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Shifting the Focus From What to Why

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After 4 decades of research on infant behavior and development, the time has come to shift our focus from What infants do to Why they do it when they do—to move beyond the single-minded search for *mechanism* and to consider the larger question of *function.* Infants are not merely incomplete adults who simply get better with age, but they are different organisms altogether, perfectly adapted at every point in ontogeny. For this reason, answers to the Why question will necessarily build upon an evolutionary framework that reflects the infant's changing "occupations" or ecological niches. Through this pursuit, infancy researchers will develop a more integrative science and a greater sense of community.

energy budget	adaptation	infantile amnesia	learning	memory
	cognitive map	evolution	ecological niche	

The title of this presentation, "Shifting the Focus From What to Why," summarizes its take-home message: Infant researchers have spent 40 years gathering data on What; the time has now come to turn our focus from What infants can do to Why they do it when they do.

First, some background. The Modern Age of Infancy was officially launched in 1958 with the inauguration of a national prospective study, carried on at 16 different sites across the country. The goal of the study was to catalog the various abilities of newborns, who would then be followed until adolescence to determine whether anything measured during infancy predicted any outcomes later on. To meet this goal, researchers had to document exactly *what* infants could do; for example, could they smell? Or hear? Or see? If so, then what could they smell or hear or see? And when could they first do it? The common finding over succeeding generations of researchers was that infants could do a lot and that they

could do it quite early on. My own work followed this pattern. Initially, my students and I asked if infants could show operant learning; then, we asked what did they learn and when could they learn it? Finally, we got around to asking the Big Question—*why* did they learn—particularly since they presumably could not remember it anyway? That question launched a new career. Initially, we asked if infants could remember. Then, we asked what infants could remember. Then, we asked when could infants remember what and for how long. Now, we have returned full cycle to the Big Question—*why* do infants remember what they do for the length of time that they do, and *why* do they forget what they do—if they forget at all?

How do we go about answering the Why question? First, we must recognize that infants are not just incomplete adults who get better with age. Rather, infants are different organisms altogether. Second, we must appreciate the evolutionary fact that parents have an enormous economic and genetic investment in an offspring, who typically is a singleton, has already exploited the mother's resources for 9 months by the time of birth, and will remain dependent for its essential resources until adolescence, when the problem shifts to the Society for Adolescent Research. (I note parenthetically that many mammals chase their offspring from the nest when they reach 35% of their adult body weight. As the mother of five sons, I have on occasion thought that this was a pretty good idea.) Third, we must recognize

The Dictionary of Occupational Titles

Body-Builder

Job description: Age 0-9 weeks. Part-time work days and nights acquiring energy and minimizing energy expenditure. Variable hours. Persistence required; strong suck and cry desirable. Net energy income will be invested in fueling growth. Around-the-clock protection and personal shopper service available.

Inventory Control Officer

Job description: Age 10-24 weeks. Full-time days/occasional nights maintaining and controlling inventory of people and objects, what goes with what, and what happens where and in what order. Must be adept at soliciting caregiving and social interactions. Regular hours, benefits.

Map Maker, Level I

Job description: Age 25-40 weeks. Full-time days, weekends; no nights. Regular hours. Acquisition of preliminary cognitive map; some babbling, receptive language skills desired. Beginning-level crawling a must.

Map Maker, Level II

Job description: Age 41-52 weeks. Full-time days, weekends; no nights. Regular hours. Self-starter. Navigational and receptive language skills required. Must know when who and what are where, and how to get there.

Figure 1. The Dictionary of Occupational Titles.

that throughout most of human history, the infancy period has occupied about one third of the life span. Some survival advantage must have been incurred by such a long introduction to the rest of the species.

Given these considerations, our Why answer begins with differentiating between a niche and a habitat. Hutchinson (1959) described a *niche* as a species' occupation or profession and a *habitat* as its address. Although the human adult is usually character-ized as a generalized social omnivore, the human infant occupies a very different niche—even, perhaps, a *series* of different niches. Figure 1 lists the different professions of infants in their first year of life as they appear in the *Dictionary of Occupational Titles*, along with their accompanying job descriptions. The behavior an infant will display at any point in time—including what the infant will learn and remember—is constrained by its niche and current habitat.

