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Perceptual Development in Human Infants

Perceptual Development: Visual, Auditory, and Speech Perception in Infancy
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The sensory systems are the primary gateway for the enormous amounts of information an infant must acquire to make developmental progress. Although the newborn infant comes into the world relatively helpless, it does come prepared with an array of sensory and perceptual capacities. Of course, these capacities are far less sophisticated than those found in an adult but one could argue that they are more than sufficient to enable the infant to begin to organize and construct a perceptually and cognitively meaningful world. The principal aim of this book is to characterize the nature of sensory and perceptual functioning in the earliest stages of human development. To do so, the various authors in this volume grapple with questions about the developmental origins of specific sensory, perceptual, and cognitive capacities and the possible developmental processes that might underlie the often dramatic changes observed in most of these functions during infancy.

The kinds of questions addressed in this book are part of a more fundamental question: what is the process of development and how can we explain the emergence of a particular behavioral capacity? For example, infants acquire auditory and visual skills very rapidly; whereas a newborn infant opens its eyes only for short periods of time and does not appear to respond in an overt way to other human beings, only 3 months later the same infant is highly responsive and engages in a great deal of smiling in the presence of other human beings. How does such a rapid transformation occur? Those who spend time pondering or studying these kinds of changes come away with a sense of awe. On the one hand, they discover that the very process of development is stunningly complex. On the other hand, they discover that the order that this process creates seems deceptively simple. How do we explain this strange contradiction? Developmental science, and developmental psychology in particular, certainly have not been lacking in theories of development. The systems view of development is one especially attractive and effective way of conceptualizing the process of development. This view has a long tradition in developmental psychobiology having appeared prominently in the theoretical writings of such developmental psychobiologists as Kuo (1976), Lehrman (1970), and Schneirla (1957). One of its principal features is that it explicitly recognizes the complexity of the developmental process and represents a backlash against the historically traditional and deeply rooted dichotomous thinking that parcellates the origins of structure and function into either the innate or acquired category.

According to one influential contemporary variant of the systems view known as the epigenetic systems view (Gottlieb, 1991), the developmental emergence of structure and function is the result of a complex and tortuous process involving the bi-directional interaction of factors both internal and external to the organism. This interaction occurs at all levels of organization, beginning with the cellular and ending with the organismic. Given such a complex process, how does one decide where to look for the critical factor responsible for the developmental emergence of a given behavioral function? This is a fundamental question and as we will see, at least for the editor of this volume, the answer takes a traditional, although to some extent curious turn.

There is no doubt that the topic of the current volume is an important and timely one because, as already noted, infants must acquire enormous amounts of information and the sensory and perceptual systems provide them with the sole avenue for acquiring this information. How they do so with the help of their visual and auditory modalities is the topic of the current volume. The volume's 12 chapters are divided into four sections. Each section is preceded by an introduction in which the editor presents a useful précis of each chapter in that particular section. The topics of the four sections are the development of the visual system at the basic structural and sensory level, the development of visual perception, the development of social perception, and the development of speech perception. The first section consists of chapters by Hainline, in which basic infant visual functions are described in great detail, and Moseley, Neufield, and Fielder in which abnormal visual development is discussed. The second section is the longest in the book and clearly reflects the editor's own interests: Gordon and Slater discuss the history of the nativism versus empiricism issue in philosophy and psychology; Slater reviews his own work as well as that of others on visual perceptual abilities, Quinn discusses object categorization skills; Cohen, Amsel, Redford, and Cassasola discuss perception of causal events, and Johnson discusses perception of objects. The third section includes chapters by Muir and Nadel on perception of social signals and by Haan and Nelson on discrimination and categorization of facial expressions of emotion. The final section consists of chapters by Lecanuet reviewing work on fetal responsiveness to sounds, by Jusczyk, Houston, and Goodman on the

