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10 Exploring Audible and Visible Events in Infancy

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EXPLORING AND KNOWING

Young perceivers face the formidable task of discovering and making sense of their surroundings. Each individual must learn about nonliving objects and happenings, about people and social encounters, about actions and their consequences. Human infants appear to approach this task by investigating events capably and persistently. Exploration may be an infant's principal endeavor. By the end of the 1st year, a baby seeks and obtains information by looking, listening, touching, locomoting, and acting on the world. Eleanor Gibson has emphasized that perception develops as young creatures actively search for stimulus information specifying the significant properties of things. Human infancy thus may be a time of rapid perceptual change.

I am intrigued by the infant's explorations because of the intimate relation of exploring to knowing. Knowledge guides exploration in two respects. First, perceivers must seek to extend their knowledge of the things they investigate. By definition, they must have questions to ask. Second, perceivers must already know something about an event in order to investigate it. Exploration would be highly inefficient—and perhaps impossible—for those who knew nothing about when, where, and how to seek relevant information. The very nature of exploration gives promise to studies of information-seeking in infancy. Observations of an exploring infant may reveal both the knowledge on which the earliest investigations depend and the knowledge to which they lead.

I focus on infants' explorations of events that they see and hear. Mature perceivers know a great deal about the audible and visible characteristics of

things. When adults look and listen to an event at once, they recognize that they are following a single episode. When they look at one event while listening to another, they perceive that the object they see is not that which they hear. Furthermore, an adult who only hears an episode can often imagine how it looks, whereas one who only sees an object may anticipate the sounds it will produce. These abilities reflect the adult's knowledge of auditory-visual relations. This knowledge increases the economy of perception. Human adults can detect objects with manifold properties from a glance or a brief sound. Knowledge also increases the effectiveness of auditory-visual exploration. When adults hear an event, for example, they can use what they know of its visible properties to look for it directly. The effects of the adult's knowledge are clear, but its origins are obscure. Studies of exploration in infancy may help to reveal those origins.

I have investigated some of the knowledge permitting young perceivers to explore bimodally specified events and some of the knowledge that they gain by exploring. A series of experiments has been conducted with 4-month-old infants. The studies reported in the next section focused on one capacity underlying exploration: the ability to detect a relation between optic and acoustic stimulation specifying an event. Infants were found to be capable of perceiving auditory-visual relations when sounds occurred in synchrony with the visible movements of objects. The experiments described in the following section focused on some of the knowledge that an exploring infant acquired. Infants who were presented with certain bimodally specified events were able to learn something about them. Infants revealed what they learned by engaging in futher exploration. Acquired knowledge permitted them to explore even when no immediately given information united what they saw with what they heard.

These experiments suggest that infants can perceive unitary, bimodally specified events. As they explore by looking and listening, infants appear to gain knowledge of the events' distinctive properties. Thus they become capable of further exploration. An adult's knowledge of audible and visible episodes may derive from a cycle of exploring and knowing that begins early in life.

A BASIS FOR EXPLORATION: SENSITIVITY TO AUDITORY-VISUAL RELATIONS

Young infants tend to look at times and in places where sounds occur. Newborns may open their eyes in a dark room if a ringing bell is played (Haith, 1968), and they may scan simple displays in a more controlled manner if the displays are accompanied by human speech (Mendelson & Haith, 1976). Newborn infants sometimes move their eyes in the spatial direction of a voice or a click (Mendelson & Haith, 1976; Wertheimer, 1961), and 2-month-old

infants increase their attention to a checkerboard pattern if they detect changes in the speech or music that accompanies it (Horowitz, 1974). These observations indicate that young infants can explore visual and auditory episodes sharing no internal structure and specifying no unitary event. The studies do not reveal, however, if infants perceive a relation between the displays they see and hear. In order to explore events effectively, perceivers must be able to distinguish sights and sounds that specify a single episode from those that occur together by chance. They must perceive the *unity* of a bimodally specified event and the separateness of unrelated sights and sounds. According to traditional associationist theories of perception (e.g., Berkeley, 1709/1910; Mill, 1829), very young infants are not capable of this. For naive perceivers, sights and sounds are not yet associated, and so are experienced as unrelated visual and auditory sensations. A different expectation arises from the perspective of Eleanor and James Gibson, who propose that there are amodal invariants in stimulus information. Eleanor Gibson (1969) has suggested that perceivers of any age should be able to discover intermodal relations if they can detect information that is available in more than one stimulus modality. I began by asking whether infants can perceive auditory-visual relations, and if so, on what basis.