THE ENERGY BUDGET

Caloric Income   Caloric Expenditure

food

TOTAL ENERGY

heat transfer

growth
activity
heat loss
body temperature
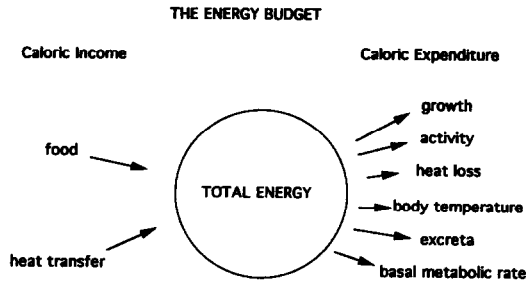excreta
basal metabolic rate

Figure 2. The energy budget, showing (left) the ways organisms can acquire energy and (right) spend it. Expending more energy on one activity requires either spending less energy on others or increasing the total energy income.

Today, I will focus on the infant's first two niches because they encompass the ages on which my research has concentrated. Consider the first one—*Body-Builder*. For approximately the first 9 weeks of life, infants are incapable of physiological regulation and must depend upon behavioral regulation for survival. Adolph (1968) characterized the newborn's regulatory arrangements and their interactions as the major constraint on infant behavior and the environmental conditions that it can tolerate. This is best understood in terms of the *energy budget* (see Figure 2).

The major problem facing all newborn mammals is to grow, which requires converting as many calories as possible into tissue (Kennedy, 1967). The optimal solution to this problem is to maximize caloric income and minimize caloric expenditure. As you can see at the left, there are only two ways to gain calories—through ingestion and heat transfer from a warmer body—but, as you can see at the right, there are many ways to spend them. To maximize the number of calories available to spend on growth requires minimizing the number of calories spent elsewhere. Thus, calories can be saved by minimizing activity of all forms, reducing heat loss, maintaining a lower body temperature, lowering the basal metabolic rate, and becoming more feed-efficient. While behaviors such as clinging, rooting, and sucking bear an obvious relation to caloric income, behaviors that reduce caloric

expenditure, such as quiescence and postural adjustments that reduce the surface area from which heat is lost, are less obvious. The energy equation predicts that the Body-Builder will learn and remember whatever facilitates growth—either behaviors that increase energy income, shown at the left of the figure, or behaviors that decrease other sources of energy expenditure, shown at the right. However, if the target behavior in a learning experiment competes with behaviors that facilitate growth, then the Body-Builder either will not learn it or will not express it. Either way, the infant will appear to be unable to learn when, in fact, it would be biologically imprudent to do so.

Rule 1. Infants CAN Learn Many
Different Relations, and They CAN
Learn Them Early On, But What They
Actually DO Learn (or Express)
Are the Relations That Suit Their Needs.

A number of years ago, Marcy Gekoski and I proposed that energy relations constrain early learning (Rovee-Collier & Gekoski, 1979). We argued that low-energy responses that permit exploration and manipulation of the infant's environment without competing with behavioral solutions to the infant's growth and regulatory problems should be learned readily, but high-energy responses should not. Thus, we were not surprised that Solkoff and Cotton (1975) failed to find evidence of learning in terms of increased footkicking in premature infants who were studied in the mobile conjugate reinforcement paradigm 4 to 6 weeks after birth. In contrast, Thoman and Ingersoll (1995) reported that premature infants did learn directional body movements that brought them into contact with a "breathing" Teddy Bear that had been placed in their isolette. In addition to showing an increased amount of contact with the bear, they located it more rapidly over time. Why did premature infants learn this? We can assume that infants would not have learned to find the bear had there been no net benefit for doing so. Thoman, Ingersoll, and Acebo (1991) previously reported that the rhythmic stimulation provided by the breathing bear increased the amount of quiet sleep in premies in the weeks following birth. Their finding suggests

what one benefit might have been. This is an example, then, of a learned response that reduces energy expenditure.

