegria & Noirot, 1978; Muir & Field, 1979; Wertheimer, 1961). The blink reflex (a simple preattentive cognitive "interrupt" of seeing, or a startle response triggered by an approaching object) and reflexive saccadic eye movements above a certain size are also nearly mature at birth, in form and periodicity (Richards & Hunter, 1998). Heart rate changes that accompany, or anticipate, periods of sustained attention in newborns appear to reflect general arousal, not specific anticipations. However, in spontaneous imitative exchanges, heart rate deceleration is a correlate of expectation for a response from the partner (Nagy & Molnár, 1994).

Vision is very immature at birth, and undergoes rapid development in the first 2 months with a long process of refinement in discrimination thereafter (Sireteanu, 2001). Nevertheless, visual interest can be shown immediately, and a newborn baby will look longer at the mother's face than a stranger's just hours after birth, even when other sensory cues are excluded, which indicates very rapid learning (Bushnell et al., 1989; Field et al., 1984; Pascalis et al., 1995). Newborns move eyes and sometimes head to follow moving face-like patterns, and they orient to upright face configurations in preference to inverted ones in the temporal but not the nasal visual field (i.e., they move to make larger orientations of their interest, not to adjust inspection of details in the binocular field; de Haan & Halit, 2001; de Schonen, Mancini, & Leigeois, 1998). Unlike adults, newborns do not recognize the face of the mother from the configuration of internal features (eyes, nose, mouth) if external features (shape of face, hair) are hidden. However, they do look at internal features of patterns if the details are of high contrast or in movement, which is obviously the case when newborns imitate face expressions. They respond to speech differently than to some nonspeech sounds, and show different ERPs to phonetic contrasts versus tone differences, apparently discriminating language general phonetic distinctions (Dehaene-Lambertz, Mehler, & Pena, 2001; Kuhl, 1987, 2001; Mehler et al., 1988; Werker & Polka, 1993; Werker & Tees, 1992). On the other hand, the sensitivity of young infants for the affective signals in a human voice, especially the mother's as one familiar from before birth, indicates that they may not be attending to any features specific to language at all (DeCasper & Spence, 1986; Fernald, 1989; Fernald et al., 1989). The imitations of face expression, voice sounds, and hand gestures that newborns show within minutes of birth are intentional acts, multimodally regulated and used in communication, and these responses show up individual differences in readiness to communicate (Heimann, 2001; Kugiumutzakis, 1998).

It is clearly established that the newborn infant has the capacity to conceive solid continuous objects outside its body and to coordinate orientations to nearby events perceived by sight or hearing. Newborns are particularly sensitive to dynamic stimuli from people and ready to learn rapidly special features or configurations that identify the mother or other caregiver. The coherence of events in the infant's mind, in time, and space have been said to constitute a set of core concepts ready to encounter real examples of natural phenomena in the outside world (Spelke, 1998), or strategies for learning, ready to acquire more discriminating awareness as perceptual sensitivities develop with increasingly acute attention (Meltzoff & Moore, 2001). The capacities for expressive action coupled to sensitive perception of contingent human signals releases social emotional signs (e.g., smiling, hand gestures, and cooing), imitations and reciprocation in the first protoconversational exchanges or social games, well before focused visual attention to the eyes of the partner is developed in the second month (A. Berger & Posner, 2001). Humans are born with rudimentary motives for engaging in collaborative action and learning, and these develop quickly in the first 6 weeks.

Six Weeks to 4 Months. The spontaneous movements of infants change in character rather rapidly as head and limb action becomes stronger, perceptual awareness (especially visual awareness) becomes more discriminating, and the world in space away from the body is examined more deeply. Writhing movements give way to more fractionated fidgety movements in the second month, and manipulative movements become common around 3 months. Asymmetric tonic postures of the head and arms alone, the trunk remaining symmetrical, appear, then asymmetries in resting postures are absent after 12 weeks (Cioni & Prechtl, 1990; Hopkins & Prechtl, 1984). Spatial localization of sounds becomes more precise in the first 6 months (Muir, Clifton, & Clarkson, 1989), and is more accurate in light (Aslin & Hunt, 2001). The minimum audible angle (MAA) becomes smaller, indicating improved discrimination of small changes of location of a sound source (Aslin & Hunt, 2001; Morrongello, 1988). Anticipatory heart rate change when attention is channeled a specific modality develops over 2 to 6 months (Richards, 2001), as does the selective modality effect of blinking in response to a stimulus in the same modality as the background stimulus (Richards, 1998). Attention-directed voluntary saccadic eye movements also develop rapidly in this period (A. Berger & Posner, 2001; Richards & Hunter, 1998; Ruff & Rothbart, 1996; Von Hofsten, 2001), and nasotemporal asymmetry of monocular optokinetic nystagmus (OKN) starts to disappear around 2–3 months, which shows that the infant is becoming more flexible in shifting attention between lateral and central parts of the visual field (Atkinson, 1998).

Infants over 3 months of age are learning perceptual categories of objects and of spatial relations, simply by being exposed to the stimuli

(Butterworth & Simion, 1998; Condry, Smith, & Spelke, 2001; Mandler, 1992; Quinn, 1998). The basic categories of cats and dogs may be recognized in pictures or with models, the infant using information from differences in the head and face. Babies can distinguish contingent from random motion at 3 months, and this serves in identification of live movement and animate causes (Legerstee, 2001). Exposure of 3- to 6-month-old infants to an attractive unfamiliar stimulus (a "Sesame Street" movie) when the infants were in a state of sustained attention (defined by heart rate), resulted in retention of a recognition memory (Richards, 2001).

Viewing artificial displays, infants perceive difference in grouping of objects shown repeatedly, but they do not abstract relations and apply them to group other objects. This difference of process is identified with the distinction drawn between procedural and declarative memory, or related to a distinction between conceptions of where (place) and what (identity) (Johnson & Vecera 1993; Quinn, 1998). The infants are believed to be using procedural, not declarative, memory.

Infants' perception of face picture information is found to be more discriminating after 2 months, and they show increased scanning of internal features of the face, extracting more invariants, and recognizing individual faces (Johnson & Vecera, 1996). Experimental face diagrams are looked at with more discrimination and there is better discrimination of children's faces as well as those of adults (De Haan, 2001). A 2-month-old expects to have a particular quality of social interaction in the presence of a face, is attentive to emotions, and becomes distressed when an adult partner ceases to interact normally (D'Entremont, 1994; Ellsworth, Muir, & Hains, 1993; Murray & Trevarthen, 1985; Nadel et al., 1999). The babies smile less when the adult partner's eyes are averted, and smiling recovers with resumption of mutual gaze (Hains, Muir, & Franke, 1994; Murray & Trevarthen, 1985). As 3-month-olds gain in interest for games with toys, there is a fall in attention to the mother.

The most striking correlations of this period are between the cognitive achievements (what is being perceived and learned), and the developments in the infants powers of motor action (stabilization of the head, improvements in ocular coordination for scanning the environment and following objects, development of controlled reaching) (Manukata, 2001; Von Hofsten, 2001). As recorded earlier, there are important developments in communication, which stimulate partners to respond with more animation. Infants are both actively playful and socially self–other conscious from this time on, making significant differentiation of persons in their world (Draghi-Lorenz & Costall, 2001; Reddy, 1991, 2000; Reddy, Hay, Murray, & Trevarthen, 1997; Trevarthen & Aitken, 2001). This escapes the observation of studies directed solely to elucidating the infants' cognitive mastery of physical phenomena, or their reactions to events as observers.

Four to 7 and 9 Months. Resolution of temporal cues in sound, and suppression of perceptual interference from echoes, become more efficient after 4 months. The MAA improves markedly, but it does not attain the adult value (1–2 degrees) until 5 years (Aslin & Hunt, 2001). These developments in auditory perception can be related to the increasing attention infants pay to speech and singing, their efficient imitative communication in vocal games, and the beginnings of vocal adaptation to the mother tongue (de Boysson-Bardies & Vihman, 1991; Vihman & de Boysson-Bardies, 1994). There are also important developments in visual awareness. The latency of cortical evoked potentials to face stimuli shortens by 100–200 ms (Nelson & Monk, 2001). Smooth pursuit eye movements show protracted developmental changes from 2 months over the first 2 years (Richards & Hunter, 1998).

It is claimed that there is no evidence of concepts before 7 months, but in this period infants are interpreting what they are looking at and setting up kinds, or categories, of object (Mandler, 1992). They can conceive categories of a number of complex natural or artificial objects (Quinn, 1998; Xu & Spelke, 2000). They are more aware of the structure or substance of surroundings. For example, infants can show in dishabituation tests that they know about transparency and occlusion at 7.5 months. Under favorable conditions (e.g., with stimuli in motion), they perceive like adults do some visual illusions that complete an awareness of fractionated objects (Condry et al., 2001). Development of such concepts is thought to depend on both innate core propensities to segment phenomena and to conceive unitary objects with edges (Baillargeon, 1986; Condry et al., 2001; Spelke, 1998) and on learning from the universals in babies' experience (Greenough & Black, 1992; Haith, 1998), but these alternatives are difficult to untangle. All infants are exposed to repeated experience of artefacts of consistent forms, and all see animate and inanimate objects (Baillargeon, 1993). Notions of force and weight relate to causal events in the infant's own handling of objects, watching other persons' manipulations, or the spontaneous or elicited motion of objects in the perceptual field. Logical implications, such as believing in the extent of a partly hidden object, or seeing an object as on another object and detachable from it (Piaget, 1954), require different anticipatory cognitive processes. New concepts for objects related to their detachability and manipulability develop after 6 months (Baillargeon, 1986; Diamond, 1991b). Infants begin to think about why events happen, and what kind of causes there may be (Legerstee, 2001). These developments can be ascribed to changes in investigative motives, and motives to communicate and play, as well as to the influence of the experience of physical configurations and events.