In these studies, infants revealed their capacity for biomodal perception by their patterns of exploration. They viewed two events, side by side, while hearing sounds appropriate to one event through a central speaker. We judged when the babies looked to the acoustically specified and nonspecified episodes. In some of the experiments, a "visual preference" procedure was used to investigate the exploratory activity of following an event by looking and listening. A sound accompaniment was played for several minutes, and total looking time to each event was assessed. Infants were expected to look more to the sounding object if they could detect the intermodal relationship. In some studies, a "visual search" procedure was used to focus on the activity of looking for the source of a sound. An auditory accompaniment was played briefly while infants looked between two events, and subsequent looking toward each event was recorded. If a baby was aware of the auditory-visual relation he or she was expected to search for the acoustically specified episode.

In an initial study, part of which was reported in Spelke (1976), the preference method was used. Four-month-old infants viewed two natural and possibly familiar events. One event was a game of "peekaboo" played by a woman they did not know. The other was a sequence of percussion music played with a tambourine, a wood block, and a moving wooden baton. Both episodes were filmed in sound, and each sound track was temporally synchronized with the movements of the appropriate visible object. While the films were shown side by side, an experimental group of infants heard each sound track in succession for several minutes. The sounds were played

through a speaker placed behind the projection screen and centered between the films. A control group of infants watched the same events projected silently. The measure of interest was the proportion of total looking time that was devoted to the acoustically specified episode.

Infants in the experimental group directed 64% of their looking time to whichever event was projected in sound [$t(21) = 5.60$, $p < .001$]. A comparison of the experimental and control groups revealed that infants responded to the sound of the percussion sequence (see Table 10.1). They looked longer to the percussion film when it was projected in sound than when it was projected with no sound accompaniment; the peekaboo sound track had no comparable effect on looking. Infants explored the musical episode by looking and listening.

In a more recent preference experiment by Bahrick, Walker, and Neisser (1978), auditory–visual exploration of other natural events was investigated. Four-month-old infants were shown a game of pattycake, a musical sequence played on a xylophone, and the movements of a Slinky toy that repeatedly opened and closed as it was held by two hands. Each infant viewed two of these events, accompanied by sounds appropriate to one of them. The subjects devoted two-thirds of their looking time to the member of the pair that was acoustically specified.

The young perceivers in these initial experiments looked primarily at events they heard. They did not simply look at times or in places where sounds occurred, since each sound was concurrent with two events and was played between them. Knowledge of intermodal relations guided looking. The babies in these studies were able to discover a relation between the optic and acoustic stimulation that specified each episode.

Infants might discover such auditory–visual relations in either of two ways. First, they might be able to detect certain familiar objects by looking and listening. For example, the infants studied by Bahrick et al. (1978) might have seen and heard the pattycake sequence to involve clapping hands, an event not depicted in the other films. Learned associations between the sight and

TABLE 10.1
Proportion of Looking Time to Acoustically Specified and Nonspecified Natural Events

	Peekaboo	*Percussion*
Event projected in sound ($n = 22$)	.72	.56
Both events projected silently ($n = 16$)	.65	.35
$t(36)$	0.74	2.20*

*$p < .05$.

sound of this event might have guided exploration. Alternatively, infants might be able to detect the common temporal structure of optic and acoustic stimulation. Every sound in the filmed events was synchronized with the visible movements of an object. The subjects might have responded to this temporal synchrony. By 7 months, infants are known to detect the invariance of a temporal pattern over visual and auditory modalities (Allen, Walker, Symonds, & Marcell, 1977). It seems possible that infants use this ability to discover intermodal relations.