development of speech perception, and by Werker et al. on the methods currently used to study infant speech perception. As a whole, the 12 chapters in this book represent a reasonable cross-section of some of the current issues under investigation in the field, although the choice of areas is somewhat idiosyncratic and there are some notable omissions. For example, a key issue in studies of development, particularly those dealing with perceptual development, is the contribution of early experience. Although various authors do consider this issue in their chapters, given its theoretical importance, a full treatment would have been desirable. It would also have been useful to have a chapter on the development of basic auditory functions; this would have made a nice parallel to Hainline's chapter on the development of basic visual functions. Finally, it is a shame that the book does not reflect some new areas. For example, the development of intersensory perception has become a central issue in perceptual development. Historically, the study of perceptual development has focused primarily on the visual modality, followed in importance by the study of the auditory modality. Although the study of intersensory perception has a long history in adult studies, only recently has its development taken on theoretical and empirical importance (Edelman, 1992; Lewkowicz, 2000; Thelen & Smith, 1994). Indeed, the last 20 years have seen a great deal of research in this area, with results that have important implications for our general understanding of perceptual development (Lewkowicz & Lickliter, 1994; Rose & Ruff, 1987).

Despite these omissions, overall this is a fine and timely volume packed with current theorizing and empirical information about perceptual development in infancy and the editor should be congratulated on a fine job of assembling work from some of the leaders in this field. The book fills a void in an area of research that is currently booming but in which integrative volumes such as this one are sorely lacking. The study of sensory, perceptual, and cognitive development in human infancy is a hot topic, with empirical findings accumulating at a brisk pace. For those trying to keep up with this area, whether they are active researchers in this field, graduate students, or behavioral scientists working in other fields but interested in the earliest determinants of behavioral development, this is definitely a book to recommend.

The big question: What is development?

The organization of the book is somewhat curious because it seems that the editor has strong theoretical views on the nature of development and it would have been useful to express them at the beginning of the book. Instead, this does not come through until Chapters 3 and 4. In Chapter 3 Gordon and Slater present a history of the nativism versus empiricism debate and use it as a vehicle for expressing their views on the process of development. On the one hand, a chapter of this sort is a useful reminder of where some of the ideas about the developmental origins of perceptual knowledge come from. On the other hand, it is somewhat of an oddity. There is growing consensus that the kind of dichotomous thinking inherent to the innate versus acquired debate is not only unhelpful but may be downright misleading and wrong-headed when considering the process of development (Lehrman, 1970; Thelen & Smith, 1994). Yet the explicit purpose of this chapter is to dredge up the historical dichotomies with the further purpose of attempting to provide a conceptual framework for the current volume. Part of the reason for this appears to be the already mentioned big question: where do novel forms and functions come from and how do we explain their seemingly magical appearance at birth.

There is no doubt that birth has a certain magical quality to it and thus is probably the most significant developmental milestones for the human species. It is a time when the fetus passes from the womb into the outside world and it is the first time that the infant is introduced to the world in which it will spend the remainder of its life. Thus, it is no surprise that it evokes such a special interest, and although this is not the sole focus of the volume, it is of great interest to many of the contributors. Before the advent of modern developmental psychology and its sophisticated and objective experimental methods, we could only turn to the philosophers for answers to such questions as what a newborn infant is capable of, how does it perceives the world, and whether it knows anything about the world it has just entered. The classic nativist answer to these questions, given by Plato, Descartes, and Kant was that humans come into this world already equipped with basic categories of knowledge about the physical world. This knowledge was presumed to be derived from rational processes of thought that operate right from birth. The opposing, empiricist answer offered by such 18th-century British philosophers as Locke and Berkeley was that newborn infants know nothing at birth because they come into the world with a blank slate on which the experience of life gradually makes its imprint. It is this innate versus acquired dichotomy that developmental psychology inherited from its philosophical ancestors and it seems that this dichotomy still holds sway for the editor of this volume.

