HANDBOOK OF CHILD PSYCHOLOGY

PAUL H. MUSSEN Editor

Fourth Edition

Volume III

COGNITIVE DEVELOPMENT

John H. Flavell
Ellen M. Markman
Volume Editors

HANDBOOK OF CHILD PSYCHOLOGY

Formerly CARMICHAEL'S MANUAL OF CHILD PSYCHOLOGY

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FOURTH EDITION

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PREFACE TO THE FOURTH EDITION

The *Handbook of Child Psychology* is a direct descendant of three editions of the *Manual of Child Psychology*. The first and second editions, edited by Leonard Carmichael, were published in 1946 and 1954, the third, called *Carmichael's Manual of Child Psychology*, which I edited, was published in 1970. Each of these editions attempted to provide a definitive account of the state of knowledge of child psychology at the time of its publication.

In the 13 years since the publication of the third edition of *Carmichael's Manual*, child psychology has been an extraordinarily lively and productive discipline, expanding in many directions and at a rapid rate. Only a few of the most important of the countless changes will be reviewed here. The volume of the research activity and the annual output of research articles and books have accelerated enormously. As more information accumulates, new questions are generated, new research approaches are invented and older ones are applied in new versions, established theories are challenged and revised, novel theories are proposed, concepts are redefined, and specialized fields of interest and investigation evolve. These changes are closely intertwined and consequently have an impact on one another. Investigation of a new issue (or a revised version of an older one) often requires novel research techniques and approaches. New research findings may evoke questions about the conclusions derived from earlier studies and about underlying theories, and these questions, in turn, lead to further research. These cycles of events are repeated, progress in the field is continuous, and the amount of accumulated data snowballs. Consequently, even an authoritative 1970 publication cannot give an adequate picture of the field in the 1980s. A brand new source book is needed and the present volumes are intended to satisfy this need.

This *Handbook* attempts to reflect the changes in child psychology that have occurred since 1970 and to present as comprehensive, balanced, and accurate a survey of the contemporary field as possible. It is twice the size of the earlier two-volume work and differs from it in many ways. The coverage is broader and more topics are included, discussed in greater depth, and organized according to different principles. Discussions of topics of enduring interest that were presented in chapters in the last edition of *Carmichael's Manual*—for example, Piaget's theory, learning, language, thinking, aggression, sex-typing, socialization in the family and peer group—are reconceptualized and brought up to date in chapters in this *Handbook*.

The reader may get a clearer understanding of the structure and contents of the *Handbook* by noting some of the most significant contrasts between it and the last edition of *Carmichael's Manual*. The *Handbook* includes more chapters on theories and fundamental approaches to research in child psychology (Volume I). The chapter by Piaget on his own theory has been retained. In addition, there are chapters on information processing and systems theories—previously applied to issues in perception, learning, cognition, and social organization—which have proven useful in integrating a substantial body of the data of developmental psychology and in stimulating research. Cross-cultural and field studies have become very fruitful in the last 20 years and these too are discussed in separate chapters, as are the latest advances in general research methodology and assessment. And, as the discipline has matured, there is heightened (or renewed) interest in its philosophical and historical antecedents, so two chapters of Volume I are centered on these issues.

Developmental psychologists have always been interested in the *origins* of behavior, and the factors involved in very early development have become more prominent foci of research attention in the last 10 or 15 years. The psychological study of infants has burgeoned, while advances in research methodology in physiology, ethology, genetics, and neurology have made possible more refined and penetrating explorations of the biological bases of behavior. These research emphases are examined in Volume II of this *Handbook*.

The content area of greatest activity since 1970 has been cognitive development and the results of this activity are apparent in Volume III. For example, the third edition of *Carmichael's Manual* contained one chapter on language development and it dealt almost exclusively with the acquisition of grammar. In contrast, the *Handbook* has separate chapters on grammar, meaning, and communication. Much of the recent research in cognitive development confirms and extends Piaget's conclusions, but the results of other studies challenge aspects of Piagetian theory. Both kinds of findings are included in chapters in Volume III.

Several research areas that were new in 1970 have become well established, vigorous, and fruitful. Among these are social cognitive development, moral reasoning, and prosocial behavior; each of these is the topic of a chapter in this *Handbook*. In addition a number of traditional issues that had been somewhat neglected until recently have become more prominent in the literature of developmental psychology. For example, this *Handbook* contains chapters on representation, on logical thinking, play, the self, and on the school as an agent of socialization. None of these topics was discussed in the 1970 edition of *Carmichael's Manual*.