In three experiments reported in Spelke (1978), this possibility was tested. I investigated infants' sensitivity to the temporal synchrony of the sounds and visible movements of objects. In the first experiment, two objects moved and sounded in synchrony, each at a distinctive rate. Sixteen 4-month-old infants were presented with two films, each depicting a toy animal—a kangaroo or a donkey—that was lifted by invisible strings into the air and dropped to the ground. A percussion sound accompanied each landing: a "thump" for one animal and a "gong" for the other. One animal bounced approximately once every 2 sec, whereas the other bounced about four times as rapidly. The animals moved out of phase with each other. When the two films were shown with one auditory accompaniment, the sounds were synchronized with only one event. The pairing of sounds and objects was arbitrary and counterbalanced. Infants could respond to the intermodal relations only by detecting the temporal synchrony of sound and movement.

The experiment consisted of a visual preference episode followed by a visual search episode. During the preference episode, each infant viewed one film of the kangaroo and one of the donkey. One animal moved in time to each percussion sound. The films were projected side by side as the sound tracks were heard in succession through a centrally placed speaker. Looking time was recorded and coded as in the previous preference studies.

The visual search episode followed 5 minutes after the preference episode. Each infant viewed the same events in the same locations. While the films were projected silently, a flashing light attracted the baby's gaze between the events and heralded the onset of a sound. The synchronized sound of one event was played for 5 sec through the central speaker while the filmed objects continued to move as before. The infant's looking to the events was recorded during that brief period. This procedure was repeated up to 12 times with each sound track, producing as many as 24 search trials. Coders eliminated all trials on which an infant was already looking at one of the events when the sound began. An average of 9 trials remained for analysis. The coders calculated the number of trials on which an infant looked first to the acoustically synchronized event after the onset of a sound, and the number of trials on which he or she looked first to the nonsynchronized event.

The principal results appear on the first three lines of Table 10.2(a). Infants tended to look to the acoustically synchronized event during the search

TABLE 10.2
Visual Exploration of Acoustically Synchronized Events

	Synchronized Event	*Nonsynchronized Event*	*t*(15)
(a) Sounds temporally synchronized with objects moving at two tempos			
Preference Session 1	52.9	32.6	1.87*
Preference Session 2	35.5	41.4	< 1
Search (Experimental Group)	4.44	3.50	2.34*
Search (Control Group)	3.12	1.62	3.83**
(b) Nonsynchronized sounds and movements at two tempos			
Preference Session 1	37.9	41.1	< 1
Preference Session 2	36.5	32.5	< 1
Search	5.00	3.50	2.14*
(c) Sounds temporally synchronized with objects moving at one tempo			
Preference Session 1	47.0	32.7	1.53†
Preference Session 2	54.6	33.1	< 1
Search	4.12	3.06	1.93*

*$p < .05$.
**$p < .01$.
†$p < .10$.

episode but not during the preference episode. The babies looked longer to the appropriate object during the first preference session only, and the overall tendency to prefer the acoustically specified event was not strong. During the search episode, infants looked first to the synchronized object on reliably more trials. When a sound was played, they tended to look for the object that moved in concert with it.

Since every infant participated in the search test after the preference test, the earlier episode served as a period of familiarization with these events. A subsidiary study revealed that visual search would occur even without this period of familiarization. Sixteen additional 4-month-old infants participated in the same search test with the kangaroo and donkey events. This test was preceded by a familiarization period with completely different events: the peekaboo and percussion sequences. The experiment was otherwise identical to the main study. An average of six usable search trials was administered to each infant. The results of the search test appear on the fourth line of Table 10.2(a). Infants again looked first on more trials to the event synchronized with each brief sound. An analysis comparing the two experimental conditions confirmed that infants tended to look to the synchronized object [$F(1, 30) = 18.64$, $p < .001$], irrespective of their familiarization condition

($F < 1$). The infants were able to search for sounding objects by detecting the synchrony of sound and movement during the search test itself, even if they had never seen the objects previously.