Explaining the initial causal factors responsible for the emergence of a particular function may seem like the principal task of the developmental scientist. In reality, however, the real and far more daunting task is finding out what processes and mechanisms underlie the developmental emergence and subsequent changes and transitions that inevitably

occur in a given behavioral function. It is precisely this question that systems theories of development focus on and they insist that questions about the processes underlying developmental changes are the fundamental ones. This view comes, in part, from embryology which has shown that development begins at conception, not at birth, and that it is an exquisitely organized process consisting of complex, bi-directional interactions at various levels of organization ranging from the cellular to the organismic. Despite this undeniable fact, many developmental psychologists still tend to treat birth as the starting point of sentient and thus of psychological life. This pre-occupation with birth as the most significant milestone and as the true starting point of development no doubt derives directly from psychology's deep philosophical roots. Indeed, these roots are very nicely reviewed by Gordon and Slater. The real problem with using birth as the starting point of development is that whenever investigators uncover some new behavioral capacity at birth, they feel compelled to make some statement about its origins and more often than not come down on one side or the other of the innate versus acquired dichotomy. This is essentially the logic Slater follows in his chapter on the visual capacity of the newborn infant.

To be fair, it must be noted that Gordon and Slater appear to reject the innate versus acquired dichotomy by asserting that most developmental psychologists have resolved this simplistic approach by adopting an interactionist approach. What is interesting, however, is that despite this assertion, in actuality they perform a kind of a sleight-of-hand that only gives the illusion that they are rejecting the dichotomous view. Their alternative to dichotomous thinking appears to be the view that the real developmental origins of any function probably are the result of a little of the innate and a little of the learned. Thus, according to Gordon and Slater, a given perceptual function is the result of the combination of some innate capacities and the acquisition of others through learning. Indeed, these authors attempt to frame the rest of the book in terms of the innate-acquired dichotomy by stating that developmental studies are "the major topic to be discussed in the rest of this book" (p. 100) and that "the most powerful way of attempting to discover the extent to which perception is genetically determined or results from experience with the world lies in developmental studies" (p. 100). Many contemporary theoreticians have roundly rejected this pseudo interactionist approach in favor of one that considers development as a process in which the question is not how much do genes and how much does environment contribute to a given function but what processes lead to the emergence of a given function (Gottlieb, 1998). This is a fundamentally different approach to the problem; rather than focusing on the question of developmental origin, it asks about the processes that contribute to the development of a given function. For example, rather than asking whether a newborn's preference for her own mother's voice over that of a stranger's is innate or learned, one asks about the contributing factors that might play a role in the emergence of such a preference. This means that one would look at what possible conditions before birth might contribute to the emergence of this preference. Doing so one discovers that, as Lecanuet shows in his chapter, the auditory system of the fetus during the third trimester of pregnancy is responsive to a variety of acoustic attributes of sound generated outside the mother's uterus. This raises the very likely possibility that the fetus' experience with the maternal voice contributes to the preference. Thus, asking questions about specific factors and processes that contribute to the emergence of a given perceptual capacity makes the question of whether it is innate or learned moot.

Visual development

Fortunately, despite Gordon and Slater's attempt to frame the book in terms of the innate-acquired dichotomy, most (though not all) of the contributors resist the temptation to fit their results to such a scheme and spend their time discussing the specific issues related to their domains. Hainline's chapter on the development of basic visual abilities is a well written and comprehensive treatment of this topic. She provides an exhaustive review of the structural and functional capacities of the young and developing visual system; in particular, she discusses the development of spatial vision (as measured by contrast sensitivity), color vision, accommodation, vergence, and oculomotor control and shows that all of these functions are far from mature in the infant. She notes an interesting paradox; despite the fact that in newborn infants acuity, color vision, binocular vision, and oculomotor control are rather poor, the infants somehow manage to function relatively well. In fact, Hainline argues that infant vision is sufficiently well adapted for the kinds of information that infants need to acquire and that, as a result, they should not be seen as handicapped. For example, she points out that in contrast to adults who need fine visual acuity and depth perception skills to perform such functions as reading or driving, infants do not need to perform such functions and thus do not need such fine visual skills. The companion chapter by Moseley, Neufeld, and Fielder continues the theme of visual development except that the focus here is abnormal visual development. The most common visual anomaly observed in infants is amblyopia and so the authors spend most of their time discussing it.