In response to social needs, developmental psychologists in increasing numbers conduct research on practical problems and attempt to apply their research findings to the solution of urgent problems, spelling out the implications of basic data for such areas as educational practice and social policy (see particularly the chapters on intervention and on risk factors in development in Volume II, on learning, memory, and comprehension in Volume III, and on treatment of children with emotional problems in Volume IV). The results of these activities are highly salutary for advancing the field of child psychology, for they extend the definitions of concepts investigated, test the findings of laboratory research in real-life settings, and illuminate the limitations of available data and theory.

The volume editors (William Kessen of Yale University, Marshall Haith and Joseph Campos of the University of Denver, John Flavell and Ellen Markman of Stanford, and E. Mavis Hetherington of the University of Virginia) and I met to plan and organize this *Handbook* over five years ago. Our objective was clear and straightforward: to prepare a source book that would present as complete, accurate, balanced, and up-to-date a view of the field as possible.

Although there is no entirely satisfactory way of subdividing and organizing all of the vast body of theory, methods, and data in a field as large, varied, and ever-changing as developmental psychology, we constructed a table of contents that in our opinion included all the key topics—that is, all the topics that are currently receiving substantial amounts of research and theoretical attention. It soon became obvious that four volumes would be required, and we decided to arrange the material in accordance with the four predominent divisions of the field—theory and methods, biological bases of behavior and infancy, cognitive development, and social and personality development.

Comprehensive coverage was not our only aim; integrative summaries were to be accompanied by new perspectives and insights, critical analyses, and explications of deficiencies in existing data and theoretical orientations. We hoped to produce more than an encyclopedic review of accumulated knowledge; our goal was a source book that would encourage sophisticated thinking about fundamental issues, formulation of questions and hypotheses, and, ultimately, more good research.

We selected and invited a group of distinguished authorities in developmental psychology and related fields who were highly qualified to contribute chapters that would accomplish these goals. Almost all of our invitations were accepted and the assignments were carried out with extraordinary diligence, care, and thoughtfulness. Each working outline, preliminary draft, and final manuscript was reviewed by the volume editor, the general editor, and another authority on the subject, and suggestions for revision were communicated to the author. Although three of the chapters included in the original plan are missing, all the key chapters are included. We are therefore convinced that the *Handbook* provides the most comprehensive picture of contemporary child psychology that exists in one place.

If the objectives of the *Handbook* have been achieved, it is due primarily to the painstaking work, dedication, and creativity of the contributors and the volume editors. The lion's share of the basic work—preparation of scholarly, integrative, and critical chapters—was done by the authors. The contribution of the volume editors was indispensable; in their difficult roles of critic, advisor, and guardian of high standards, they were infinitely wise, patient, and persistent. My debts to all these individuals are incalculable.

Paul H. Mussen

PREFACE TO VOLUME III

This volume contains rich and insightful pictures of the current state of knowledge and belief in most contemporary areas of cognitive development and the artists who painted these pictures include some of the best scientists and scholars in the field. We asked them to write the only kind of review chapter that we thought busy and talented people would consider writing. Please write a chapter that presents a fair and adequate review of the literature, we asked, but also one that is selective, thoughtful, and interesting. We want a responsible, thorough survey, of course, but feel free to refer the reader to good secondary sources for any subareas you do not feel warrant detailed coverage. Long review chapters can be rather dull, we said. Try to make yours lively and compelling by conspicuously putting your own stamp on it. Make its organization, coverage, ideas, and conclusions reflect your hard-won wisdom and expertise in the area. That wisdom and expertise deserve to be shared with the reader, not hidden in a thicket of study summaries and literature citations. Besides, the opportunity to speak your mind on matters of great interest and importance to you is one of the few recompenses you will have for all your drudgery and suffering.

We hoped that almost everyone invited to write would agree to do so, but of course we never thought it would really happen. But it did happen: To our delight and gratitude, almost everyone we asked said yes. Unfortunately, the drudgery and suffering were also unavoidable, and were even worse than anticipated. Some things just have to be experienced to be imagined and writing a review chapter of this length, scope, and depth is one. It entails innumerable hours of very hard work. Worse, it involves repeated frustrations at the organization or integration scheme that won't come, battered self-esteem for the vision and creativity one is supposed to have but seemingly doesn't, and other torments known only to authors of such reviews. "Mussen chapters," as we all came to call them, are plain hell on wheels to write. They may have some delights, but they certainly have many devils.