Real-world experiences with human stimuli lead to discrimination of social events and gender attributes of persons (Legerstee, 2001; Quinn, 1998). Around 6 months, infants recognize and remember faces and the difference between male and female faces (de Haan & Halit, 2001; de Schonen et al., 1998). Hemispheric differences in face processing appear in the last half of the first year, thus the preference to see the mother or a familiarized face is stronger in the left visual field (the right hemisphere) (de Schoenen et al., 1998). Six-month-olds can recognize face expressions of emotion, and they show categorical awareness of emotions in the happy–fear continuum like adults do (de Haan, 2001). Obviously, some sensitivity to facial expressions of emotion exists much earlier (Field et al., 1982).

Vocal pattern recognition is highly proficient in this age range and rhythms of syllabic sounds are immediately learned (Bertoncini & Mehler, 1981; Jusczyk, 1997, 1999, 2001; Kuhl, 1985, 1987, 2001; Locke, 1993), influenced by both auditory and motor capacities of the infant (Lacerda & Sundberg, 2001). Familiar words designating common objects of interest to the infant are noticed first. For example, in an English environment, infants of this age categorize "loose" and "tight" as words signifying the appropriate action in demonstrations of putting things in containers with different fit. The infant's own name may be the first word listened to more and recognized—the frequency as well as the social salience of utterances clearly has great influence on learning (Jusczyk, 2001). Native language contrasts in speech attract the attention of the infant and begin to influence the vocalizations produced (de Boisson-Bardies & Vihman, 1991; Locke, 1993). Infants perceive speech as integrated signs of the speaker's expressive motives; for example, they expect mouth movements of speakers facing them to match and synchronize with the sounds produced in the speech (Kuhl & Meltzoff, 1982; McGurk & MacDonald, 1976). But the greatest sensitivity and interest of infants at this age is, as it was earlier, in the affective tone of utterances (Fernald, 1992, 1993; Kitamura & Burnham, 1998). They are listening to emotion and expression of motive states in the very complex sounds around them in the home (Davis & Lindblom, 2001)

In person-person-object games, the mother shows toys and infants attend, showing an increasing preference for looking at the toys the mother is presenting, looking less at other toys. In response, the mother attracts the infant's attention by talking and inviting the infant to look at the toys (Ruel, 2000). When an infant of 7–10 months encounters a problem in attempting to reach over a barrier, the infant may look up at the experimenter, then successfully reach to and pick up the object (Diamond, 1991). The infant is interested in sharing purposes, attentions, and feelings about events and situations (Butterworth & Grover, 1990; Klinnert, Campos, Sorce, Emde, & Svejda, 1983; Trevarthen & Hubley, 1978).

Nine to 18 Months. In the last part of the first year, an infant is becoming very interested in the strategies by which objects can be combined in manipulation, and at the same time discrimination of spatial relations in artificial displays improves. Their recognizing the difference between a dot "above" or "below" a line is taken as evidence for development of both what and where systems in the brain (Quinn, 1998).

In 6 to 12 months, infants pass through five stages of mastery of negotiating barriers in the Object Retrieval task, at the same time as they master the A-not-B object permanence task (Bower, 1982; Diamond, 1985; Piaget, 1954). There is variation between infants, but performances of the two tasks change in a given infant at the same rate. Both tasks require sustained attention or the information-maintenance component of working memory of Baddeley (1992). Alternatively, they can be explained as reflecting changes in motivation and attention affecting the awareness of the circumstances that determine access to the reward that the child desires (Luciana, 2001). This significant shift of interpretation is discussed further later (Table 8.4).

Infants of these ages also attend more carefully to what other people are doing with objects, taking increasing interest in novel objects and new ways of using objects (Legerstee, 2001; Mandler & McDonough, 1994). In games with objects, mothers talk less as they accept that the infant understands gestures and minimal comments (Ruel, 2000). Infants also are more aware of the kinematics in natural human movements, and are dismayed by a robot that seems to move on its own (Poulin-Dubois, Lepage, & Ferland, 1996). Identification of people is aided by domain-specific knowledge or a natural capacity to recognize the effects people create

TABLE 8.4
Other Age-Related Developments

Motive Phases (Trevarthen, 1982b)	*PRCS (See Fig. 8.6)*	*Psychological State*	*New Developments*	*Sources*
Phase I (0–10 weeks) +	A (0–4 weeks)	Neonate	Regulation of sleep, feeding, & Breathing	Kohyama, 1998; Sander, 1997a, 1997b Zeifman et al., 1996
			Innate prereachingInnate expressive imitation & provocation	Trevarthen, 1974; von Hofsten, 1982 Kugiumutzakis, 1985, 1993, 1998; Meltzoff & Moore, 1977; Nagy & Molnár, 1994, 1997
	B (3–7 weeks)	Primary intersubjectivity Protoconversations	Mouth & tongue imitation	Field et al., 1982; Heimann & Schaller, Heimann et al., 1989; Maratos, 1973, 1982; 1985; Kugiumutzakis, 1985, 1993, 1998
	C (6–12 weeks)		Vocal & gestural imitations	Maratos, 1973, 1982; Kugiumutzakis, 1985

Phase II (10–30 weeks) +	D (10–16 weeks)	Games,with people Self–other play	Mother assists playful interests Person–Person games, mirror recognition	Ruel, 1998; Trevarthen, 1986a Trevarthen & Hubley, 1978; Reddy, 2000
	D (11–22 weeks)	Visual and manipulative exploration of objects Person–person–object play	Smooth ocular tracking, reaching and catching Hand imitations, body games Mother assists person–person–object games Looking at mirror self	von Hofsten & Rosander, 1996; von Hofsten, 1983 Trevarthen & Hubley, 1978 Ruel, 1998; Trevarthen, 1990; Fiamenghi, 1997
	D (12–26 weeks)	Conventional mannerisms	Imitation pointing & clapping Back stronger, rolling over prone-to-supine Mother watches and extends object games	Trevarthen, 1986a; Kokkinaki, 1998 McGraw, 1945 Ruel, 1998; Trevarthen, 1990
	E (24–54 weeks)	Performing, other-aware self	Playful imitating, "showing off," stranger fear Excludes other from manipulation	Trevarthen, 1990 Trevarthen & Hubley, 1978
Phase III (30–60 weeks) +	F (32–54 weeks)	Secondary intersubjectivity Rational interest in objects	Joint attention, cooperative task performance Follows gaze & pointing Strategic (executive) thinking Combining objects Categorization of experiences	Bruner, 1983, Trevarthen & Hubley, 1978 Bakeman & Adamson, 1984 Churcher & Scaife, 1982 Butterworth & Grover, 1989 Piaget, 1954; Diamond, 1985, 1990; Reznik, 1989
	G (44–¿ weeks)	Cultural learning starts	First words Conventional mannerisms, tasks, tools Creative imaginative imitative play begins	Bruner, 1983; Tomasello, 1988 Tomasello et al., 1993 Trevarthen, 1990

when they move (Legerstee, 2001). Infants of this age are proficient at delayed imitation, which aids their recognition and retention of ideas about the significant intentions of other persons (Meltzoff & Moore, 2001)

This is a key time in the development of speech awareness, and in detection and learning of rhythmic and prosodic features of speech that define the speaker's intentions, and help the infant identify important things in communication (Jusczyk, 2001). The infants will remember common words dealing with objects and actions of interest. They are beginning to notice and use the special advantages of language for denotation, social sharing, and recall (Locke, 1993).

Beyond 18 Months. The middle of the second year is a milestone for a child mastering the delayed nonmatching to sample (DNMS), a task said to be independent of language development and requiring a searching for information kept in memory and a strategy for shifting attention according to a rule (Overman & Bachevalier, 2001). A child can solve the DNMS task at 9 months if the reward is stuck to the bottom of the hinged lid that hides it, and not if it remains hidden in a well. This confirms that the difficulty the younger child has is related to the need to shift attention from the desired goal and search (Luciana, 2001, Table 8.5). Usually the DNMS is taken to be a test of recognition memory, a kind of declarative memory (Overman & Bachevalier, 2001). It is likely that the memory

TABLE 8.5

Seeking and Consummatory Motivation Systems

	Seeking	*Consummation*
Neurobiology	Dopamine	Opiates
Affect	Anticipation/desire incentive	Well-being/contentedness
Cognition	Search Expansion of attention Spatial coordination Cross-temporal memory Strategic thinking Contingency updating	Tunnel vision Narrowing of attention Object recognition Immediate encoding Place + object preference
Motor	Diffuse/active exploration	Localized/consummatory

Note: From "Dopamine-opiate Modulations of Reward-Seeking Behavior: Implications for the Functional Assessment of Prefrontal Development," by M. Luciana, in *Handbook of Developmental Cognitive Neuroscience* (Table 41.2, p. 657), 2001, Cambridge, MA: MIT Press. Copyright © by MIT Press. Reprinted with permission.

function is a reflection of the motives that lead to retention of experience at the time it is needed to direct intentions or "executive" functions.

Object reversal learning shows interesting sex differences attributed to the effects of the perinatal testosterone surge in males on brain development and thence on cognitive functioning. Males around 30 months of age perform, on average, better than females on this practical task, and females show "hyperemotional behaviors commensurate with the start of reversal training" (Overman & Bachevalier, 2001, p. 113). For concurrent discrimination, however, females under 36 months are superior to males of the same age in what they notice about the stimuli.