Cognitive development

In his chapter on object and spatial categorization of objects, Paul Quinn tackles one of the key problems for perception and cognition. An infant who is faced with a multitude of sensory experiences arising from the stimulus flux must somehow organize these into meaningful wholes that must, in turn, be organized into common categories of objects with similar meanings and functions. One of the key questions here is how the perceptually based categorical representations that emerge first in development give rise to more conceptual, knowledge-based representations of children and adults. Drawing on the neurophysiological distinction between the "what" and "where" brain systems devoted to object recognition (the former devoted to object identification and the latter devoted to object localization), Quinn organizes his review of studies along these two lines. Thus, in the first part of his chapter, he presents evidence showing that infants even as young as 3 months can form some basic-level categories (e.g., domestic cats and horses) and that they can form more global categorical representations for mammals that includes instances from novel mammal categories but excludes birds, fish, and furniture. Unfortunately, Quinn also falls into the dichotomy trap when he asks whether certain spontaneous preferences that are observed for certain kinds of perceptual attributes might act as facilitators of category formation and whether these preferences are "innately specified." In the second part of his chapter, Quinn asks whether young infants also can categorize objects spatially in terms of above, below, left, right, between, inside and outside. He reviews mostly his own studies showing that spatial categorical representations are at first rather concrete and specific to given objects and it is only later in development that these categories of spatial relations become more abstract and general (i.e., several different objects can be spatially related to each other within the same representation). Quinn ends the chapter by considering the possible role of maturational and experiential factors in the development of object and spatial categorization by reviewing studies that he and his colleagues have been conducting with prematurely born infants. An infant who is born prematurely is maturationally younger at the time of testing. To correct for this immaturity, one can test the infant at an older age. Quinn argues that by comparing the performance of infants corrected with those who are uncorrected for prematurity one can separate the effects of experience and maturation. This is problematic, however, because an infant whose age is corrected may be equivalent to a fullterm infant in terms of her maturational status but she also will have had extra postnatal experience during the weeks that are added for the correction. Quinn and his colleagues found that premature infants whose age was not corrected did not perform spatial categorization whereas those whose age was corrected did. Quinn argues that this indicates that biological maturation is a more potent determinant of spatial categorization. However, it could be argued that infants whose age was corrected were successful because they also had extra experience. More troubling is the fact that neither group of premature infants performed successfully in an object categorization task and Quinn concludes that preterm birth exerts a limiting effect on object categorization. This sounds too much like wanting to have it both ways; all the premature infants tested were healthy, making it difficult to understand what specific aspects of preterm birth are being referred to and making the maturity versus experience comparison based on comparisons of corrected and. uncorrected infants questionable.

The chapter on the development of infant causal perception by Cohen et al. is a highly readable and scholarly treatment of this important area. In essence, Cohen and colleagues contrast an information-processing, constructivist view, which they favor, with a nativist-modular view, which is currently in vogue in cognitive psychology. They make their position explicit right from the beginning by stating, "The nativist-modular position, especially when taken to its extreme, reduces to a patently circular form of argument" (p. 168).

Because the modularity view posits that infants have an encapsulated, autonomous causality module, they must respond to any type of causal event, without exception, as causal. Cohen and colleagues point out, however, that it can be shown that infants as old as 10-12 months perceive causal events as causal or not depending on the specific perceptual features of the events. To make their argument, Cohen and colleagues first provide a clear historical account of the idea of causality and note that their primary interest is in what is known as mechanical or physical causality (the causal relationship between two or more objects external to the observer).