As predicted by the energy budget, the very young infant also learns behaviors such as orienting, rooting, mouth opening, and sucking that are associated with the identification, procurement, and ingestion of milk (Blass, Ganchrow, & Steiner, 1984; Lipsitt & Kaye, 1964; Marquis, 1931, 1941; Papousek, 1967). Because newborns cannot know beforehand what specific benefits will result if they exhibit these behaviors, these behaviors are ideal candidates for experimental studies of learning. Thus, Butterfield and Siperstein (1972) found that newborns sucked longer when their sucks were synchronized with music than when the music was synchronized with the pauses between sucks; DeCasper and Fifer (1980) showed that newborns sucked preferentially to hear the voice of their own mother versus that of a strange mother; and Eimas, Siqueland, Jusczyk, and Vigorito (1971) showed that slightly older infants sucked to produce the speech sounds /p/ and /b/. Because none of the infants in these studies received milk for sucking, why did they learn these relations? Of course, we can observe that sucking is not very costly. The ultimate benefit, however, was originally suggested by Skinner. He wrote, "Any organism which is reinforced by its success in manipulating nature, apart from any deprivation, will be in a favored position when important consequences follow" (Skinner, 1953, p. 78).

There also are more specific benefits. Consider, for example, the DeCasper and Fifer (1980) finding that infants learn to suck selectively to hear their own mother's voice. DeCasper and Prescott (1984) subsequently eliminated postnatal experience as the underlying factor for their preference by exposing newborns postnatally to their father's voice and finding no preference for it. Then, French researchers put a microphone in the pregnant mother's uterus and discovered that it recorded only her speech sounds and not the speech sounds of others within a normal speaking range (Querleu, Renard, Versyp, Paris-Delrue, & Crespin, 1988; Versyp, 1985). Meanwhile, Noirot and Algeria (1983) had reported that hungry breast-fed newborns root in the direction of their mother's voice irrespective of the arm in which they are held, that is, whether

they must root to the left or to the right to locate the breast. Therefore, learning the mother's voice *in utero* increases the efficiency with which the newborn localizes a food source.

The facility with which newborns learn appetitive responses is matched only by the difficulty with which they acquire defensive ones. The biological advantage of anticipating an appetitive event is clear—infants can increase the efficiency with which they locate, procure, ingest, and process food. Moreover, newborns have the behavioral capacity to do this. In contrast, newborns are motorically incapable of escaping or avoiding aversive events signaled by cues in the environment. The conditioned eyeblink, a defensive response, is an exception (Little, Lipsitt, & Rovee-Collier, 1984). Instead, the newborn's first line of defense is to cry, alerting a parent, who is biologically invested in providing around-the-clock protection. Not surprisingly, most of the successful examples of aversive conditioning in infants have been obtained after the age of independent locomotion, when the infant is more likely to be at a distance from the protection afforded by the parent. This is reflected, for example, in the timing of the onset of fear of strangers (Kagan, 1979), social referencing (Sorce, Emde, Campos, & Klinnert, 1985), and fear of the visual cliff (Bertenthal & Campos, 1990).

In addition, very young infants lack shutdown mechanisms for some response systems, such as the response system associated with ingestion. This should not be viewed as a maturational deficit but as the result of *selection pressures that have favored behavioral persistence* in some response systems critical to the survival of the very young, particularly when the optimal stimulus for responding is present, such as a nipple in the mouth. A baby lamb, for example, will continue to take milk from a bottle even while milk is dribbling out of the sides of its mouth. Likewise, nursing rat pups will not acquire a taste aversion if a flavor in the dam's milk is paired with an injection of LiCl that makes them sick but will continue nursing from the dam (Martin & Alberts, 1979). For preweanlings, however, the dam is the sole source of food, and it would obviously be maladaptive for pups to avoid nursing. However, preweanlings who are made sick while ingesting the flavored milk will display the learned taste aversion later, after they have been

weaned, avoiding a solid food that is saturated with the same flavor (Gubernick & Alberts, 1983). We conclude, then, that nursing rat pups could learn and did learn the relation between a novel flavor and sickness, but they simply could not express this learning until they had other ingestive options.