Between 18 months and 2 years is a period of transition in language learning when there is a vocabulary burst, with two- and three-word sentences appearing and then a rapid acquisition of inflection and function words. The foundations for this development are found in growth of neural systems in the left hemisphere that are set up to learn language (Vicari et al., 2000). With increased attention to phonetic detail and accurate lexical representation, the conceptual resources and conceptual flexibility of the child are increased, as reflected, for example, in the toddler's understanding of spatial relations between things within a group that can be readily labeled by phrases such as "to the left of...." Thinking in words, the child can "decentre" and master navigational maps or orienteering descriptions. Language maps onto shared "sense," not just perceived entities (Tomasello, 1988; Trevarthen, 1987b). There is much overextension of meanings still at 2 years, but the child is actively comparing words and their referents to get at more precise meanings (Mandler, 1988). In all these developments, whereas there is a clear age-related process intrinsic to the growing brain, there is great variation in the path followed by individual children (Locke, 1993).

Periods of Rapid Change in the Self-Regulation and Motives of Rhesus Monkeys and Chimpanzees

If there is a biological (i.e., organismic and adaptive) agenda for emergence of motives to learn in new ways in the growing human brain, it is likely that age-related changes triggered by intrinsic regulations of brain development will show similar growth strategies in other mammals, and especially in phylogentically close species. Interesting support for this idea comes from comparing human infant development with what is known about the early development of young rhesus monkeys and chimpanzees.

Suomi reported that at around 1 month, 2–3 months, and again around 4–5 months, at the very least, rhesus monkeys have periods of marked change or reorganization in behavior, emotional reactivity, and (to the extent it has been tested) cognitive capabilities. Accepting the rule that rhesus monkey young mature about four times more rapidly than human infants, which is supported by evidence on development of binocular acuity (Boothe, Dobson, & Teller, 1985; Teller, Regal, Videen, & Pulos, 1978), these times of change correspond to the human ages of 4 months, 8–12 months, and 18 months.

Suomi (personal communication, July 2001) reported that the 1-month behavioral change coincides with the "disappearance" of most neonatal reflexes, the stabilizing of the hypothalamic-pituitary-adrenal axis (after the first month, individual differences in cortisone levels become stable, but not before), and the infant begins to leave its mother for brief exploratory forays.

The 2- to 3-month transition coincides with the emergence of a "developmentally determined, inborn fear response" in the monkey as demonstrated experimentally by Sackett (1966), who showed socially naive juveniles, 2 weeks to 7 months old, pictures of monkeys threatening. Cognitive developments also appear to be comparable between the two species, if the standard correction for maturation rates is applied. For 3-month-old monkeys, learned delayed nonmatching to sample (DNMS) is about four times more difficult than the concurrent discrimination (CD) task, as is the case for these two tasks with 12-month-old human infants (Overman & Bachevalier, 2001). This is attributed to earlier development, in both species, of the procedural memory system of the basal ganglia than the declarative memory system of rhinal and orbitofrontal cortices.

The transition around 20 weeks occurs in the context of weaning, with major shifts in the mother–infant relationship (Hinde & White, 1974). Prior to 6 months, monkeys cannot solve abstract problems like learning set, but after that they can, although they do not achieve "adult" levels of performance until they are 2 years old (Harlow, 1959). Similarly, both species improve in the DNMS task at roughly equivalent ages: 6 to 12 months for rhesus young and 18 to 32 months for human infants (Overman & Bachevalier, 2001).

Chimpanzees, compared with rhesus monkeys, develop more slowly. They, and possibly the other apes as well, are much closer to man in the rate of their development, at least in some of their psychological abilities. The initial stages in ontogeny of man and chimpanzees are similar, as witnessed for instance by a comparative study of the fetal development of the skull (Starck, 1973). Chimpanzees are born relatively helpless and remain dependent on maternal holding for about the same period as human infants (Plooij, 1984, chap. 3). They cannot support themselves for more than seconds at a time (Bard, 1995a). The mother can safely stop supporting or "securing" her baby after 2 months (van de Rijt-Plooij & Plooij, 1987). In contrast, rhesus monkeys may be walking in the first days after birth. On the other hand, chimpanzees can hold their head in the pull-to-sit test within the first month, and shortly thereafter are able to sit with support (Bard, Platzman, Lester, & Suomi, 2001; Riesen & Kinder, 1952). They locomote independently by 5 months, climbing, or walking on hands and feet.

In visual development, chimpanzee newborns, unlike human newborns, see as well at 60 cm as they do at 25 cm. However, chimpanzees are closer to humans than to monkeys in the rate of development of visual acuity in the first year of life (Bard, Street, McCrary, & Boothe, 1995).

It is clear that there are strong environmental influences on development of self-regulation in chimpanzees, as there are in human infants. Chimpanzee newborns raised in a human nursery are able to maintain a quiet and alert state for minutes, but when raised by their chimpanzee mothers they are less able to regulate the attentive state than are human infants (Bard et al., 2001). They may develop the ability to regulate behavioral state more quickly than do human infants. Thus, they do not express colic, even though they have clear peak in fussiness at around 6 weeks (as do human infants; Bard, 2000).

In contrast to the case for the motor system, when one compares socioemotional development in chimpanzees and humans, there are comparable milestones, with chimpanzees being only slightly earlier (Bard, 1998; Veira & Bard, 1994). Chimpanzees smile, or show a "playface," to familiar sights and sounds around 4 weeks of age. They laugh in response to tickles in the second month of life. Fear of strangers occurs around 5 to 7 months (mean of 6.2 months in a sample of 16 nursery chimpanzees; Bard, 2000). Four free-living chimpanzee babies were observed to show stranger-anxiety for the first time in month 8 (van de Rijt-Plooij & Plooij, 1987), this being identified as the "fear of losing mother" (Escalona, 1968) as opposed to "fear of strangers." It appears that chimpanzees show a similar distribution to human infants in the quality of attachment with favorite caregivers (with predominantly secure attachments, some resistant attachments, and very rarely avoidant attachments; Bard, 1991b). Moreover, the pattern of development of social cognition is strikingly similar. Chimpanzee newborns imitate facial and vocal expressions (Bard & Russell, 1999), and exhibit social referencing at the youngest ages tested, additionally exhibiting empathetic responses and spontaneously showing objects to favorite caregivers, requesting the sharing of attention to objects for no other reason that to attract mutual interest (Russell, Bard, & Adamson, 1997). Self-recognition is evident in the mirror responses of 28-month-old chimpanzees (Bard, 2003, in prep.; Lin, Bard, & Anderson, 1992). Complex social communicative skills, such as requests for grooming or modifying communicative signals in response to social partners with different skills, are not functionally in place until after the first year of life. More complex cognitive abilities evident in the ability to hunt cooperatively, with knowledge of reciprocity in hunting roles and proportioning of the meat in the group when an individual is successful, may develop only in mature adulthood. Boesch and Boesch-Achermann (2000) argued that this is the best evidence for a sophisticated theory of mind in wild chimpanzees.

Plooij (1984) compared the sequence of developmental phenomena for chimpanzee and human babies and found a striking resemblance: In chimps, "blind rooting" disappeared from the age of 6 weeks onward and was replaced by "going straight on the nipple." Rooting had completely disappeared by the age of 12 weeks. Making faces, including "playface-half" and moving mouth parts, emerged from the age of 6 weeks onward. The first clumsy grasp with an enormous overshoot was observed at age 8 weeks. Around the age of 2–3 months, a shift takes place from reactions to an intensity-change of nonspecific stimulation (a sudden change in stimulus intensity in any one of a wide variety of stimuli) to a selective responsiveness to specific (calls and sight of members of the own species) stimulation. A sudden and short-lasting increase in the interest in the face of the mother was observed around age 3 months. A selectivity in behavior toward other individuals than the mother was observed between the ages of 4–7 months. A preference for other infants over adults was observed at the same age. The first clear-cut aversive reaction to strangers was observed at age 7 months. Infants from the age of 8 months onward were observed to follow other individuals who interacted frequently with the infant, such as a sibling, an uncle, or a grandmother, while whimpering (multiple attachment). From age 7 months onward, no behavior was observed to indicate that out of sight was out of mind; infants from this age are concerned with the distance of their separation from their mother. It is only toward the end of the second year that infants can be observed to go "on excursion" for some time. From age 9 months, infants are occupied in experimenting with manipulating relationships such as "against," "on top of," "into," "behind," and so forth. At the same age, the social gesture of "begging" for food was observed for the first time. From 11 months, requests for grooming and requests for a play-tickling session were observed.

CONCLUSIONS: PROCESSES OF MENTAL DEVELOPMENT BEFORE LANGUAGE

Constructivist developmental theory prompts a search for evidence that, in their psychological processes, infants progress from an initial unintentional reflex state, lacking all mental images, through sensorimotor stages involving only schemata for separate momentary objects, to conceptions of objects with permanent existence and identifying features and properties. Motor skills and memories are built up, according to this theory, from physiological reactions, possibly with emergent dynamic transformations at particular ages. A cognitive theory may add modules of information processing and memory formation, from procedural (or private) to declarative (or socially shared), but the concept of a consciousness and purposefulness that is acquired from experience is retained.

Any such theory is difficult to reconcile with what is known about how brains develop, and the evidence that infants' curiosity and emotional responses undergo systematic age-related developmental phases, which affect their perceptions, concepts, memories, acquired knowledge, and skills.