To examine how the infant's understanding of causality develops, Cohen and colleagues habituate infants to one inanimate object (typically a circle, cube, or some other more complex object on a screen) moving toward another identical stationary object. The moving object can make contact with the stationary object, "causing" it to move immediately (direct launch event), can make contact with the stationary object but there is a delay before the stationary object begins to move (delay event), or it can stop without making contact with the stationary object while the stationary object moves off anyway (gap event). The direct launch event is perceived by adults as clearly causal,

whereas the delay and gap events are not. By habituating infants to one of these events and then testing for responsiveness to one of the other events it is possible to determine independently whether infants respond to these types of events on the basis of spatio/temporal differences or on the basis of the causal relations between the objects. Based on their studies, Cohen and colleagues argue that there is a four-step progression in the development of causal perception: initial preference for causal events but no understanding of causality at 4 months, responsiveness to the independent spatial and temporal features of these types of events but still no understanding of causality at around 5.5 months, responsiveness in terms of causality by around 7 months of age, and understanding the agent-patient relationship at around the same age. Consistent with an information-processing, constructivist view, however, this developmental sequence holds only for responsiveness to simple objects such as circles or blocks. When more complex objects are used, requiring greater processing before they are distinguished as separate entities, it is not until later (10 months of age) that infants show evidence that they perceive causality. Even more significant is the finding that when habituated to an action performed by multiple and different objects (thus requiring the formation of a causal category), even 10-month-olds do not perceive this as a causal event. Finally, the perception of the agent-patient relationship, the ultimate categorical form of causality, does not emerge until 14 months of age when complex events are used. This kind of developmental progression is contrary to the modularity view, which predicts that infants should be able to perceive any causal relationship regardless of the kinds of objects and number of objects used during testing.

In addition to showing that developmental differences in response to causal types of events throw the modularity view of causality perception into serious question, Cohen and colleagues point out that the encapsulated nature of a causality module also places serious limits on the kinds of questions one can ask. For example, the modularity view does not permit one to ask questions about the relationship between the child's understanding of the concept of causality and language development. This question is addressed in the final section of the chapter and the results from some preliminary studies investigating labeling of specific causal actions are presented. These studies showed that 14-month-old infants were unable to learn the association between a nonsense verbal label and a specific action (pulling or pushing). Cohen and colleagues then present a number of alternative explanations based on the notion that the cognitive understanding of action concepts should precede the acquisition of verb categories expressing similar kinds of object relations.

Johnson's chapter on infants' perception of objects is a nice complement to Cohen et al.'s chapter in that it asks how infants come to understand the perceptual unity of objects and their independent and permanent status. Unfortunately, Johnson succumbs to the innate-acquired dichotomy when he asks about the developmental origins of object perception. In asking whether infants learn about objects through manipulation, language, or looking, he muses, "Or is object knowledge present at birth as part of our genetic endowment?" (p. 213). Assigning complex psychological functions to genes is fraught with danger and probably completely off the mark (Gottlieb, 1998). The only function that genes perform is to code for proteins and the pathway from gene expression to an immature young organism with already complex object perception skills is immensely complicated. Consequently, it is incumbent upon those putting forth nativistic explanations to elucidate this pathway. Because no proponent of nativistic explanations ever specifies this pathway, this is essentially a throw away argument that is not helpful in the search for real developmental precursors and processes underlying the emergence of perceptual and cognitive skills.

Johnson surveys the literature chronologically starting at birth. Because neonates' visual perceptual skills are very limited, they would not be expected to have sophisticated visual perceptual abilities. At the same time, Johnson points out that evidence from Slater's laboratory indicates that neonates can perceive object and shape constancy but not object identity and that neonates prefer faces to non-face stimuli. In addition, he shows that neonates do not meet one of the critical requirements for object perception: the ability to perceive independent, bounded entities. For example, unlike 4-month-old infants who perceive a partly occluded object (a moving rod with an invisible center) as a single rod, neonates respond to it as two disconnected rods. Johnson then reviews some of the most intriguing but controversial findings on infants' perception of objects. According to Jean Piaget, the premier developmental psychologist of the 20th century, infants first become aware of the independent and permanent existence of objects between 8 and 12 months of age. Johnson reviews work by Baillargeon and others, however, showing that infants as young as 4 months of age are aware of object permanence as well as identity and size. He also notes that some of Baillargeon's findings have not been replicated and thus cautions us to withhold judgement on the emergence of such fundamental perceptual and cognitive capacities so early in development. Finally, he reviews some of the work on infants' understanding of the concept of individual objects (sortals) and work