However, the months did pass and the chapters did get planned, replanned, drafted, critiqued, revised, copy edited, proofread, and—now, at long last—published. We couldn't be more pleased with the final results. These chapters provide masterly, insightful reviews that, in our opinion, will prove to be truly significant and lasting contributions to the field. We think they are treasure troves of information and ideas about what the field presently is, and also about where it may or should be heading. A person who absorbs what is in these chapters will understand the contemporary scene in the field of cognitive development with a breadth and depth previously unavailable to anyone, however expert and knowledgeable. We are sure that working through them had that profound an effect on our own understanding, and for this we feel deeply indebted to the authors. We can only hope the chapters will have the same deep and abiding effect on your command of this fascinating field.

The field of cognitive development has greatly changed since the publication of the 1970 *Carmichael's Manual of Child Psychology*, and, in our opinion, it has greatly improved. In reading these chapters, we were continually struck by the experimental ingenuity of investigators, by the many surprising new empirical discoveries, and by the theoretical advances that have been made. In the last decade, every subfield in the area has gained a more explicit appreciation of the subtlety and complexity of cognitive development.

One of the more striking changes is the movement away from orthodox Piagetian theory. It is a tribute to Jean Piaget's greatness that almost everything people think and do in this field has some connection with questions that Piaget raised. This was true during most of the 1960s and all of the 1970s, is true today, and probably will continue to be true for a long time. Although investigators continue to address these fundamental Piagetian questions of cognitive development, the nature of the answers has changed greatly. Piaget's theory and research findings, while never uncontroversial, are more and more being challenged from all quarters. There is growing criticism, and burgeoning efforts at reinterpretation, revision, and extension. This is not surprising, given all Piaget did and wrote, and given the extraordinary amount of thought and research the field has addressed to the problems that he raised. This change, we feel, is also a sign of progress.

Another noticeable change is that researchers across many different areas have become skeptical of stage-theoretic accounts of development. Piaget's logical-algebraic models of concrete- and formal-operational thought seem to have all types of problems. Cognitive development may not be as stagelike as he thought, or, if it is, its stages or *coupures naturelles* may be somewhat different from those he postulated.

In the past, we may have been too wedded to particular Piagetian methodologies to measure many cognitive abilities adequately. This situation has been remedied in part by the more sensitive assessment procedures that have been developed to uncover early cognitive competence. Preschool children have been shown to have more cognitive potential than Piaget believed, and infants more than he or anyone else would have dreamed a few years ago. The field of infant cognition is clearly in its Golden Age. Researchers are discovering many important and often surprising things about babies' sensory, perceptual, conceptual, learning, and memory capabilities. Highly interesting research is also being done on a wide range of early-childhood cognitive phenomena, some of it representing fruitful extensions or revisions of Piagetian work but much of it involving essentially new directions. Examples include research on young children's knowledge of number and classification, logical reasoning, and social cognition. One other important new focus is the concern with characterizing developing knowledge structures (e.g., schemas, scripts, etc.). There are now many elegant studies suggesting that very young children may have the capacity to represent knowledge in a format quite like that of the adult. Methodological and conceptual advances have paved the way for these revised assessments of capacity.

At the other end of ontogeny, adolescents and adults do not appear to be as consistently formal-operational or otherwise rational as Piaget's theory suggested. It no longer seems feasible to expect total uniformity of cognitive level in the way any individual approaches cognitive problems. Instead, it is now clear that the formal structure of any given problem is only one factor affecting its solution. A solution derived from a formal logical analysis may conflict with one based on a more practically oriented reasoning. A child's familiarity with the material, experience in solving similar problems, and many other factors will affect performance. This conclusion is emphasized by cross-cultural, individual-differences, and life-span-developmental psychologists.

To oversimplify, one way of summing up these changes is to point to the recent movement toward information-processing approaches to cognitive development. Here we refer to information-processing approaches in the most general sense, rather than to any specific model. This approach emphasizes careful analysis of the processing requirements implicit in any task and the recognition that failure on a given problem could result from a breakdown in any one of the processes. Another important assumption of these models is that humans have limited capacity to process information. This approach underlies much of the recent research directed at revising and refining Piagetian theory as well as the more radical departures from Piaget. It can be seen in such areas as the development of logical reasoning and related intellectual abilities, of communication skills, and of social cognition, to name only a few. In each case, developmental differences in performance could result from any number of factors that consume resources more rapidly for children than for adults, without assuming fundamental differences in the nature of representation or of cognitive competence.