Laboratory tests of infants' attention, perceptual preferences, learning and habituation, and their willingness to investigate and negotiate situations to discover desired objects, have yielded much information on growing awareness of the appearances and uses of things and memory for past events. The tests employ situations where the infants have restricted mobility and choice of experience, and the stimuli are artificially contrived to generate contrasts between theoretically important configurations or sequences of physical event, or models of objects that adults perceive as in different verbal or conceptual categories. It appears as if the reported developments are gradual, and individuals differ in the speed and course of their development. However, most studies do not make longitudinal measures that are capable of detecting rapid age-related changes in motivation or ability. Nevertheless, some agreement has been reached about a few highly significant developments that take place around particular ages in the first 2 years. It seems likely that changes measured in information-processing attention, perceptual discrimination, memory, and categorization may be coupled by motivations and emotions developing in the infant, which have usually not been studied.

Possibly, the brain functions in infancy in such a way as to regulate two phylogentically ancient complementary motive states of an animal organism, or states of commitment to engagement with environmental resources—one trophotropic, or contributing to the maintenance of organic functions and bodily well-being, the other ergotropic. In the human, the latter seeks experience to build efficient anticipatory cognitive systems that will exploit situations and objects, make adaptive actions, and store memories of how behaviors are to be executed and what affordances of objects they should seek in perception. Communicative functions of the conversational and cooperative kind should serve to integrate these two, and, further, in infancy, especially, the signaling of interpersonal interests and responses to attentions of other persons will be elaborations of autonomic or self-regulatory motor activities. Mammalian self-regulation by emotions (Panksepp, 1998, Table I) and the emotional motor system (Holstege et al., 1996) are evolutionary successors to the autonomic regulatory systems of lower vertebrates (Porges, 1997). They have special vitality in the kinds of creative and adventurous behavior known as *play,* which all agree functions to promote development of experience, body coordination, and social relations (Bekoff & Byers, 1998). Play is richer and more intense, and lasts longer in development, in highly social species.

Figure 8.7 is an attempt to show how oscillations between states of motivation respectively dominated by environment-exploiting ergotropic and self-sustaining trophotropic goals might relate to the transitional events and regressions charted in the first year of infancy. There are periods when the infant is less willing to engage the environment adventurously and with exploratory curiosity, and is more restless and susceptible to complaining or seeking proximity with a caregiver. It is also evident that the willingness of the infant to attend to and communicate or cooperate with a companion's consciousness undergoes similar fluctuations. These effects cannot be explained as simply emergent from fertile chaos in complex systems of biomechanical, sensorimotor or cognitive processing, nor are they linear products of a progressive learning process that increases a memory story of objects and meanings. The growing brain retains intrinsic, embryogenic control over when and how new be-

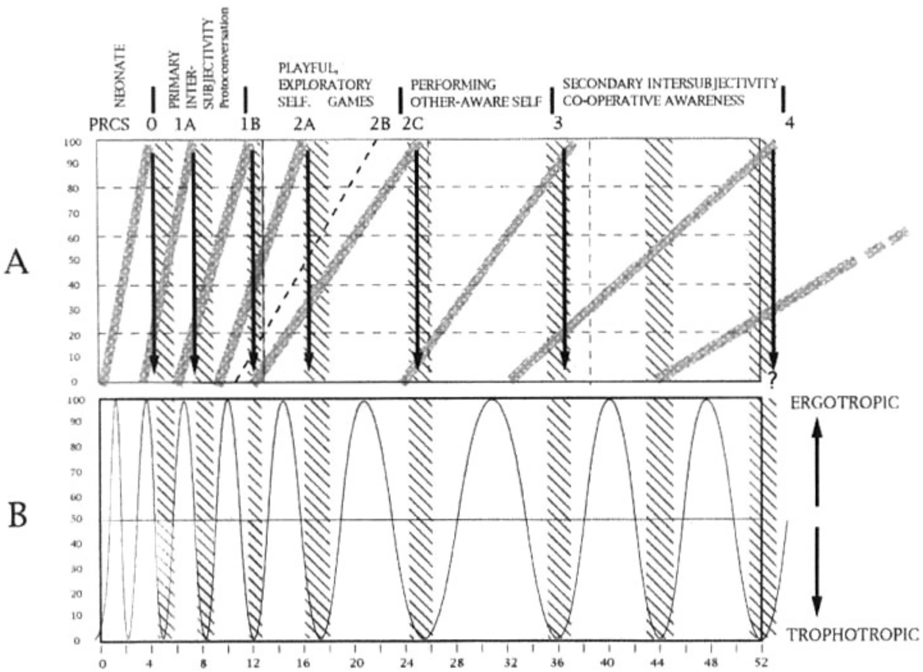

FIG. 8.7. Hypothetical oscillations in states of motivation for behavioral engagement with the environment (ergotropic) and self-sustaining regulations (trophotropic), which may explain observed transitions in behaviors of infants in the first year.

haviors will appear, and how they will exploit different forms of anticipated support from the environment.

Biodynamic Systems, Self-Regulation, and Adaptive Use of the Environment

All nature is composed of dynamic systems and many of these are very complex. This was known by ancient Eastern philosophers, and by Herakleitos in Ancient Greece. Like them, the English philosopher Whitehead (1925) emphasized the "organismic" processes of "dynamic self-organizing" in nature, including human nature. Maturana and Varela (1987) called it "autopoesis." The idea is not new.

Among the most complex of dynamic systems are those that have life. Complex dynamic life systems self-generate processes and patterns that prove to be stable and prophetically adaptive in varied contexts or environments. At no point in their existence, even in the zygote, is a living organism either simple or static. The generation of quasi-stable states and functions depends on the initial state; that is, on the forms of components and potentialities for interaction among them that came into being in the past, and act in the present as intrinsic constraints on the emergent attractors that influence the developmental process in its future. Like obedient, well-educated sheep dogs, they prompt each of the many spheres that run like a flock of sheep down the Waddingtonian epigenetic landscape to take one or other channel of opportunity, leading them to differentiate into specialized components of a functional complex. Fundamental time–space dimensions of the process are determined intrinsically and antecedently, and the emergent context in an external environment determines the idiosyncratic shape of the developmental outcome, accelerating or retarding the generation of effective functions by growth. These are the "future sensing" adaptive features that make life hard to model.

Similarly, "crystal forms" emerge (become integrated) from the properties of their constituent molecules in a large homogeneous population (Kauffman, 1993). The process of development depends on the energy level of the molecular population, which in turn draws on external energy sources. Animal bodies and brains are self-organized as individuals from the coherent molecular and supra-molecular structures and processes that are initiated in fertilized eggs. Human minds emerge in utero from intricately organized tissues and organs of embryonic and fetal bodies and brains. Children's minds develop their psychological properties in dynamic and reciprocal engagement with other more mature minds, their conscious purposefulness co-constructed in a system that is constrained by this intrinsic antenatal inheritance in the children, as well as by the intuitive responses of the adults, which are adapted to recognize and assist the children's motives for growth and learning (Maturana & Varela, 1987; Varela, Thompson, & Rosch, 1991). None of these developments can be understood as emergent only from the present circumstances in which the adaptive system, or any one part of it, finds itself and acts. The process of developmental construction is always effected with active and directive involvement of the whole living system that functions as a coherent adaptive "agent." The development is coherent in space and time because its substances and processes are continuously integrated from the past into the future through a progressive elaboration of quasi-stable states.

Inherent dynamic life functions of plants and animals cause them to grow, behave, and develop in consistent forms and life histories, despite variation in the environment in which they live, provided that variation is not so extreme as to threaten life itself. An obvious manifestation of this internal determination is the form and sensorimotor organization of a body that makes each species a distinct morphological kind, with implicit way of life or habit adapted to sense, use, and learn from the ordinary natural circumstances of a particular habitat (A. R. Damasio, 1999; Greenough & Black, 1992; Varela et al., 1991). Transmission of species-specific forms and habits is genetic—dependent on the replication of developmental determinants in the form of genes. But even in the zygote, or most elementary one-cell developmental stage, gene action depends on the already determined organization of the extra-genic cell soma, and the properties of nongene molecules in it. The life form and its developmental fate cannot be equated with, or reduced to, its DNA, even at this first stage.

Psychological adaptations of animals depend on perceptually guided movements—on the form of a muscular body that will move in adaptive ways to excitation from the brain, and on the form and functions of a nervous system that will integrate sensory perceptions in the body and of the environment with the purposeful actions that seek sensory confirmation, making emotional adjustments to regulate the outcome (A. R. Damasio, 1999; Panksepp, 2001). The body has two complimentary functions—it must sustain its continuing vitality and well-being, and it must engage with the habitat to obtain essential resources. Individuals may behave to collaborate in either or both of these functions, by which the inherent life activities are sustained through their separate and interacting developments (Fig. 8.2).

How "Plastic" Are the Minds of Infants?

Infancy is a preparatory stage of the human life history in which a fragile creature is supported in its initial growth and learning by parental care, and *through its own agency and learning* it begins to imitate a unique cultural intelligence that will learn to exploit categories of knowledge and skills acquired by the behaviors and inventiveness of past generations. The whole process of cultural development through many generations of human historical time, and many centuries of cosmic time, depends on innately generated mental time by which the actions of every individual are regulated, and through which individuals collaborate in shared narratives of consciousness in which acquired ideas and objects are re-cognized and re-presented to make social sense. The innate brain-paced motives of the young that enable them to collaborate in action, awareness, and learning with older individuals are an essential part of the motor that drives this progress of human consciousness of meaning from generation to generation.