showing that it is not until the second half of the first year that infants show evidence that they understand the influence of such physical properties as gravity and support on objects. There is no doubt that questions about infants' understanding of the physical properties of objects and the world that they inhabit are fundamental. As Johnson points out, however, current theories, such those of Spelke and Baillargeon arguing for the existence of innate core principles or innate learning mechanisms, respectively, do not fully account for the findings in the literature. Indeed, systems views such as the dynamical systems view of development (Thelen & Smith, 1994), can provide highly persuasive and useful theoretical alternatives to the kinds of nativistic and/or dichotomous views offered by Spelke and Baillargeon.

Perception of socially meaningful stimuli

The two chapters in the section on perception of socially meaningful stimuli are both concerned with how infants respond to the human face because this is the principal source of social information for the infant. At the very beginning of their chapter, Muir and Nadel set up a nice dialectic for this section and by doing so put the issue of how best to study infants' perception of social information front-and-center. They note that the kinds of studies reviewed by de Haan and Nelson in their chapter on infants' ability to discriminate facial expressions are an important source of information about infants' perception of social information. They note, however, that most of these studies present infants with photographs of expressions and that this may not be the best way to elicit maximal social competence in infants. They suggest that to elicit maximal social competence, infants should be tested in social contexts in which they engage in an active interaction with another human being. This "ecological validity" argument is certainly powerful because if there is any psychological function that has evolved in close intimacy with its environment, it is social behavior. At the same time, however, it should be noted that the criterion of ecological validity is slippery and that one often can obtain similar patterns of results with "invalid" stimuli as with "valid" ones (Lewkowicz, submitted).

Muir and Nadel show that neonates have a limited, if not non-existent, social behavioral repertoire. The only curious aspect of this part of their review is that after discussing the work on neonatal imitation, they conclude that imitation must be an innate capacity in the human species. Moreover, they present Meltzoff and Moore's (the investigators who originally discovered neonatal imitation) opinion that imitation is not a form of perception-action coupling but rather a form of behavioral regulation intended to bring the infant in line with a dynamically changing, animate display. Although Muir and Nadel do not take a stance on this position, it suggests that neonates should attempt to imitate any dynamic object, regardless of whether it is another human being or a dynamic inanimate object.

By the second month of life infants become highly sensitive to the contingent nature of social stimulation and thereafter they continue to be. Muir and Nadel note that it is not clear whether this sensitivity is a general one that applies to any interactive dynamic object or is specific to beings with whom the infant has had experience and whether it is the auditory, visual, or combined aspects of the adult's communicative signals that are responsible for the infant's response. Indeed, this kind of work makes questions about the importance of multimodal stimulation key to understanding perceptual development. Although Muir and Nadel show that initially infants respond to the voice but that later they respond more to the face, it is also possible that it is the combined audio-visual attributes of the adult that are responsible for the infant's response profile. This is because one of the most consistent findings from many studies comparing responses to unimodal versus multimodal stimulation, be it inanimate or animate, is that responsiveness to multimodal stimulation is always the most robust (Lewkowicz, 1999). In addition to raising interesting questions about the separate roles of the components of multimodal stimulation, Muir and Nadel argue that the measure matters. They note that measures of visual behavior do not always indicate that infants are sensitive to perturbations of social contingency during interactions but that measures of smiling do.

Perhaps measures such as smiling are the most optimal for indexing "social" responsiveness in an interaction episode, but Muir and Nadel's view that measures of visual fixation are not nearly as good for indexing infants' discrimination of facial expressions of emotion may be too extreme. If that were the case, then no differential responsiveness would be expected. It is clear from de Haan and Nelson's review of the literature, however, that measures of visual fixation have shown that young infants can discriminate between different affective expressions and that by the end of the first year of life infants can categorize different expressions. An interesting argument put forth by de Haan and Nelson is that discrimination of facial expressions does not differ from general visual perceptual abilities in infancy and, thus, is not likely to reflect the operation of some specialized mechanism.