On the other hand, *selection pressures have also favored behavioral shut-down* in response systems associated with reducing energetic costs, such as the inhibition of distress (Gekoski, Rovee-Collier, & Carulli-Rabinowitz, 1983).

Rule 2. Infants are Perfectly Adapted at Every Point in Ontogeny.

Adolph (1968) speculated that over the course of evolution, selection pressures operated most strongly early in development and concluded that infants are perfectly adapted at every point in ontogeny. This is an important point to remember. Just as we consider the adaptive benefit of various kinds of learning, we should also view a learning failure—not as cognitive deficit (in, for example, habituation, aversive conditioning, and discrimination learning)—but in terms of the disadvantage that a particular kind of learning or its expression might confer.

Let me cite one final instance of the Why question vis-à-vis the newborn's niche. In 1972, the Introductory Psychology text I was teaching from proclaimed that "newborns' sense of smell is rudimentary at best." I knew from my own dissertation research years earlier (Rovee, 1969) that newborns' sense of smell is probably better than it ever will be again in their lifetime. But, *why* is their smell so good? Teicher and Blass (1977) showed that when a chemical found in the amniotic fluid is wiped on a mother rat's nipples, as it normally is when she cleans off her newborn pups and then licks her ventrum, the pups use this olfactory information to find her nipples and attach to them. If the mother's nipples are washed first, the pups will never attach to them.

Macfarlane (1975) reported that newborn humans could discriminate the odor of their own mother's breast from the odor of another

Figure 3. A 1-month-old infant producing conjugate illumination of a visual target by means of high-amplitude sucks. (Photograph courtesy of E.R. Siqueland).

Figure 4. A 3-month-old infant performing a differentiated response of the left leg to produce mobile conjugate reinforcement.
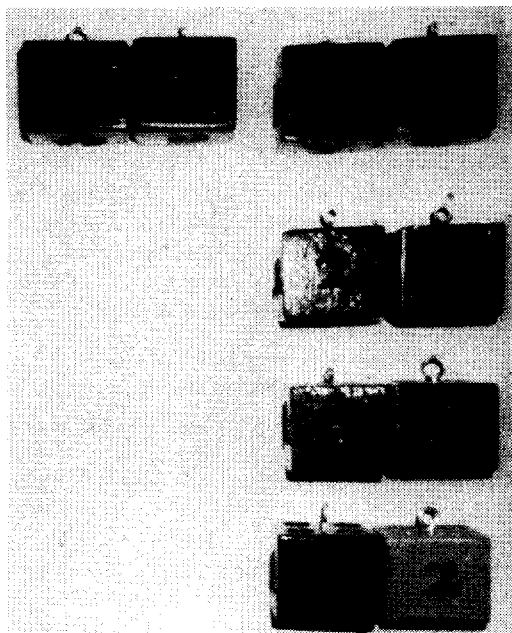

Figure 5. The two sets of combinations, shown on the blocks at the left, with which all 3-month-olds were trained. These were a black A on a red block or a yellow 2 on a green block. The test recominbations are shown in the right column. They were a switch in *figure color*, in *figure form*, in *block color*, or a *block-color/figure-color reversal*. *(From Bhatt & Rovee-Collier, 1994, 1996).*

lactating mother and preferred it. In addition, breast-fed infants exhibited behavioral calming to a breast pad that had been worn by their own mother but not to a breast pad worn by another lactating mother (Schaal et al., 1980). Porter and his colleagues (Porter, Balogh, & Makin, 1988) asked if bottle-fed infants whose mothers were not lactating could likewise recognize maternal odors. To this end, they simultaneously presented infants with two gauze pads that had been worn in the underarm area by the mother and an unfamiliar adult. Although breast-feeding infants oriented preferentially to their mother's underarm pad, nonbreast-feeders did not. In ancient hunter-gatherer societies, of course, all infants were breast-fed. Their ability to recognize their own mother and discriminate her by her odor from others in their extended family was clearly adaptive. The finding that mothers can also recognize their own infant's odor—as can other closely related family members—suggests that olfaction may subserve the more general function of kin recognition (Porter et al., 1988).