The first 18 months of a child's life normally see the cultural imitation—of roles, manners, symbols, tools, myths, and institutions—well on its way, with little use of language. The mimesis of human understanding is a foundation for representations in words, not a by-product of language. It demands intense cooperation between generations, in awareness, in action, and in imagination. In their early stages, the motives that regulate this cooperation demand intense negotiation of purposes and concerns between parent and child, so their emotional attachment can, as Darwin put it, "guide the child along the right path" (Darwin, 1872/1998, final paragraph).

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9

The Trilogy of Mind

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The studies in Spain, England, and Sweden (chaps. 2–4, this vol.) have shown that the phenomenon of age-related regression periods can be replicated in other countries and cultures. Multimodal distributions in other phenomena (e.g., illness and SIDS) are also quite likely to exist, with peaks around the same ages as those of the regression periods (chaps. 6 and 7, this vol.).

The evidence presented herein provides good support for the claim that age-related regression periods exist, and for the conclusion that their existence should be taken into account whenever developmental processes in infancy are discussed.

Some people might think that the number of regression periods found in the original study (van de Rijt-Plooij & Plooij, 1992; 10 in the first 20 months of life) is high and this is unexpected and difficult to explain. Admittedly, so many regression periods were not expected and the findings came as a surprise. However, the data were firm, and they have been replicated.

Intrinsic changes must be going on at times when infants are so grumpy, difficult in temperament, demanding of parental attention, and vulnerable. Chapter 8 (this vol.) has shown evidence that age-related brain developments are at the core of at least some of these intrinsic changes in motivation, but, of course, no single anatomical or physiological event can explain any such change—there is a complex interplay between the central nervous system, the immune system, and the endocrine system in regulation of emotion and temperament at any age (Ader, Felten, & Cohen, 2001).

To prevent misunderstandings, first some clarifications of past research and suggestions for further research need to be made. Thereafter, strategies in the quest for underlying processes and models of these processes are discussed.

SPECIAL CONDITIONS AND "NOISY" DATA

The questionnaire data on the regression periods may produce a "noisy" signal and it is important to filter out this noise to get a clear signal of general developmental trends (chap. 3, this vol.). It is difficult, under some conditions, to observe the phenomenon of regression restricted to particular periods, because similar regressive behaviors can be observed when the baby experiences stressful life events, such as parental divorce, going to the day-care center for the first time, holidays, switching between caretakers, or when the baby is ill. Similarly, the differences found in various countries (e.g., the "weaker" effect seen in the Swedish sample as described in chap. 4) may be reflecting differences in lifestyle and culture of infant care. This is a topic for further study.

In a similar vein, it is interesting to study how other special conditions in families influence the way regression periods express themselves. One could think of twins, children with Down syndrome, parents with psychic problems such as postnatal depression, other major life events, daily hassles, stress, and a chaotic way of life. For instance, in a preliminary study of three pairs of twins (one monozygotic and two dizygotic twins), it appeared that the twins alternated their difficult behavior: When one was difficult, the other was not and vice versa (van de Rijt, 1992, personal communication). It seems that twins react to each other. This is a topic for further research.

Direct observation measures of the regression periods have been shown to be influenced by the context (chap. 5, this vol.). For instance, measures of body contact are changed by a variety of circumstances from something as simple as the parent encouraging the child to walk bipedally alone ("come to mommy"), to more complex, special parental conditions like postnatal depression, phobias, and the administration of rigid sleeping-, contact-, and feeding-schedules. Needless to say, such special conditions have to be taken into account in direct observations studies.

Consequently, it is clear that the phenomenon of age-related regression periods can best be observed in a baby when there are no unusual perturbations in family life and maternal care and when the social and interpersonal conditions in the family are rather stable and consistent over the period examined.

STRATEGIES IN THE QUEST FOR THE UNDERLYING PROCESSES

A central role can be assigned to age-related regression periods in the quest for the processes underlying psychological development of the human baby. On the one hand, there is the link with brain changes. On the other hand, each regression period signals the start of a period of developmental progress and the emergence of new skills, task performances, and behaviors. The age-related regression periods stand out as lighthouses to direct the study of developmental change.

Age-Related Brain Developments

In chapter 8 (Trevarthen & Aitken), a review of the literature on the human, prenatal brain development finds evidence for a predictable, gene-regulated spatiotemporal history of the adaptive motive systems of the mind. It is evident that such a development does not stop at birth and age-related brain developments occur from infancy to senescence. However, the search for the causal processes in brain development is frustrated by the limited information available. Apart from the six age-related brain developments reported by Fischer and Rose (1994), no new developments were found other than the growing recognition of the importance of subcortical regions in the regulation of the structure of the neocortex. More information is needed on week-by-week anatomical and physiological changes through early childhood, especially for the subcortical motivating systems that regulate cortical growth and modification. Further progress is to be expected from the application to infant development of the new, noninvasive technique called "continuum mechanical tensor maps" (Thompson et al., 2000). So far, this technique has been applied to children from ages 3 to 15 years. The technique creates four-dimensional, quantitative maps of growth patterns in the developing human brain with far greater spatial detail and sensitivity than previously obtainable.

New Skills, Task Performances, and Behaviors

There is no simple one-to-one relation between new skills, task performances, and behaviors on the one hand and the age-related regression periods on the other. In the past, developmental psychologists tried to establish a temporal link between brain maturation and the so-called developmental milestones. They failed. The developmental milestones did not appear to be age-related. Developmental psychology has shown abundantly that children may show huge individual differences of many months in the age of first appearance of some milestones (Rosenblith, 1992).

This is understandable in light of the following. What develops are not the new behaviors, skills, or task accomplishments, which are manifestations of underlying processes after interaction with the environment, but the underlying processes themselves that lead to the learning (Campbell & Bickhard, 1986). In similar vein, Elman et al. (1996) argued that such *overt* changes in dynamical systems are not a clue to fundamental *internal* structural change, but simply the outcome of a single process resulting from the interaction between the aforementioned constraints or internal organization and the structure of particular types of input.

Bickhard (1992) emphasized the necessity of models of unobserved processes in explaining learning and development, in order to avoid the trap of having descriptions of behavior become explanations of learning and development, and (if they are transition theories) the necessity of mechanisms depicting the movement of systems from one state to another. (In light of this, it is striking that recent studies of developmental transitions are limited to a description of the emergence of concrete, observable skills and the movement of systems from one state to another without providing a real explanation by offering a model of those systems.)

In the quest for the underlying processes, the only information available is description of overt behavior, but such descriptions cannot be used as explanations of learning and development. This creates a dilemma.

A partial solution to this dilemma may be to restrict the study to the earliest possible age at which a new behavior, skill, or task performance was ever observed. This is what was done in chapter 8 (Fig. 8.7), where the age at which a shaded regression line (summarizing a period of rapid change, PRC) crosses the *x*-axis tends to co-occur with a (trophotropic) regression period. From this earliest possible age onward, each baby could have developed the skill, behavior, or task performance. The reason why one baby does so immediately and another baby does so at a later age depends on the circumstances, and these are not of interest at this moment.

Another part of the solution for this dilemma has to do with the commonalities underlying behavioral development. By finding out what various new behaviors, skills, or task performances that emerge after the same earliest age have in common, one may find out what underlying process is involved. For instance, Diamond, Werker, and Lalonde (1994) argued that the "perception of or memory for temporal order" (e.g., the order in which things or events occurred) is one example of such a general ability underlying the development of object search, detour navigation, categorization, and speech perception.

In the search for such commonalities, keep in mind that perception and cognition have become organized through phylogeny and are recapitulated in ontogeny around emotional drives that serve as primitive and fundamental forces (Luciana, 2001). After each "earliest possible age," it is necessary to search for the commonality in the purposes, goals, or rewards the baby is seeking. This is not an easy task. These regulatory processes, are so to speak, "hidden" (Hofer, 1978). Golani (1976) showed that chaos seems to be present in the observed behavior as long as one does not know what an animal is after. As soon as this is known, the same overt behavior appears orderly. There is a chicken and egg problem here. Ideally, a researcher would like to have some idea about what to look for in order to facilitate finding the order behind the seemingly chaotic behavior. Therefore, it might be fruitful to go forward and backward between observational data and models of the underlying processes.

For the sake of stimulating future research, the remainder of this chapter indulges in some speculation on models of the processes underlying the phenomenon of age-related regression periods.

MODELS OF UNDERLYING PROCESSES

Scheerer (1989) described the history over centuries of the trilogy of mind, that is, cognition, affection, and conation, or thinking, feeling, and desire (or appetite, or willing). All three fell into disgrace at times, only to revive again after some time. For instance, there was the well-known "cognitive revolution" following developments outside of psychology, such as communication theory and computer science (Scheerer, 1988). Once cognitive theorizing was considered proper and compatible with scientific methodology again, psychologists discovered in the history of their field that prebehaviorist psychology had been cognitive all along.

Likewise, there has been a "volitional revolution," according to Scheerer (1989). Certainly, there was the work of Powers (1973a, 1973b, 1978) and associates who defined volitional action to deal with intended, self-controlled input. They revived the notion of man as autonomous and turned their backs to the concept of man as automaton.

And recently, there was the "affective revolution" (Panksepp, 2003), which argued that "primitive affective and motivational processes may well have been foundational for the emergence of many cognitive processes in brain evolution" and that "cognitive abilities have co-evolved with affective processes in many higher regions of the brain." Therefore, Panksepp proposed to rename the field into "Affective neuroscience of cognitions" instead of "cognitive neuroscience."

Now that the three pillars of the trilogy of mind have been rediscovered, one should beware not to lose any one of them. Ideally, any model of processes underlying development should integrate the best of three worlds. Some of the models discussed may limit themselves to only one or two pillars and do not live up to this ideal. Nevertheless, they are mentioned to illustrate a certain way of thinking.