One factor that is gaining increasing attention is the amount of information and knowledge that children have on any given topic compared to adults. Children's lack of expertise in an area could result in striking developmental differences even if there were only minor age changes in the basic processes themselves.

Another consequence of this shift is the emphasis on different strategies that children use to solve problems. This in turn is one reason that metacognition (i.e., knowledge and cognition concerning cognition) and such related processes as executive functioning and cognitive monitoring have become popular research topics in recent years. Work in this area initially addressed children's developing knowledge and cognition concerning language (metalanguage) and memory (metamemory) but now includes knowledge and cognition about perception, attention, comprehension, learning, communication, and problem solving.

Also, partially as a result of this new emphasis, the relationship of cognitive competence to behavior has become a near-ubiquitous issue. To what extent do we use and express in everyday behavior that which we know and know how to do? To what extent and under what circumstances are our metacognitive knowledge and know-how translated into effective cognitive strategies? How, and to what extent, is our social-cognitive knowledge about self and others actually used, "on line," in everyday social interactions? What about the relationship between our ability to reason morally and our moral behavior? And somewhat differently, how much concordance between linguistic competence and linguistic performance should we expect to see?

In addition to information processing, there have been many new theoretical approaches guiding developmental research. Examples include attribution theory and other theories from social psychology; linguistic and psycholinguistic theories concerning phonology, morphology, syntax, semantics, and pragmatics; and many cognitive theories dealing with perception, attention, memory, comprehension, knowledge, problem solving, logical reasoning, judgments and decisions, and other processes. This expansion of new approaches has led to a greater diversity in the kinds of questions that have been formulated about development and in the kinds of empirical studies conducted. The compatibility of developmental and nondevelopmental accounts of cognition can lead to a more unified approach to studying cognitive processes from childhood through adulthood. This can have the advantage of clarifying and emphasizing the importance of studying development, in seeing how successive changes result in the adult performance. Thus we expect to see a growing integration of research in developmental and adult cognition, with theories of adult performance influencing developmental accounts and with what is known about development constraining theories of adult cognition.

The authors and we are very grateful to Thomas J. Berndt, Jill deVilliers, Rachel J. Falmagne, Nancy S. Johnson, Paul H. Mussen, and Tom Trabasso for their help in critically evaluating chapter drafts, and to Sophia Cohen and Peter Coles for their assistance in translating the Bullinger and Chatillon chapter from French into English. We also want to thank Paul Mussen for his help and wise counsel throughout the book's genesis.

JOHN H. FLAVELL
ELLEN M. MARKMAN

CONTENTS

THE DEVELOPMENT OF PERCEPTION 1

ELEANOR J. GIBSON, *Cornell University*
ELIZABETH S. SPELKE, *University of Pennsylvania*

CHAPTER CONTENTS

INTRODUCTION

What Is Perception?

Perception is the process by which animals gain knowledge about their environment and about themselves in relation to the environment. It is the beginning of knowing, and so is an essential part of cognition. More specifically, to perceive is to obtain information about the world through stimulation. The perceptual systems of animals have evolved to detect patterns of light, of sound, and of pressure on the skin that carry information about the events, things, and places in the world. This information is in the world, but it is not the events and places themselves. It is to be found in the structure of stimulation, and it specifies the world that an animal perceives. To understand perception, we must first understand what aspects of the world an animal perceives and what information specifies the things it perceives.

Perceiving is an active process; it depends on perceptual systems that pick up stimulus information. Stimulation does not simply fall passively upon a receptor surface like rain upon the ground, for the perceptual systems are more than receptor surfaces. We do not just see, for example, we look, and in the course of looking, our pupils adjust to the level of illumination, our eyes converge or diverge, we move our heads or change our position to get a better view of something, and sometimes we even put on spectacles.

If the perceptual systems are active and are adjusted constantly to optimize the information being picked up, it is obvious that perception is selective. A continuous flow of information is available in the flux of stimulation; what is actually extracted by the animal's perceptual systems is only a part of it. It is this aspect of perception that can be referred to as attention, but attending is not really separable from perceiving itself.

What Is Perceived?