Next, consider the infant's second niche— *Inventory Control Officer* (see Figure 1). Marcy Gekoski and I had also proposed that when the infant's physiological regulations became functional, usually by 9 weeks of age, the infant would be liberated from the energetic constraints on its behavior and could acquire energetically more costly responses (Rovee-Collier & Gekoski, 1979). In fact, infants who occupy this niche learn a vast amount of information about their environment as well as how to control significant features of it—including their caregivers. Thus, for example, infants quickly learn to cry when their wind-up mobile has wound down, apparently so that their mother will appear rapidly to rewind it—which they usually do. Infants also pick up information

about their environment by visually exploring it. As a result, they quickly discover that they can produce "interesting spectacles" in it.

Thus, Siqueland and DeLucia (1969) reported that 4-month-olds more than doubled the proportion of their high-amplitude sucks within 4 minutes when they were conjugately reinforced with colored slides of geometric forms, cartoon figures, and human faces (see Figure 3), and we found that 3-month-olds learned with equal rapidity when their footkicks were conjugately reinforced by the movement of a crib mobile (see Figure 4; Rovee & Rovee, 1969). Although 8-week-olds also learned the mobile task, their kick rate was decidedly lower (Davis & Rovee-Collier, 1983; Vander Linde, Morrongiello, & Rovee-Collier, 1985).

As Inventory Control Officers, infants must also acquire information when there is no specific reinforcement contingency for doing so. In two studies of feature binding, for example, 3-month-olds were trained with a six-block mobile containing three blocks each of two sets of feature combinations (Bhatt & Rovee-Collier, 1994, 1996). The two sets of feature combinations were *black As on red blocks* and *yellow 2s on green blocks*. These two training combinations are shown on the pair of blocks at the upper left of Figure 5. Groups were tested with a mobile on which a single feature from one of these two sets was switched with the corresponding feature from the other set, while the two remaining features in each set were unchanged. The test recombinations—a switch in figure color, in figure form, in block color, or a block–color/figure–color reversal—are shown in the right column of Figure 5.

During testing 1 day later, infants discriminated every recombination except the figure–block chromatic reversal (the recombination that is most apparent to adults), which they discriminated after 1 hour (Bhatt & Rovee-Collier, 1994). After 3 days, they had forgotten which figure color went with which block color but still discriminated which figure form went with which block color; after 4 days, they had forgotten this relation as well. Even after this delay, however, they still recognized the original colors and figure forms they had been trained with, and discriminated if a novel figure color, a novel form, or a novel block color was substituted for one of the original features on

the test mobile (Bhatt & Rovee-Collier, 1996). These data reveal that infants learn feature correlations earlier than previously thought. Learning exactly which features go with which others, *even though there is no specific reinforcement for doing so*, is just part of the job of an Inventory Control Officer.

In her dissertation, Boller (1993) showed that infants also pick up information about correlations in their environment *before* they have ever learned anything about the significance of this information. In Figure 6, the left column shows the typical delayed recognition performance of 6-month-olds who are trained and tested with the same mobile in the same context; the middle column shows the typical recognition failure of infants who are trained and tested with the same mobile in a different context; and the far right column shows the test performance of infants who had been simultaneously exposed to two contexts, Context A and Context B, for 1 hour daily for 7 days. (The context was defined in terms of the immediate visual surround—a distinctively colored and patterned cloth that was draped over the sides of the playpen during training.) Later, infants in the latter group learned to kick to move a mobile in one of these contexts (Context A) and then were tested in the context (Context B) that had previously been paired with it. Apparently, when infants had been exposed to the two contexts simultaneously, Context A had been associated with Context B. As a result, the infants were subsequently able to recognize the mobile in a context different from the one in which they were trained (see Figure 6, right panel). Infants who had been initially familiarized with the two contexts for the same amount of time but separately, at different times of day, did not recognize the mobile in Context B after training in Context A, behaving like infants in the middle column of Figure 6. This example illustrates the important fact that infants had learned that Context A and Context B went together long before they were given an occasion to *express* this knowledge on a transfer test. Again, this learning occurred in the absence of a specific contingency.