The results of these experimental conditions provide evidence that infants are sensitive to the synchrony of sound and movement. Babies can use this temporal relation to guide exploration of unfamiliar events. A young perceiver does not need to learn that the particular sight and particular sound of an object belong together through a long and laborious process of association. He or she can detect this relation in events never before witnessed, provided that the sounds and visible movements are temporally synchronized.

Infants in this experiment could have detected either of two aspects of the temporal relation. First, since the objects moved at different rates, infants may have responded to the common tempo of sound and movement. They may have discovered that one object moved at the same speed as the auditory accompaniment. Second, since each object contacted the ground at the time that the appropriate sound occurred, infants may have responded to the simultaneity of sounds and moments of impact. The next two studies revealed that young perceivers can do both these things. They detect both the common tempo and the simultaneity of sounds and visible impacts.

In the second experiment of this series, infants were presented with two objects moving at different speeds, accompanied by sounds that occurred in the rhythm of one object's movement, but not at the time of either object's impacts. The films and procedure of the preceding study were used with one modification—each accompanying sound was played out of phase with the event that it specified. Tape recordings of the sound tracks from the kangaroo and donkey films were played as the films were shown. The films and recordings were begun at haphazard locations so that sounds did not systematically accompany either object's impacts. Furthermore, the speeds of each machine varied slightly and changed the phase relations of sounds and movement. Sounds did not always occur at the same point in the cycle of movement of either object. Since each auditory accompaniment occurred at the same rate as the movements of one filmed object, an infant could perceive an auditory–visual relation by detecting this common tempo. The events were shown to sixteen 4-month-old infants during a preference episode followed by a search episode. The search episode provided an average of 10 usable trials.

Infants once again perceived the auditory–visual relations, as indicated in Table 10.2(b). They showed no tendency to look to the acoustically specified events during either preference episode, but they looked for those events reliably during the search test. By their searching, infants revealed their ability to detect the common rate of sound and visible movement. Objects need not make contact at the time that sounds occur in order for a baby to perceive that the sounds and objects go together.

In the third temporal synchrony experiment, infants' sensitivity to the simultaneity of sounds and visible impacts was investigated. Infants viewed films of the kangaroo and donkey, each moving at the identical rate of one bounce per 2 sec. A sound was produced whenever the appropriate object made contact with the ground. One event was synchronized with the "thump" sound and one with the "gong." The films were begun at haphazard times, and the exact speed of the projectors varied slightly. Therefore, the objects rarely moved in phase with each other, and their phase relation changed over the course of a session. The simultaneity of sounds and impacts consistently tied each sound with one visible event, whereas the tempo of an auditory accompaniment was equally compatible with both events. Sixteen 4-month-old infants participated in a preference episode followed by a search episode. The procedure followed that of the preceding studies. An average of nine usable search trials was administered.

The results of the experiment appear in Table 10.2(c). Although infants showed no clear visual preference for the synchronized events, they searched reliably for an object when the appropriate sound was played. Infants were able to detect the simultaneity of sounds and impacts, even when the tempo of impacts could not be used to discriminate the acoustically specified event from the nonspecified event.

These experiments reveal that human infants can discover and explore unitary events by detecting a temporal pattern in light and sound. Infants are sensitive both to the common tempo and to the simultaneity of sounds and visible impacts. They should therefore be able to detect bimodal relations when sounding objects move in a variety of rhythms. This ability should serve them well, since many sounds are produced by visibly moving objects.