Based on the previous commonalities in new skills, task performances, and behaviors, shortly after the earliest possible age Plooij (1984) and Plooij and Van de Rijt-Plooij (1990, 1994) suggested a number of hierarchically ordered perceptual systems or "types of perception" to emerge one after the other at specific ages (see Fig. 9.1), accompanied or followed by regression periods and an adaptation to the new "world of perception" through a new type of learning. The emergence of each new type of perception is age-related and predisposed or triggered by regulatory or motivational changes in the brain. Perception is not considered to be a passive process where the outside world is impinging on a person (controlling variables), but an active search for and control of a certain type of input (controlled variables). Each new perceptual world is similar for all children. However, babies explore a perceptual world in their own, unique way. One baby may attend to social skills first. Another may start at skills in the motoric domain. And yet another may be a champion in preverbal skills. The way each new type of perception is worked out into new skills and performances in interaction with the caretakers is highly variable from individual to individual and, consequently, so are the ages at which new skills and performances appear.

The types of perception that develop one after the other are described in Van de Rijt and Plooij (1992, 1994, 1996, 1997, 1999, 2000, 2003) and are illustrated with many examples of naturalistic observations of infants in the home environment. These examples are not restricted to any domain and cover topics as diverse as social and personality development, preverbal development of communication, and motor development.

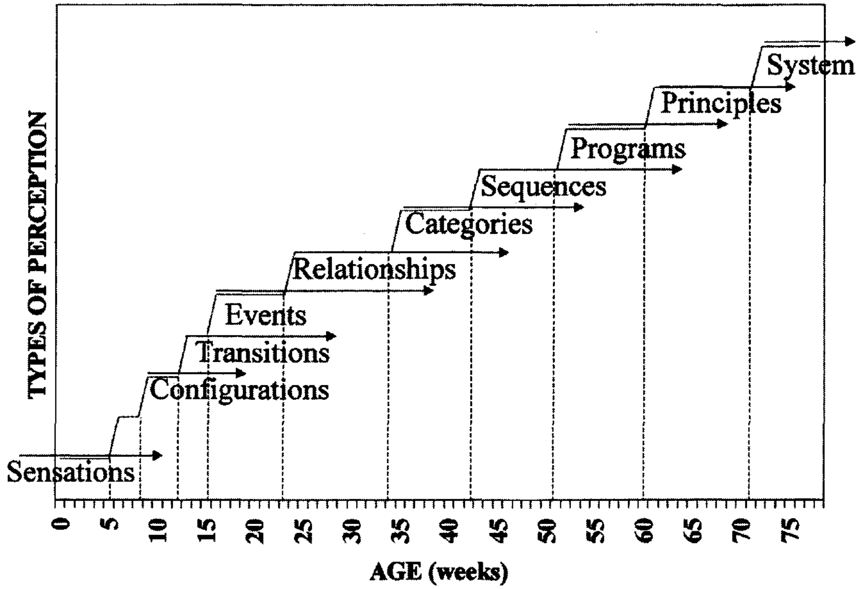

FIG. 9.1. Ages at which various types of perception emerge during the sensorimotor period of development.

Similar ways of thinking about (part of) the processes underlying human development can also be found in the literature, as witnessed by the following examples:

> Ontogeny is not a random walk through an unpredictable life course mysteriously reaching an apex in the adult form. The development of organisms has been shaped by a long process of natural selection acting upon individual ontogenies, resulting in a species' life history (Surbey, 1998).
>
> Smotherman & Robinson (1990) view ontogeny as a process that incorporates adaptation to a succession of niches. This predicts that disruption in behavioral organization will occur during the period of adjustment that immediately follows a sudden transition to a novel adaptive mode.
>
> Brazelton's (1992) 'touchpoints' come very close to the above mentioned regression periods. Where the latter stem from naturalistic observations in the home environment, the touchpoints were observed in a clinical setting. Touchpoints are universal and occur just before a surge of rapid development. During such touchpoints the baby's behavior falls apart shortly.
>
> As Gould & Marler (1987) argued, a species which is so very dependent on learning in its long and vulnerable development should at least know what aspects in

its environment to attend to at what age. Otherwise it is utterly impossible to create order out of chaos. They talk about 'learning instincts.'

Elman et al. (1996) have pointed out that some innate predispositions—mainly architectural and chronotopic—channel the infant's attention to certain aspects of the environment over others. They describe babies as actively selecting their environment by choosing what they will attend to and even where they will be and what they will do. Children have their own agendas and their behaviors are typically goal-oriented. The question is where these goals come from. These authors do not believe that the many basic goal-oriented behaviors are learnt or taught. Some problems are too difficult to be learnt anew in each generation. Rather, provisional solutions to them have been evolved during evolution.

A central message of evolutionary psychology, according to DeKay & Buss (1992) is that the enormous flexibility and context contingency of human behavior requires a highly articulated, extremely complex architecture of dedicated, species-typical psychological mechanisms. Without those mechanisms to guide action, the islands of adaptive solutions could never be discovered amid the expansive oceans of maladaptive possibilities.

A major reaction to Piaget's account and the accounts of contemporary connectionists is the charge that they do not offer a concrete account of representational change. Integrating neural, cognitive and computational perspectives, Quartz (1999) suggests the evolution of robust, flexible developmental strategies for dealing with a dynamic environment where intrinsic developmental programs interact with activity-dependent neural growth mechanisms to construct a hierarchy of representations underlying mature skills. The intrinsic developmental programs direct the developing system towards certain classes of stimuli. In our opinion Quartz' classes of stimuli are synonymous with our "types of perception." According to Quartz, "cortical areas closer to the sensory periphery encode lower-order, or more elementary, representations than do areas further removed, which involve more distributed networks lacking the topographical organization of lower areas." In the three modalities vision, touch and audition a hierarchical stacking of perceptual memory categories can be observed in progressively higher and more widely distributed networks (p. 455). "This hierarchical organization of representations combined with its hierarchical developmental pattern lends support to the view of development as a cascade of increasingly complex representational structures, in which construction in some regions depends on the prior development of others." In our opinion Quartz' notion of representation construction is synonymous with our notion of adaptation to each new "world of perception" through a new type of learning, where each new type of perception is worked out into new skills and performances.

Quartz' so-called "neural constructivist" approach strongly reminds one of another functional model of the human nervous system which has been around for a long time (Powers, 1973a). The negative-feedback model is described in the Hierarchical Perceptual Control Theory (HPCT) (Powers, 1979, 1998; Robertson & Powers, 1990). Perception instead of behavior plays a central role. Behavior is the control of perception, the model says, and not the other way around. This model, is made up of a number of hierarchically ordered levels of "search for" or "control of" perception. There is a striking similarity between the "types of perception" we found and the levels of perception as described in the HPCT-model.

Based on a comparative study of primate play behavior, Lewis (2000) suggested that different types of play may have evolved at different stages in evolutionary history, to allow the development of distinct regions of the brain. In our opinion the types of perception and types of learning we suggested to emerge during development express themselves in analogous types of play.

One may wonder what the intrinsic, gene-regulated changes in the brain or the intrinsic developmental programs look like. According to Buck & Ginsburg (1997) simple creatures are controlled by the genes, more complex creatures are cajoled by the genes (to cajole means: to persuade with artful flattery or false promises; to coax, to wheedle). The means by which the genes exert their persuasive influence involve primary motivational-emotional systems *(primes).* Primes are based on genetically structured neurochemical systems. Neurochemical systems involve neurotransmitters, with their agonists and antagonists, and neural structures, including neural networks and synapses (transmittal and receptor systems for neurochemicals). Primes in this view constitute "voices of the genes," the means by which genetic influences are actualized or "read out" when activated by effective stimuli. The readout source is the motivation: the potential for behavior inherent in neurochemical systems. The readout process has to do with emotion and is the realization of the motivational potential when activated by challenging stimuli.

The notion of primary motivational-emotional systems is in accordance with the 'Motive theory' (Trevarthen & Aitken, chap. 8, this vol.) that claims that "the first events that set behavior and learning in action during development are attentional (stimulus seeking) and intentional (motor action forming) states, or motives, that are generated spontaneously in anatomically organized brain systems", where the later maturing limbic and neocortical circuits emerge in reciprocal, dynamic and increasing involvement with the core regulatory systems of the Intrinsic Motive Formation (IMF; Trevarthen & Aitken, 1994). According to Aitken & Trevarthen (1997), "the human embryo and fetal brain displays elaborate formation of *intrinsic regulatory mechanisms* that are connected, on the one hand, with the most complex (facial, vocal, and gestural) expressive organs among the primates, and, on the other hand, with the most elaborate reciprocal connections between motivating structures of the core and limbus of the brain and the expanding neocortical system in which post-natal experience will be elaborated. The neocortex is laid down in the late embryo, as a 'proto-map' of rudimentary cell columns, but its dendritic arbors and billions of synapses mature post-natally, and this process is regulated, at every step, by the brain core intrinsic motivating systems. The process of regulated cortical differentiation continues after birth, by sympathetic communication with the social environment, in intimate affective exchanges with more mature persons and their more experienced brains (p. 657).... The 'epigenetic landscape' of Waddington is structured by internal constraints on development imposed by the developing organism itself (p. 658).... A wide range of homologous genes have been identified across mammalian species enabling features that were selected for stability (pp. 658–659).... They specify a potential 'behavior field' around the body into which acts are projected and within which *layouts and goals are defined prospectively by perceptual systems* (italics are mine), and retrospectively by memories (p. 659)."