A description of perception starts with the events and things in the world and proceeds to the information in stimulation that is actually picked up by the perceptual systems. Do we, then, perceive this information? Such an answer can be immediately rejected. We do not perceive stimuli or even any momentary representation of them on a receptor surface, such as a retinal image. We perceive the events and things in the world. To perceive any event or thing, the information in stimulation must correspond to it, in the sense of *specifying* it. Events and things are specified in many ways for us, for example, in light, in sound, and in pressure patterns on the surfaces of the body. These sources of energy provide information to the visual system, the auditory system, and the haptic system. But through the activity of the perceptual systems, we perceive a unitary world, not separate collections of visual, auditory, and tactile impressions. This review is organized in terms of what is in the world for humans to perceive: events, objects, places, and artifacts that represent them.

Events

What goes on in the world goes on in a continuous stream with no full stops and starts and with few displays that remain perfectly still while one contemplates them. Nor does the perceiver herself stand still. Heads containing eyes and ears and noses and vestibular organs are almost continually moving. This chapter does not focus, then, on perception of static displays but on perception of continuous happenings in the world, specified by continuously changing arrays of stimulation. These happenings are events, and they seem to have a beginning and an end, even though the information for them is continuous over time. When a perceiver observes an event, she perceives changes that occur over time as well as a persisting, underlying layout of objects and places.

Objects

The world is furnished with objects, closed surfaces that are substantial and that retain their integrity over time. Many objects, such as people, stones, and books, are detached; they are capable of moving around or being moved. Some objects are attached to immoveable surfaces, such as a tree that is fixed to the terrain. Although attached objects are not moveable, they can be walked around. Each object is perceived as a unit, a separate whole, and it has properties that are perceived as well. The unity and most of the properties of an object are specified by information in a flow of stimulation that occurs as the object participates in events.

Places

Places are segregated parts of the layout of the world at which surfaces meet one another, often forming an enclosure. Places may have vistas and paths that can be seen or walked through, walls that constitute obstacles and conceal things, a ground that can be walked on, and dropoffs that must be avoided. An animal always lives and acts in some place. After a certain age, it can move around in that place and even move out of it, but the place persists. At any given moment, the animal occupies one point of observation, but that point changes continuously as the animal moves, and it can be exchanged with the vantage point of another animal. As the animal changes its location in a layout, objects come in and out of view; they are occluded and disoccluded. Over these changes, there is information to specify the persisting layout of the environment.

Pictures

Many of the furnishings of the world are artifacts, and some of these represent the events, objects, and places of the world. Pictures are representations par excellence, and they afford a means of obtaining knowledge about the world secondhand. They are very interesting for the study of perception because of their dual character as objects and as serviceable, although imperfect, representations of real scenes and events.

The Point of View

We approach the problems and the literature of perception by beginning with the ecology of an animal, its way of life as a species, and the biological structures with which it has been endowed by nature. Every species has evolved in a habitat, and in the long course of evolution, its niche and its biological structures have developed in reciprocity with one another. The perceptual systems developed in the context of this mutual relationship. They have adapted to enable the perceiver to extract the information that he needs for survival in the kind of world he lives in, especially to extract information about the affordances of things.

Affordances are a way of talking about meaning, but a special way. The term was introduced by J. J. Gibson (1979):

> The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill. . . . I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment. (p. 127)

Places, objects, and events all have affordances for human animals. A floor affords support, and it can be walked on. A wall is an obstacle that affords collision, but a doorway in the wall affords walking through. A cave affords shelter from the rain, which affords getting wet. Water affords drinking, but not walking on. A screen affords hiding. A fire affords warming oneself and reading by its light. Affordance is a functional term that emphasizes the utility of some aspect of the environment for an animal (E. J. Gibson, 1982).

The properties of events, objects, and places are specified by constant, higher order relationships in the flow of stimulation, relationships that we, after J. J. Gibson (1966, 1979), call invariants. Invariants are abstract and relational. Many are also available to more than one modality, that is, the same higher order relationship may be constant over changing stimulation to the eye, the ear, and the skin. Perhaps the most familiar case of an invariant is the optical structure that persists over movements of the eyes, head, or body. As a person moves over the ground, or moves a rigid object in his hands, there is a continuous transformation of the stimulation projected to his eyes. Nevertheless, the projective properties of the optic array, such as the cross-ratio of the distances between any four collinear points, remain constant. Despite the optical flow, these projective properties are invariant and provide information about the layout of surfaces and the objects resting upon them. In this case, as in others to be described throughout this chapter, "the flow of the array does not destroy the structure beneath the flow" (J. J. Gibson, 1979, p. 310).