It is puzzling that such weak visual preferences were exhibited in the last three experiments, in view of the results of the earlier preference studies. I suspect that infants looked proportionately less to the sounding animals because of the extreme redundancy of these events. Babies may have attempted to follow both events during the preference episode, not just the event that they heard. A similar pattern of results has now been obtained with adult observers. College students were shown the kangaroo and donkey films under conditions like those of the infant preference studies. They viewed two films with one sound track on each of 4 trials (16 subjects) or 10 trials (12 subjects). Different sounds, films, and film positions were used on different trials. On each trial, the students were asked which event, if either, was projected in sound and where the sound had come from. These observers were clearly aware of the auditory–visual relations. They reported that the sound "went with" the synchronously moving animal on every trial. They also tended to localize the sound in the direction of the synchronized event. Although the sound track was always played from a central speaker, the subjects judged that the sound came from between the films on only 41% of the trials. They judged that the sound came from a speaker on the side of the synchronized object on 44% of the trials and from a speaker on the opposite side on 15% of the trials. The students nevertheless showed no visual preference for the synchronized events. Looking times were vicariously recorded on the first trial. Only 50.3% of the total looking time was devoted to the synchronized event. Clearly, neither infants nor adults always look and listen to the bimodally specified events they perceive. Infants nevertheless demonstrated their ability to detect auditory–visual relations by looking to an object at the time that its sound began.

In summary, 4-month-old infants consistently attempted to explore by listening and looking. Their searching revealed an ability to perceive the unity of certain events. They perceived an auditory-visual relation when sounds accompanied the visible contacts of an object with the ground. Infants probably detected the synchrony of sound and movment in the more natural events studied by Spelke (1976) and by Bahrick et al. (1978) as well. They appear to perceive the unity of a variety of audible and visible episodes.

The present findings complement those of research on exploring by sight and touch. Babies consistently seek to manipulate the objects that they see. Furthermore, their reaching, grasping, and precursory activities are noticeably accommodated to an object's visually specified distance (Bower, 1972; Field, 1976; von Hofsten, 1976), size (Bower, 1972; Bruner & Koslowski, 1972), and shape (Bower, 1972; Bryant, Jones, Claxton, & Perkins, 1972; Gottfield, Rose, & Bridger, 1977). Although the age of emergence of these activities has been debated, all appear within the first year of life. Young perceivers use knowledge about a variety of intermodal relations to guide their investigations of objects.

THE FRUITS OF EXPLORATION: LEARNING ABOUT AUDITORY–VISUAL RELATIONS

I have focused so far on the perceptual knowledge that makes exploration possible. I consider now the further knowledge to which exploration may lead. As adults, we possess knowledge about many of the objects that we see and hear. We know, for example, that telephones have a characteristic look and sound, and that people gesture and speak in certain ways. When an infant perceives a bimodally specified event and investigates it by looking and listening, does he or she begin to learn about its properties? In two experiments, I sought to determine whether infants can acquire knowledge about the audible and visible properties of events.

These experiments have a precedent in Lyons-Ruth's (1977) recent study of infants' ability to learn about a moving, sounding object. She familiarized 4-month-old infants with a toy by waving it in front of them and producing its

sound. The sound was heard in the toy's direction. Lyons-Ruth tested learning by presenting the sound to the baby's side, where the original or a different toy could be seen. Infants looked less to the novel than to the familiar toy. This difference was taken to reflect "gaze aversion" from the novel object, a conflict reaction to the unexpected juxtaposition of the sound and object. Whether or not her subjects were really in conflict, they evidently learned something about the sight and sound of the toy.

In the present experiments, I investigated whether acquired knowledge of an object could guide auditory–visual exploration. Infants were shown two familiar sounding objects, presented in such a way that optic and acoustic stimulation were spatially and temporally unrelated. The babies participated in a visual search test. I expected that infants who encountered a familiar sound would look for the object that it specified.

The first experiment, conducted with Cynthia Owsley, confirmed that 3½- to 7½-month-old infants know about the audible and visible characteristics of their parents. We used a variant of the visual search method. Each infant sat facing between the mother and father, who faced their baby. After a toy was waved between the parents to attract the baby's attention, one parent was heard to speak for several seconds. The parent's voice was played from a tape recording made prior to the experimental episode. It was heard between the two adults, who remained motionless. Thus, faces and voices were neither spatially coincident nor temporally synchronized. Only an infant who knew about the audible and visible characterisitics of the parents could search appropriately. The procedure otherwise followed that of the previous search experiments. Thirteen usable trials, on average, were administered to each baby. (For more information, see Spelke & Owsley, 1979.)