It seems clear that the preceding examples are only the tip of the proverbial iceberg in terms of the kind and amount of information that infants who occupy this niche spontaneously pick up
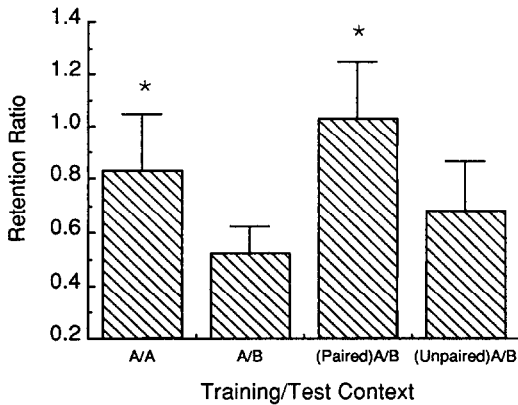
Figure 6. Mean retention ratios of four groups of 6-month-olds who were trained in Context A (a distinctively colored-and-patterned playpen liner) and tested in either the same context or a different one. Groups A/A and A/B received no preexposure treatment. Group(Paired)A/B was simultaneously exposed to Contexts A and B (i.e., paired) for 1 hour/day for 7 days before being trained in A and then tested in B. Group(Unpaired) A/B was successively exposed to Contexts A and B at different times a day (i.e., unpaired) for a total of 1 hour/day for 7 days before being trained in A and tested in B. The letters before and after the slash indicate the training and testing contexts, respectively. An asterisk indicates that the group exhibited significant 24-hour retention (M baseline ratio significantly > 1.00). Vertical bars indicate ± 1 SE. (From Boller, 1993, Experiment 1).

from their environment but are given no opportunity to express. Recent research by Baillargeon and her students (e.g., Baillargeon, 1995; Needham, Baillargeon, & Kaufman, in press) has revealed more of this information.

Just like 6-month-olds, 3-month-olds also "pick up" information from their environment simply by passively observing it, and they do so with uncanny rapidity. In a series of studies, we found that if infants learned to kick to move a particular mobile and, at some point within the next few days, they were briefly shown a novel mobile or another object in motion, then they would treat that new object as if they had actually been trained with it and would attempt to move it later by kicking (Greco, Hayne, & Rovee-Collier, 1990; Rovee-Collier, Adler, & Borza, 1994; Rovee-Collier, Borza, Adler, & Boller, 1993; Rovee-Collier, Greco-Vigorito, & Hayne, 1993). Note that this also occurred

even though infants *were never reinforced* for kicking in its presence and *had never practiced* doing so. If the passively exposed object was not moving when infants saw it, however, then they did not kick when tested with it later. The latter result eliminates stimulus generalization as an account for their subsequent test behavior. Apparently, because the new object *functioned* like an object infants had already learned to control, they did not have to learn how to control it; instead, they simply associated it with the old object in memory. This example also reveals how infants' prior memories are updated and expanded—clearly an adaptive capacity for very young organisms who encounter more things that are novel than are not. I will return to this issue later.

Deferred imitation is another example of learning by passive observation. Here, instead of seeing a novel object display an action that they already know how to produce and do so the next time they see the object, infants see a person display an action on a novel object and imitate it the next time they see the object. Meltzoff and Moore (1994) asked why infants display deferred imitation of an individual who models an action such as sticking out his tongue. Their answer is intriguing. They proposed that infants label the person's social identity in terms of this act. Later, when the infants display deferred imitation, they are asking the modeller, in effect, "Are you the person who sticks out his tongue?" Deferred imitation is just another of the many activities of an Inventory Control Officer.