Most striking in this quoted literature is the theoretical link between the intrinsic motives (or intrinsic developmental programs, or intrinsic regulatory mechanism) and the buildup over development of a hierarchy of types of perception. This goes some way in the direction of an integration of the three pillars of the trilogy of mind. However, none of the quoted literature tried to model this theoretical link, except for Trevarthen and Aitken (chap. 8, this vol., Fig. 8.1) and Powers (1973a, 1998). In his reorganization theory, which is part of his hierarchical perceptual control theory (HPCT), Powers suggested a link that is really a control system of a basic kind: the reorganization system (Fig. 9.2).

When the baby is born, its primary occupation for the next few years will be to develop a hierarchy of perceptual control systems enabling the baby to move around, adapt to, and survive in an environment in which it happens to be born. The problem for the baby is how it can do this in such a way as to meet its real physiological and biochemical needs and maintain its own life support systems. What the reorganization system does is sensing all sorts of physiological intrinsic quantities representing the intrinsic state of the organism (or emotional state), and comparing the resulting intrinsic signals with intrinsic reference signals (or motives) provided by the genetic source. This comparison is called emotional evaluation by Trevarthen and Aitken (chap. 8, this vol.). If a discrepancy results, then intrinsic error signals result that drive the process of reorganization, which alters the existing connections in the hierarchy of perceptual control systems or adds new ones on top of the existing hierarchy. The reorganization process stops as soon as the intrinsic state of the organism conforms to the intrinsic reference signals and, consequently, the intrinsic error signals are reduced to zero. Termination of the reorganization process has nothing to do with a perceptual control system achieving some goal state for its perceptions. It only depends on the physiological effects of carrying out any given behavior. The reorganizing system alters the properties of the behavioral systems that control sensory effects, and only indirectly it controls the intrinsic state with respect to intrinsic reference levels. This solves the "little-man-in-the-head" problem. The reorganizing system should not have any property that depends on the operation of the very hierarchy that is constructed by the reorganizing system. The reorganizing system cannot be intelligent, because it has to work even in tiny infants or fetuses, long before complex intelligence arises in the brain. So, the reorganizing system and the intrinsic motives are primary, the development of the perceptual control systems and cognition are secondary. This is in accord with the notion of subcortical regulation of the later developing neocortex (Trevarthen & Aitken, chap. 8, this vol.), and with the notion that

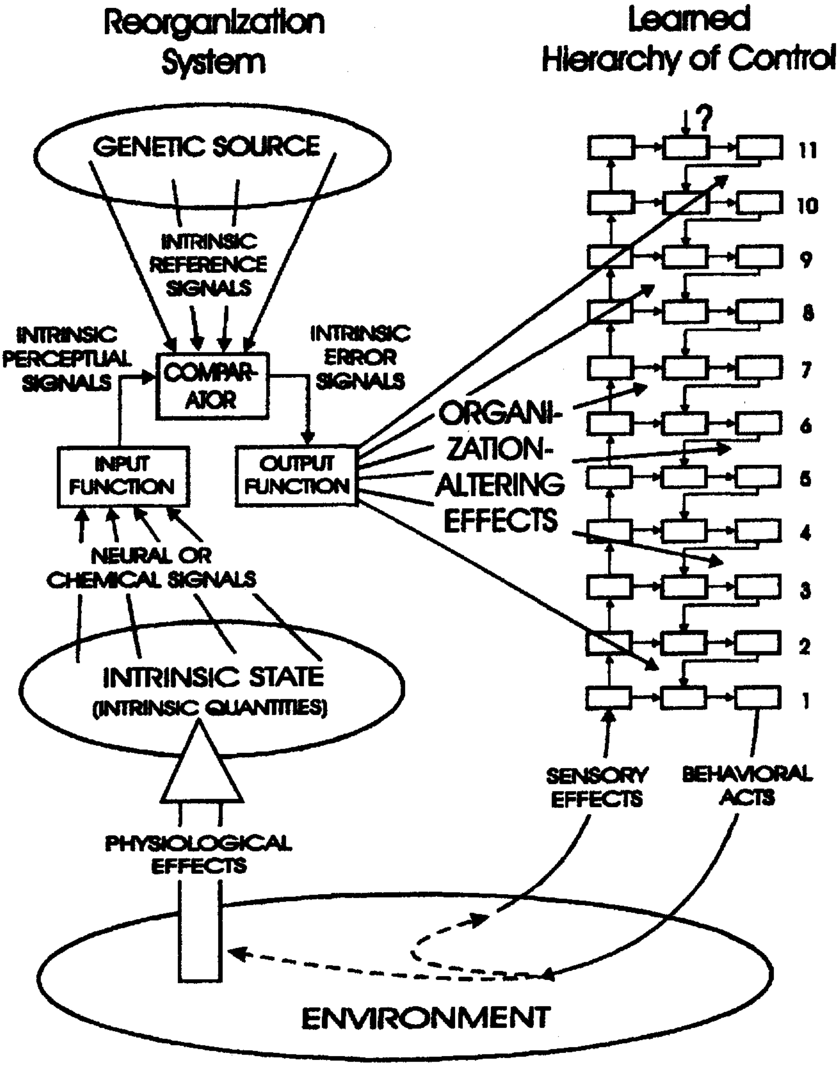

FIG. 9.2. Relationship of the reorganizing system to the behavioral hierarchy and physical environment. The control loop for the reorganizing system is closed via physiological results of behavior, not through sensory effects. (This illustration is based on Powers, 1973a, p. 188. Updated for clarity by Mr. Powers in June, 2002. Reproduced with permission from the author.)

core emotional mechanisms are important in regulating developmental changes (Panksepp, 2001).

Powers (1973a) hastened to add that the reorganizing system described so far cannot be that simple. For one thing, the distinction between sensory and physiological effects of behavior may not be as sharp as presented. The distinction was introduced to make thinking about the subject easier. It may well be that neural signals carrying sensory information involve physiological effects as well that potentially would have an effect on intrinsic state. He gave the example of the "total error signal"; A hierarchy of perceptual control systems in which there was a generally high level of error would be a poorly organized hierarchy in need of reorganization. Ignoring the complications that any such model of a reorganizing system necessarily has at the present state of knowledge, the general idea that comes across is that beside the types of perception representing the external world there is a completely different "perception of perceiving." The operations of the hierarchy of perceptual control systems are monitored or evaluated from the very beginning and the neural connections of the hierarchy are changed when intrinsic reference signals or motives tell the reorganizing output system to do so. In this reorganization process, the trilogy of mind is well preserved.

It was Bruner (1968) who introduced the notion of intrinsic motives for learning. Together with his notion of "the uses of immaturity," this is in accordance with the idea of one intrinsic motive (for a particular type of perception and learning) after the other (for another type of perception and learning) emerging during development. According to Powers (1973a), an intrinsic motive may provide a type of reference level that contains the general idea of a certain corresponding type of perceptions specifying a desired consequence of learned behavior that is independent of what is being learned. Thus, such a type of reference level can be inherited as a useful guide to reorganization without being the "little-man-in-the-head." The claim that these intrinsic motives for learning only contain a general idea without filling in any specifics is nicely supported by parental reports in the studies. According to the parents, their babies "seem ready for something new, but they don't know what."

To illustrate the relation between the general idea of a certain type of perception and the actual skills, performances, and behaviors being learned, one type of perception is elaborated a little further by giving a few examples, without claiming to be exhaustive.

Around 4 months, another regression period can be observed and the perception of "events" is suggested to emerge (Fig. 9.1). Events have a special meaning here and have nothing to do with special occasions. An event is defined as "a short, familiar sequence of lower order perceptions such as 'transitions,' 'configurations,' 'sensations,' or 'intensities'" (van de Rijt & Plooij, 2003, chap. 6). The realization that our experience of life is split up into familiar events is something that adults take for granted. If someone drops a rubber ball, adults know it will bounce back up, and will probably continue to bounce several times. If someone starts a jump up into the air, adults know that the person is bound to come down. They recognize the initial movements of a golf swing and tennis serve and they know what follows. An organism with only the four lower order perceptions of "transitions," "configurations," "sensations," or "intensities" can only control its own position, some external configurations, and movement. Nothing more. It cannot select one movement instead of another. And "although it can make configurations change at controlled rates, it cannot select when and in what combination to produce these changes" (Powers, 1973a, p. 137).

When the fifth-order perception of events has emerged, for the first time babies are able to do such things and they can be observed, among other things, to learn the following skills, performances, and behaviors: a stage transition in performance on a battery of sensorimotor tasks, fine manipulative dexterity, grasping, mouthing, imitation of gestures, hand clapping, attention for movements in the face of others, end of primary intersubjectivity, decline in vocalizations to parents, use of common motion in perception of object unity, "cerebral peep" and regression of vocalization development, babbling, banging, action units, segmented perception, musical phrases, sound events, and/or musical and language acculturation. These are described next.

> A stage transition was found at about 4 months by examining infants' performance on a battery of six sensorimotor tasks weekly as they crossed the age range between 2.5 and 5.5 months. For all tasks, a pass rate of 50% was first observed between 3.7 and 4.6 months, and task profiles showed some evidence of clustering or synchrony. In addition, onset age data indicated intra-individual synchrony in task acquisitions, suggesting discontinuous or spurt-like changes in overall development (Lewis & Ash, 1992). The tasks concerned adjusted reach and grasp, and two types of visual events.
>
> The developments between 16 and 24 weeks, which include not only efficient grasping to hold objects and to explore them in the hand and mouth but also a more deliberate imitation of finger extension and other gestures such as hand clapping, appear to form a natural group of events.
>
> Once human infants have learned through experience about faces at around 2 months, they then behave differently than neonates and prefer stimuli that resemble real faces to the high contrast blob stimulus. Later still, *at around 5 months,* they preferentially attend to the movement of internal features of the

face, suggesting that the infant is learning increasingly more about details concerning the facial characteristics of conspecifics from the subcortical predisposition that makes it attend to face-like objects in the first place (Johnson & Morton, 1991; Morton & Johnson, 1991). The movement of internal features of the face is composed of events.