Infants tended to search visually for the parent whose voice was played (Table 10.3). They looked to the "speaking" parent on more trials than to the "silent" parent [$F(1,24) = 10.22, p < .01$]. This tendency did not interact with the age of the subject ($F < 1$). Although searching was most consistent at the oldest age, a separate replication confirmed that the youngest infants searched as well. Since no spatial or temporal information united a parent's

TABLE 10.3
Visual Search for a Parent Who Is Heard to Speak

Age	*"Speaking" Parent*	*"Silent" Parent*	*F*(1,24)
3½	6.67	4.43	5.48*
5½	6.56	5.67	1.36
7½	7.44	4.89	5.98*

*$p < .05$.

face and voice, knowledge must have guided looking. By four months, infants possess and use such knowledge.

The mother and father are surely among the most well-known objects in the child's environment, but they are not the only ones that a baby comes to know. A final experiment indicated that babies can learn rapidly about the audible and visible characteristics of less familiar things. Infants were introduced to two new sounding objects. Their learning about the objects was revealed through a subsequent search test.

In this experiment, I used the films and sound tracks of the last temporal synchrony study: the kangaroo and donkey, each bouncing at the same tempo. Sixteen infants viewed these events in two visual preference sessions. During each session, the objects moved out of phase with each other, and a sound occurred whenever one of them hit the ground. The infants subsequently participated in a search test in which sounds and movements were not synchronized. As in the mother–father study, the sound tracks were played from a tape recording. Since the objects moved at the same rate, no temporal information united either sound with either object during the test. Infants could search for the object that was previously synchronized with each sound only if they had learned about the auditory–visual relations.

The results are given in Table 10.4. Infants did not consistently prefer the acoustically synchronized event during the familiarization period, but they learned something about it. During the search test, they looked first reliably more often to the event that had previously been synchronized with each sound. Infants searched despite the absence of any temporal information uniting what they saw and heard. They evidently acquired knowledge during the preference episode that guided their looking.

In summary, a baby can develop knowledge about temporally synchronized sounds and objects. He or she can use this knowledge to explore in the absence of any spatial or temporal information. Infants successfully searched for their parents in the study by Spelke and Owsley (1979) and for new objects in the last experiment. A child seems to learn rapidly about auditory–visual

TABLE 10.4
The Effect of Knowledge on Visual Search for Aurally Specified Events

	Acoustically Specified Event	*Non-Specified Event*	*t*(15)
Preference Session 1	48.6	31.2	1.04
Preference Session 2	29.7	40.9	< 1
Search	4.94	3.88	2.72*

*$p < .01$.

relations. Knowledge derived from prior investigations leads to further investigations.

ISSUES AND QUESTIONS

The findings that I have discussed lead to several questions. First, in what sense can infants perceive a bimodally specified event? Do they experience a direct association of visual and auditory patterns, or do they perceive these sources of information to specify an object not tied to stimulation in any particular modality? For example, do infants perceive that the mother's speaking face "goes with" her voice, or do they perceive that the mother's face and voice are two specifiers of a single, "amodal" object? The experiments described so far certainly do not resolve this difficult issue. Studies of the child's ability to learn about objects that can be seen, heard, and felt may do so. Suppose, for example, that infants were familiarized first with an event specified visually and tactually, and then with the same event specified aurally and tactually. Would these infants grasp the relation between the sight and sound of that event? If infants could learn about intermodal relations under these circumstances, it would seem that they are learning about objects, not simply about auditory–visual correspondences. Experiments to test this possibility are getting under way.

The second question concerns the nature of the child's acquired knowledge. What is learned by infants who search for an object that is spatially and temporally unrelated to its sound? Do they learn to look for the object, or do they learn that the object can be brought to view by executing a particular response, such as a leftward turn of the head? If babies look for an object, do they identify it by its location or by certain of its internal characteristics? Preliminary research on these questions suggests that babies acquire knowledge about objects with particular visible characteristics, not about places or responses. Infants were familiarized with two sounding objects and then were given a search test. During the test, the lateral positions of the objects were reversed. Infants nevertheless tended to search for the object that each sound specified, looking in a new direction and toward a new place in order to do so.