Inventory Control Officers must also keep track of temporal-order information, or What happens When, and place information, or What happens Where. They do both. In the case of temporal-order information, 6-month-olds who were trained with a list of three mobiles for 2 minutes each on 3 days displayed a classic primacy effect (see Figure 7, left panel) when tested on the fourth day with a single mobile from either the first, second, or third serial position (Merriman, Rovee-Collier, & Wilk, in press). When the length of the list was increased to five mobiles, infants recognized all of the mobiles on the list and discriminated a novel test mobile, but they no longer displayed a serial position effect. Apparently, they had learned item information but not order information when the list was longer. As a direct test of whether infants in the original study had

learned the serial order of the three-mobile list, new groups were again trained with a three-mobile list and were tested with the mobile from serial position 2 or 3, but this time they were primed immediately before the recognition test with the mobile from the immediately preceding serial position. Excerpts of these data are shown in the right panel of Figure 7. Infants recognized the mobile from serial position 2 if they were primed with the mobile from serial position 1 but not if they were primed with the mobile from serial position 3. Infants tested with the mobile from serial position 3 recognized it only if they were successively primed with the mobile from serial position 1 and then with the mobile from serial position 2 (Gulya & Rovee-Collier, 1996).

In the case of place information, even 3-month-olds know when they are in the crib or in the place where they had played the mobile game (Hayne, Rovee-Collier, & Borza, 1991). Undoubtedly, they know other place information

as well, such as the changing table, the feeding chair, and other significant places associated with specific kinds of activities. We know this because if infants learn to move the mobile or a miniature train in one place and then the location is changed at the time of testing, then they do not recognize the mobile or the train in the new place—even though they readily recognize it in the old one. That is, infants do not recognize a familiar object "out of context." In one study, 3-month-olds were trained in a portacrib in their bedrooms, allowed to forget the task, and then were reminded in the kitchen—a familiar room but not where they were trained (Hayne et al., 1991). Even though the portacrib was draped with a distinctively colored and patterned cloth liner during both training and reminding, the reactivation treatment failed to recover the memory in the different room. Apparently, differences in the remote place cues that were visible above the portacrib precluded memory reactivation.

We obtained the same result at 6 months when infants learned a train task in one room and were later reminded with the same train in a different room in their house (Hartshorn & Rovee-Collier, in press). The reminder did not work there, although it did in the original room. Even if they had been reminded in the original room, however, infants who were tested in a different room the next day failed to recognize the original train (see Figure 8, far right column). In contrast, their retention was excellent if they were tested the next day in the same room (Figure 8, second column from left).

Although the retrieval context constrains early memory, once infants are able to self-locomote, either by crawling or scooting about in a walker, their definition of context seems to change. Before this time, they know what happens in what place, but they do not know how to get there. Once they can get there without being carried, however, they acquire spatial relations along with their new navigational skills and begin to construct a cognitive map. This behavior characterizes infants' next niches—*Map Maker, Levels I & II* (see Figure 1). As shown in Figure 9, a Level-I Map Maker learns to *fill in the arrows between the places it had previously learned about.* This is particularly important because *once these different places become related to each other, the memories of events that transpired in those places also become associated with each other.*
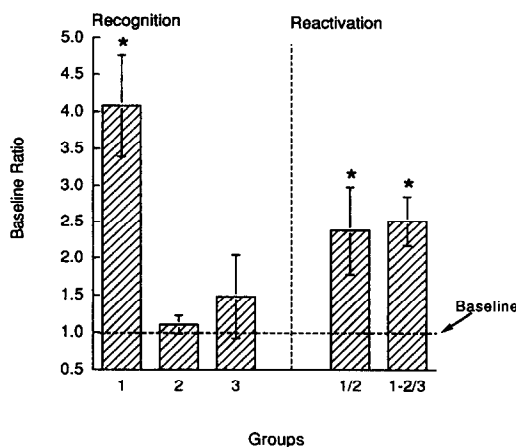