An animal perceives events, objects, places, and their affordances by seeking out and detecting invariants. Some mechanisms for detecting invariants are present at birth, but sensitivity to invariants increases as new perceptual and exploratory abilities mature or become modified by experience. Furthermore, the child's developing perceptual systems provide information that is increasingly accessible for new purposes. For the very young infant, perception of an affordance might guide only a limited repertoire of adaptive actions. For the older child, perception of an affordance will come to guide actions of many kinds and can even become an object of thought.

The point of view espoused in this chapter is not constructivist. We do not conceive of perception as the building of a representation of the world from a collection of elementary sensations through processes of association, inference, or assimilation to a schema. We stress, instead, that perception depends on a search for invariance in stimulation that is continually changing. An important function of perception is to search for the persisting structures and the invariants that provide information about the environment and its affordances. Perception develops not through the construction of new descriptions of the world, but through the discovery of new information about it.

EXPLORING AND ATTENDING

Over the course of development, animals gain knowledge about the events, objects, and layout of the world and of what they afford for behavior. By what means is a human infant prepared to proceed with this massive program? Human infants are far from being precocial; nature has given them little in the way of ready-to-go knowledge about the situations they will encounter in the world. But they are richly endowed with the means of finding out about the environment. Active exploration begins at birth, and exploratory skills increase with maturation and with practice. An infant's looking and listening and to some extent her feeling, smelling, and tasting are inherently coordinated for obtaining information. Furthermore, coordinated multimodal exploration, such as auditory-visual coordination, is functional very early and does not appear to depend on learning. These precoordinated systems provide a way of learning about the world at an early age, and we have seen in recent years that infants are motivated to use them actively in seeking information. From infancy to childhood, exploration appears to become more specific in its direction, more economical, and more systematic, but it has a purposeful look from the start.

The Beginnings of Information Pickup

Visual Exploration

Visual exploration provides the major means of information gathering for very young infants. Fixating high-contrast patterns, tracking moving ones, and moving the head and upper trunk to assist in localizing and following objects are all preadapted coordinated systems, imperfect but functional at birth. These exploratory activities improve rapidly during the first few months with maturation of the visual system.

Infants of 1 month reliably turn in the direction of a target by saccadic movements of the eyes when the target is introduced as far as 30° from the line of sight along horizontal and diagonal axes and as far as 10° along the vertical axis (Aslin & Salapatek, 1975). The first saccade is not very accurate: It is usually short of the target and is followed by one or more saccades of equal amplitude. Infants shift their gaze further when the target is farther away, however, showing adaptation to the target's distance. Evidence from directionally appropriate first saccades and multiple saccades following them led Aslin and Salapatek to conclude that the infants were motivated to look at the targets.

Even newborn infants shift their gaze toward the side of the field in which a peripheral target is introduced (Harris & MacFarlane, 1974). Localization of a peripheral target is swifter and occurs for a target at a greater distance if there is no central stimulus present. The probability of locating a distant peripheral target is enhanced if the central target is stationary and the peripheral one is in motion (Tronick, 1972). The effective visual field was thought to expand with age by earlier investigators (see Tronick, 1972), but no expansion was found between 1 and 7 weeks when a competing central stimulus was introduced with a peripheral one (MacFarlane, Harris, & Barnes, 1976), suggesting that selective attention to a centrally located target occurs at both ages.

Infants under 2 months do not track a moving stimulus with smooth-pursuit movements that match the velocity and direction of the stimulus; instead, following occurs in the form of a jerky series of saccadic refixations (see Salapatek & Banks, 1978). Kreminitzer, Vaughan, Kurtzberg, and Dowling (1979) observed that smooth pursuit occurred only about 15% of the time in newborn infants. Its velocity increased with target velocity up to 19°/sec. and deteriorated at faster speeds. Tracking occurs at 8 weeks when an object is displaced relative to a background, but not when the object and background move together (Harris, Cassel, & Bamborough, 1974). When an object moves against a stationary background it successively occludes texture in the background field. Occlusion and disocclusion of a stationary field provide information for differentiating objects from background surfaces.

Movements of the head in relation to a peripheral stationary target or a target moving across the field have been studied less, probably because infants have usually been observed in a supine position making head control difficult. Bullinger (1977) observed neonates seated in a chair before a white background. A flock of red wool was dangled at the infant's eye level, 70-cm distant. The object was presented at the left, right, or center for 1 min. Infants oriented head and eyes toward the object. When the object was swung in front of the infant, both head and eyes turned slowly to follow it, but the movements were jerky rather than smooth and were not well calibrated to the object's rate of motion.