A final question concerns the kinds of intermodal relations that babies can detect. Optic and acoustic stimulation from an event are usually related in three general ways. First, the visible impacts of surfaces are synchronized with any sounds that they produce. Second, sounds and their visible sources can be perceived in the same place. Third, objects tend to be audible and visible at the same time. We have seen that infants are sensitive to the temporal synchrony of sound and movement. Do they detect the other auditory–visual relations as well? Babies were not able to respond to those relations in my studies, since

each sound accompaniment occurred at the same time as two visible events and was centered between them. Further research could compare infants' sensitivity to the three kinds of auditory–visual relations directly. Such comparisons may reveal which relations are detected first, and whether infants' appreciation of one serves as a basis for their discovery of the others.

CONCLUSIONS AND SPECULATIONS

My experiments have focused on the infant's ability to explore bimodally specified events. Their findings suggest that infants engage in a cycle of perceiving, exploring, and knowing. Exploration of events, guided by an ability to perceive their unity, may bring the infant knowledge, and this knowledge may make further investigations possible. A mature perceiver's awareness of the visible and audible properties of objects may ultimately derive from this cycle of exploratory activity.

In discussing these studies, I have so far bypassed two issues that dominate most investigations of intermodal coordination in infancy. I will conclude by considering: (1) the roles of nature and nurture in the development of auditory–visual perception; and (2) the qualitative or quantitative nature of of developmental changes in intersensory functioning. These comments are speculative. My ideas evolved as I considered the role of exploration in learning and development.

Although many earlier psychologists have credited the newborn infant with little knowledge about the world, it is now clear that babies arrive with a host of capacities (cf. Cohen & Salapatek, 1975; Gibson, 1977). Empiricist assumptions are yielding to a growing appreciation of the infant's considerable native endowment. Quite paradoxically, this new respect for the innate competence of humans may ultimately provide new ground for empiricism. Infants appear blessed primarily with the ability to explore and learn. They know how to find out about their environment. They are able to investigate objects and events in order to begin developing the rich perceptual capacities that will support them as adults.

To focus on the infant's intermodal exploration is to bridge the nativist–empiricist controversy in a special way. In order to explore a visible and audible event, the infant must be able to relate information from different sensory systems and perceive a unitary episode. However, babies may begin with little knowledge of the characteristic sights and sounds of most objects. They may use their capacity to explore audible and visible events primarily in order to gain knowledge. As knowledge accrues, this capacity will grow.

What happens to the child's perceptual abilities as he or she develops? Do the abilities undergo qualitative change? According to some descriptions of intersensory development, young infants perceive events in fundamentally

different ways from adults, and their perceptions often deceive them. Infants are thought either to experience unrelated modality-specific sensations or to perceive at any moment all sights, sounds, smells, and other feelings as one unique and indivisible whole. In either case, perception must undergo a particularly dramatic developmental change. Infants must shed false perceptions for true ones as they come to appreciate that information in different stimulus modalities sometimes specifies a unitary event and sometimes does not. Similar developments have been proposed in other realms: The child progresses from experiences of fleeting images to the awareness of permanent objects, from amorphous bodily sensations to the differentiation of self from world, from egocentrism to social reciprocity.

If infants are viewed as seekers of information, they will appear to suffer not from perceptions that are misguided but from knowledge that is insufficiently precise. Infants, like adults, recognize that patterns of light and sound are sometimes related and sometimes not. They may begin with some ability to perceive bimodally specified events. But infants know vastly less about these events than an adult, and their means for exploring them are few. As they grow, infants gain knowledge that permits them to perceive and explore ever more effectively the things they see and hear.

One who views infants as explorers will be impressed both with their native abilities and with the enormity of what they must learn, both with the adaptiveness and with the poverty of early perception. Such a person will affirm, with Eleanor Gibson, that perception, exploration, and knowledge of an event are nearly always adapted to the event's real properties but that this correspondence becomes increasingly specific and differentiated with development. He or she might turn to research on human infancy, as Gibson herself has done, in order to discover the initial capacities for exploring, perceiving, and knowing that allow this development to begin.

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