Perception of speech

Speech perception lays the foundation for the development of language. One of the most exciting findings to emerge in modern research on perceptual

development is that the human fetus not only hears sounds in-utero but also responds to them and that this prenatal experience has consequences for responsiveness in postnatal life. Lecanuet does an admirable and comprehensive job of reviewing findings on the acoustic structure of the fetal environment, the development of the peripheral auditory structures in the fetus, and fetal responsiveness to a variety of sounds including speech sounds. He shows that the cochlea attains functional status around the end of the 8th month of fetal life and that auditory competencies are initially poor but improve rapidly. Of greatest significance is the fact that many prosodic and some non-prosodic attributes of sound pass into the amniotic environment and that by the end of gestation the fetus is able to perform a number of important speech-relevant acoustic discriminations.

The result of this prenatal auditory experience is that when it comes to dealing with basic speech sound distinctions, postnatally infants are not novices. Jusczyk, Houston, and Goodman pick up where Lecanuet leaves off and review the research to date on infant speech perception abilities in the first year of life. Nicely complementing this chapter is the last chapter by Werker et al. in which the three major methods used to study speech perception (conditioned head turning, visual habituation, and high-amplitude sucking) are described and contrasted and some illustrative studies are discussed.

The chapter by Jusczyk et al. provides a highly comprehensive and historically rich account of the current state of knowledge regarding the development of speech perception. The latter is partly because Jusczyk is one of the pioneers in this field, having participated in a now classic study of infant speech discrimination in 1971. Jusczyk et al. trace the development of the theoretical issues and questions in this field and show that after an initial interest in whether infants can discriminate a variety of consonant and vowel contrasts, investigators turned to questions about the contribution of an infant's specific linguistic environment to the emergence of speech perception skills. For those interested in development as a process, this is where some of the most interesting and intriguing findings can be found. In general, the findings have shown how powerful the effects of experience, acting in concert with previously acquired perceptual capacities, can be and to some extent these findings have been counter-intuitive. A straight learning account of the development of speech perception skills might posit that as infants grow they learn to make increasingly finer acoustic discriminations. A straight nativist account might posit that infants come prepared with a full complement of such skills. Neither account is correct. Rather, the findings bear a striking resemblance to findings from studies of brain development showing that initially there is an overproduction of neurons and that this is followed by selective neuronal death (Innocenti & Clarke, 1984). In a similar fashion, infants' ability to discriminate speech contrasts is so broad initially that it includes contrasts that are inherent to both the infant's native language and non-native languages. With continued exposure to their native language, however, the range of discriminable contrasts narrows to match those inherent to the infant's language environment and sensitivity to many non-native contrasts declines.

Phonetic discrimination is certainly basic to acquiring speech perception skills but language acquisition also requires that infants be able to segment the speech stream into its meaningful components (words and phrases). How they do so is the topic of the remainder of this chapter. Here it becomes even more obvious that experience is the great tutor of language development and what is even more fascinating is that the prosodic, allophonic, and phonotactic cues that infants use to segment speech probably differ as a function of the specific language that infants are learning.

One of the most interesting theoretical parallels between the findings on speech perception and the findings on face perception is that both abilities appear to be general ones; indeed, Jusczyk et al. argue that the current evidence suggests that speech discrimination abilities reflect more general acoustic discrimination mechanisms rather than specialized speech perception mechanisms. Taken together with Cohen et al.'s objections to the modularity argument, the findings on face and speech perception are a powerful argument against notions of modularity of function in early development and caution researchers studying development to focus on questions about process rather than origin. The former question leads to a deeper understanding of how behavioral functions come about whereas the latter leads to non-productive pseudo-explanations.

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