In spontaneous play mothers and fathers imitate vocal, facial and gestural expressions of infants, and between 8 and 24 weeks the number of head imitations declines as interest transfers to the intentions of other persons' hand movements and hand imitations increase after 16 weeks. In fact, those hand movements are events. At the same age mothers tend to use objects more in play, a change described as a transition from 'person-person games' to 'person-person-object games.' This transition marks the end of 'primary intersubjectivity' (Trevarthen, 1977). As interest transfers to objects, infants vocalise less to their parents after 16 weeks.

The influence of motion is seen at different levels in visual processing of depth information. Four-months-old infants use the common motion, in three-dimensional space, of the visible parts of a partially occluded object as information for the unity of the object. They perceive a partially occluded object as connected behind an occluding surface if the visible parts of the object move together in three-dimensional space. In contrast to adults, common fate is critical for infants' perception of object unity: in the absence of motion, infants do not unambiguously perceive partially occluded objects as unified (Craton & Yonas, 1990).

Schindler (1989) observed a "cerebral peep" in children of 16–18 weeks. This peep typically occurs in regression periods in vocalization signalling the start of a new developmental stage. Although babbling (Oller, 1986: canonical babbling; Stark, 1986: Reduplicated babbling; Landberg & Lundberg, 1989: Reduplicated consonant babbling) is first produced by most children around six months, it may be observed as early as 18 weeks (Koopmans-van Beinum & Van der Stelt, 1986; and personal communication). Only the latter age is relevant for our purposes. Babbling is composed of short, familiar sequence of the same sound element, produced by a short sequence of mouth movements. Thus, babbling consists of events.

Synchronous with their acquisition of babbling, infants also make rhythmic banging of objects they are manipulating, and, moreover, the rhythms of babbling and banging have the same period or interval between the repeated movements. They are paced by the same intrinsic clock.

Just as these repeated movements are structured in time, human action is segmented in relatively narrow time windows of a few seconds at the first level of goal-oriented behavior (Kien, 1994; Kien & Altman, 1995; Schleidt & Kien, 1997). This is a universal phenomenon in human action which has its beginning around the age of 4 months. Phrases of speech carrying a semantic content and divided by pauses all fall within the time domain of a few seconds (Schleidt & Kien, 1997). Different mammalian species show comparable segmentation of a few seconds in their movement patterns. This is a compelling indication that similar neuronal processes underlie the generation of mammalian movement.

Adult human perception is similarly segmented in time spans of approximately 3 seconds (Pöppel, 1997). This is illustrated by the following findings, taken from Schleidt & Kien (1997). Segmentation on the order of a few seconds was first discovered in human perception by psychophysical studies that provided evidence of "short time constants."... Time estimation up to 3 seconds is rather good, after that it becomes quite bad.... A Necker cube tends to alternate with a peak around 3 seconds.... Western television directors (and video and film editors)—probably unconsciously—use time spans of mostly 2–3 seconds to structure film events, no doubt reflecting the preferences of the television viewers.... Human perception is not continuous but in discrete quanta.... Other authors have also suggested that the inflowing information is broken down into a string of sequential units (Fodor et al., 1974; Fraisse, 1957; Garner, 1974). Michon (1977, p.191) writes about "the concept of psychological *present.*"... And, last but not least, most of the musical themes in the music of Haydn, Mozart, Beethoven, Brahms, and Mahler are in the range of a few seconds.

The latter example brings us back to babies. Infants as young as 4.5 months are sensitive to the integrity of musical phrase structure (Trehub & Trainor, 1990). Infants were presented with a listening choice between Mozart minuets with pauses between the phrases or within such phrases. The infants exhibited listening preferences for musical samples that preserved the appropriate musical phrase structure (i.e., between-phrase pauses), while they had not been familiarized with the original or intact sequences. The same authors report that some parallels are evident in recent research on running speech. For example, infant-directed speech that is manipulated by the insertion of pauses within clauses disrupts infant attention more than pauses inserted between clauses, an effect that is absent in adult-directed speech. Krumhansl & Jusczyk (1990) used a visual preference procedure to examine 6- and 4-month-old infants' sensitivity to phrase structure in music. Sections of Mozart minuets were divided into segments that either did or did not correspond to the phrase structure of the music. Infants in both age groups listened significantly longer to the appropriately segmented versions. Their behavior accorded well with judgments of the same materials made by adults, suggesting that protracted musical experience may not be necessary to perceive phrase structure in music. 4.5-Month-olds preferred to listen to their own names over foils that were either matched or mismatched for stress pattern (Mandel, Jusczyk & Pisoni, 1995). The results indicate when infants begin to recognize sound patterns or sound "events" of items frequently uttered in the infants' environments.

Musical acculturation from infancy to adulthood was studied by Lynch, Eilers, Oller & Urbano (1990) by testing the abilities of Western 6-month-olds and adults to notice mistunings in melodies based on native Western major, native Western minor, and non-native Javanese pelog scales. Results indicated that infants were similarly able to perceive native and non-native scales. Adults, however, were generally better perceivers of native than non-native scales. These authors suggest that infants are born with an equipotentiality for the perception of scales from a variety of cultures and that subsequent culturally specific experience substantially influences music perception. The support for this "innateness" hypothesis challenges the antithetical hypothesis which suggests that Western scales should be inherently easier to perceive, because their intervals approximate small-integer frequency ratios. In similar vein, children appear to settle on the mothertongue's repertoire of sounds within half a year of birth (Kuhl, Williams, Lacerda, Stevens & Lindblom, 1991). It is equally possible that the equipotentiality for the perception of scales from a variety of cultures is based on the "innate" motive to learn (sound-) events emerging around 4 months instead of birth, giving the infant a "general idea" of what perceptions to seek.

This exercise in reinterpreting existing literature could be repeated for the other types of perception—such as the perception of longer sequences which, according to Diamond et al. (1994), underlies the development of a list of other skills—but lack of space makes it impossible to do that here.

HPCT was applied successfully from robotics (control of a multilegged robot, Kennaway, 1999; object recognition, Young & Illingworth, 1999) to animal behavior (Cools, 1985) and in various domains of human behavior from lower levels of perception (e.g., the accuracy and reliability of predictions generated by the HPCT model: Bourbon, 1996, Bourbon, Copeland, Dyer, Harman, & Mosely, 1990; physiological correlates of behavior: Bourbon, Johns, & Nussbaum, 1982; physiological stress as the result of frustrated intentions in the form of total system error: Pavloski, 1989, Pavloski, Barron, & Hogue, 1990; ingestion: Johns & Bourbon, 1981; control movements in a tracking task: Marken, 1980; intentional and accidental behavior: Marken, 1982; perceptual organization of behavior: Marken,1986; purposeful behavior: Marken, 1990; degrees of freedom in behavior: Marken, 1991; controlled vs. controlling variables in psychology: Marken, 2001; adaptive stabilization: Powers, 1994; evolution: Powers, 1995; overview and empirical demonstrations: Forssel, 1993, McCord, 1982; movement of the arm: Nussbaum & Bourbon, 1981, Powers, 1999; information processing in the human retina: Zocher, 1999a; and visually guided oculomotor control), to higher levels of perception (e.g., cooperation and mutual interference: Bourbon, 1989, 1990; the impossibility of all linear causal models as explanations for the actions of living things: Bourbon & Powers, 1999; cognition: Bourbon, 1994, 1995; educational research: Cziko, 1992, 1995, 2000; management and leadership in business and industry: Forssell, 1995–2001; cooperatively controlled perceptions and social power: McClelland, 1994; group behavior: McPhail, 1990, 2000; simulating individual and collective action in temporary gatherings: McPhail, Powers, & Tucker, 1992; collective locomotion as collective behavior: McPhail & Wohlstein, 1986; the assessment of children in education and in intellectual development: Ozer, 1979; obsessive-compulsive psychopathology: Pitman, 1987; when statistics are appropriate and when functional models are required, with explanation of PCT: Runkel, 1990).

The fact that 11 levels of perception have been described in HPCT makes one realize that 10 postnatal regression periods might not be all that many after all.

OVERVIEW

The following picture emerges. At gene-regulated ages, intrinsic processes in the core of the brain generate a new motive, directing the baby's attention to a new type of perception. Consequently, disruption in behavioral organization occurs. The baby withdraws from the world, and gets closer to the parent. The baby touches base, so to speak. A regression period has started. A more intensive caretaking spell and social interaction follow, culminating in parent–infant conflict (van de Rijt-Plooij & Plooij, 1993). In the process, the parents have become acquainted with the new motive of the baby and his/her new perceptual abilities. The baby starts to explore the new perceptual world resulting in a new type of learning and, consequently, a progression toward a higher level of independence. The baby works out a set of new skills, behaviors, and task performances typical for that perceptual world. Each baby "selects" the set of skills (s)he likes most. That is the reason why, depending on the personal preferences of the baby and the prevailing conditions of the (social) environment, there may be weeks or even months between one or the other baby learning a particular skill.

When the next motive comes along, the baby enters the next perceptual world, which is one level higher in the representational hierarchy. Then the whole process starts all over again.

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