Auditory-Visual Exploration

Visual exploration of sounding objects is a precoordinated system of particular interest because it provides a basis for perceiving a unified world. Does the very young infant turn head and eyes to look at a sound source and explore it visually? Evidence for innate coordination was reported by Wertheimer (1961); a newborn infant turned her eyes in the direction of a sound (a click). Other experimenters have reported different results. Butterworth and Castillo (1976) observed that newborn infants moved their eyes away from a loud click. Sound intensity may affect the direction of looking (Hammer & Turkewitz, 1975). McGurk, Turnure, and Creighton (1977) also failed to find ipsilateral eye movements to clicks in neonates. Several more recent experiments with persisting, structured sounds nevertheless have obtained results that confirm Wertheimer's (1961) earlier observation.

Mendelson and Haith (1976) used a 40-sec. presentation of human speech. It was presented laterally, and there was a stationary bar on either the same or the contralateral side of the infant's visual field. Visual scanning of the field was influenced by the speech; infants turned at first toward the sound, then away from it. The authors interpreted this as an extended search for a change in the visual field. A signal detection analysis of eye turning to the sound of a human voice saying "baby" was performed by Crassini and Broerse (1980). The infants turned toward the sound at significantly greater than chance level. The frequency of these turns was not high, but it was greater than the frequency of turns in the absence of a laterally presented sound. Alegria and Noirot (1978) reported that infants turned their heads in the direction of a human voice as well, opening their eyes as they did so.

Identification of the conditions that promote visual exploration to sounds has been extended in further experiments. Muir and Field (1978) investigated head turning toward sound (a rattle produced by shaking a plastic bottle containing popcorn) in neonates held in such a way that they could turn their heads spontaneously. All babies turned correctly on the majority of trials, appearing to investigate the locus of the shaking rattle: "They hunched their shoulders, actively pulled their heads up, turned to the side of the stimulus, and then seemed to inspect the sound source visually" (p. 432). The importance of a more continuous sound and a free-to-move head are apparent. In a further experiment, Field, DiFranco, Dodwell, and Muir (1979) presented 2½-month-old infants with a recording of a woman's voice reading poetry. Infants turned both head and eyes toward the voice. Sustained, complex, auditory stimulation again seemed to favor visual orientation. Field, Muir, Pilon, Sinclair, and Dodwell (1980) compared infants aged 1, 2, and 3 months for head and eye turning to a sound produced by shaking a popcorn-filled bottle. Infants turned reliably at 1 and 3 months, but less reliably at 2 months.

Several experiments indicate that introduction of auditory stimulation enhances visual exploration in early infancy. Haith, Bergman, and Moore (1977) studied visual scanning of an adult's face by infants who were 3 to 11 weeks old. A dramatic increase in fixation of the face occurred between 5 and 7 weeks, and the introduction of a voice intensified scanning, particularly in the eye area (see also Hainline, 1978). Horowitz (1974) and her colleagues conducted a series of studies of habituation to visual displays with and without auditory accompaniment. Infants of 5 to 14 weeks habituated to a visual pattern accompanied by a continuous sound, such as a voice reading poetry, and subsequently dishabituated when the sound was changed. The change in sound led to further looking without a change in the visual display, as if the infant were searching for a change in the visual scene as well (see also Walker, 1982).

Exploration of the visible source of an ongoing sound has been observed with a preference method (Spelke, 1976). Motion picture films of two events were presented side by side on a small screen before the baby. During the filming for each event, a sound track was made. One of the two sound tracks was played from a central location as the baby viewed the films. An observer stationed behind the screen monitored the baby's looking so that the total looking time to each film could be assessed. Infants looked longer at the film specified by the sound track. A search test given after presentation of the films and both sound tracks provided further evidence for coordination (Spelke, 1979, 1981). The films were again presented side by side. On each of a series of trials, the baby's gaze was centered by means of a flashing light, a short burst of one sound track was given, and the baby's orientation to one film or the other was noted. Infants looked to the event specified by each sound. A number of experiments using this method have now been performed with 4-month-old infants (e.g., Bahrick, 1980; Bahrick, Walker, & Neisser, 1981; Spelke, 1976, 1979; Walker, 1982). These experiments have displayed a variety of events, including peekaboo, patacake, hands playing musical instruments, and bouncing puppets (see *Obtaining Information About Events*). Visual-auditory exploration of a temporally extended event is highly functional by 4 months.

Finally, there is some evidence that sound influences visual tracking of an object that moves laterally and is temporarily occluded (Bull, 1978, 1979).

A sound moving with the occluded object facilitated looking to the object's point of reappearance from behind the occluding screen at 4 months of age.

Haptic Exploration

Haptic exploration occurs earliest in the form of mouthing, whereas active manual exploration of objects appears considerably later. There is reason to think that mouthing activity of neonates is spatially oriented toward external events, as is activity of the visual system. Alegria and Noirot (1978, 1982) observed asymmetrical mouthing as a function of absence versus presence of a human voice and as a function of the voice's location. Asymmetrical mouthing came to be directed toward the voice within the first three feedings. Breast-fed babies (held either on the right or left arm for feeding) oriented toward the voice, whereas bottle-fed babies showed mouthing in the direction of the arm that characteristically held them. Asymmetrical mouthing was negligible in the control condition when the baby was held but not spoken to.

An experiment by Meltzoff and Borton (1979) provides evidence that mouthing is exploratory, that it furnishes information about the surface properties of objects, and that it is coordinated with looking at objects. Infants 4 weeks of age were allowed to explore by mouth one of two objects—a smooth sphere or a sphere with nubs. The objects (actually, larger versions of them) were then presented as a pair for visual inspection. The infants were reported to look preferentially at the object similar to the one familiarized by mouthing. Infants 4 months old, in a similar experiment, looked longer at the novel object (Meltzoff, 1981). The infants apparently learned something about the object from haptic exploration that was also detectable visually. However, a recent experiment with infants 1, 3, and 5 months old failed to replicate these effects (Baker, Brown, & Gottfried, 1982).

Oral exploration was used by Gibson and Walker (1982) in an experiment on intermodal perception of substance by 4-week-old infants. A cylinder-shaped object made of either lucite or spongy rubber was inserted in the baby's mouth and left until the baby had mouthed it for 60 sec. A test of preferential looking followed. Identical cylindrical objects were displayed simultaneously side by side before the infant, one object rotating in a pattern characteristic of a rigid substance and the other object deforming in a pattern characteristic of a spongy substance. The infants looked preferentially toward the object moving in the pattern of the *novel* substance. This experiment also provides evidence for detection of an intermodal correspondance.

Oral exploratory behavior was investigated directly by Allen (1982), who recorded pressure changes during oral exploration of objects. Infants of 3 months showed a decreased rate of sucking during familiarization with one object. They subsequently differentiated between the familiar object and a novel object of a different shape, sucking more vigorously on the novel object.

Infants learn very readily to suck at high amplitudes to obtain some contingent, seemingly arbitrarily related display, such as a human voice uttering "ba" or "ga" (e.g., Eimas, Siqueland, Jusczyk, & Vigorito, 1971). This learning may be facilitated by the exploratory function of mouthing, which is especially adapted for the pickup of information about affordances at an early age when other means of exploration are limited. An experiment by Kalnins and Bruner (1973) supports this interpretation. Infants 5 to 12 weeks old quickly learned to suck at high amplitudes when sucking brought a motion picture display into focus. But in the symmetrical condition, in which a picture came into focus only when the infant inhibited sucking, no learning occurred. Instrumental learning in infancy appears to build on the infant's inherent propensity to explore.

Mouthing continues as a means of exploration all through the first year of life. It is still used in preference to manual exploration between 8 and 9 months. Kopp (1974) studied visual-manipulative behavior of infants between 32 and 36 weeks of age when presented with a rigid object. Types of behavior included examining by turning an object in the hands and looking at it, mouthing, and actions like banging or sliding the object on the tabletop. Mouthing was the predominant behavior, followed by examining. Some infants still only explored the object visually.

Active touching and manipulation of an object with differentiated finger movements is late in developing. The precedence of the mouth over the hands for haptic exploration recalls Gesell's anatomical rule of head-downward and proximodistal development. But by 1 year children do explore the affordances of objects manually to some extent, differentiating elastic and rigid substances with such behaviors as squeezing versus banging (Gibson & Walker, 1982). Ruff (in preparation) reported an increase in exploratory fingering of objects between 6 and 12 months, particularly when the objects varied in surface texture.