Figure 7. Left panel: Six-month-olds displaying a classic primacy effect in a 24-hour recognition test with mobiles from serial positions 1, 2, and 3 on a training list. Right panel: Facilitated 24-hour recognition of mobiles from serial positions 2 and 3 immediately following priming by the mobile(s) preceding the test mobile on the training list. Asterisks indicate significant retention (M baseline ratio significantly > 1.00); vertical bars indicate ± 1 SE. (From Gulya & Rovee-Collier, 1996.)
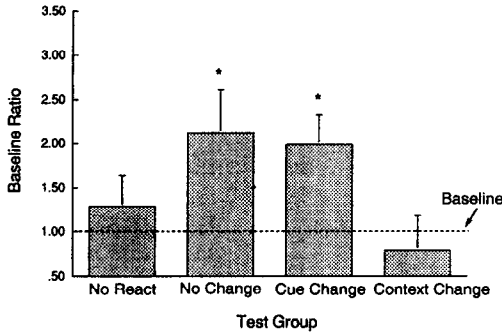
Figure 8. The memory performance of 6-month-olds 1 day after a successful reactivation treatment (3 weeks after the end of training) showing that recognition was impaired when the place where infants were trained was changed at the time of testing. *Group No Change* was tested with the original cue (a miniature train set) in the original context (a room in the infant's house); *group Cue Change* was tested with a different cue in the original context; *group Context Change* was tested with the original cue in a different context; and *group No React* (a forgetting control) was tested without having received the reactivation treatment 1 day earlier. Asterisks indicate significant retention (*M* baseline ratio significantly > 1.00); vertical bars indicate ± 1 *SE*. *(From Hartshorn & Rovee-Collier, in press).*
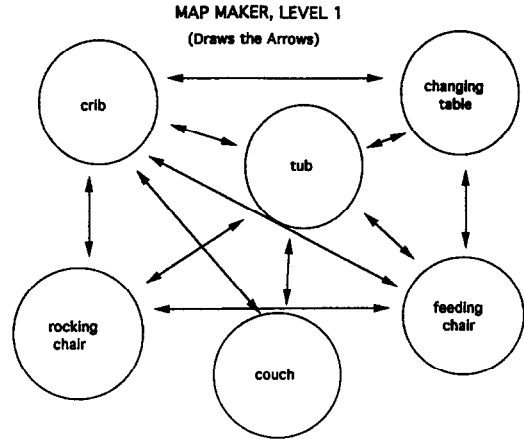

Figure 9. Once an infant begins to locomote, the infant becomes a Map Maker, Level 1 (see Figure 1). Infants who occupy this niche learn the spatial relations or links (i.e., they draw the arrows) between the places they had previously learned about. Once these places are linked or associated, so too are the memories of events that transpired in them. The result is an apparent cognitive leap because a memory that was encoded in one place can now be indirectly activated or brought to mind by directly activating another memory that was encoded in a different place.

For infants who occupy these niches, changing the room where they learned the train task no longer impairs retention. This is true both at 9 and 12 months (Aaron, Hartshorn, Klein, & Rovee-Collier, 1994). Similarly, 14-month-olds who saw actions modeled in either the laboratory or the day-care center readily produced those actions a few days later when they were tested at home (Hanna & Meltzoff, 1993). Obviously, infants in the latter study had not learned to drive themselves from home to the day-care center by this age, but they had clearly acquired a memory link between "here" and "there."

Rule 3. Infant Learning and Memory is a Problem of Economics, Not Capacity.

The preceding data suggest that what infants learn and remember is a problem of economics, not cognitive capacity. First, consider capacity. Figure 10 shows that the maximum duration of retention of infants trained and tested in a stan-

dardized procedure with standardized parameters increases monotonically over the first year of life. These data were collected from 2- to 6-month-olds trained for 2 days in the mobile conjugate reinforcement paradigm (Rovee & Rovee, 1969; Sullivan, Rovee-Collier, & Tynes, 1979) and from 6- to 18-month-olds trained for 2 days in a new task (Hartshorn & Rovee-Collier, in press) that we developed for infants too old for the mobile task. In this new task, each lever press briefly moves a miniature train around a circular track within a fairly complex stimulus display.

There are several important points to notice in Figure 10. First, at 6 months of age, infants' memory performance in the two tasks is identical (Hartshorn & Rovee-Collier, in press). Second, there is no indication that memory changes abruptly in the last part of the first year, when a qualitatively different memory system has been hypothesized to emerge (Kagan & Hamburg, 1981; C.A. Nelson, 1995; Schacter & Moscovitch, 1984). Third, there is
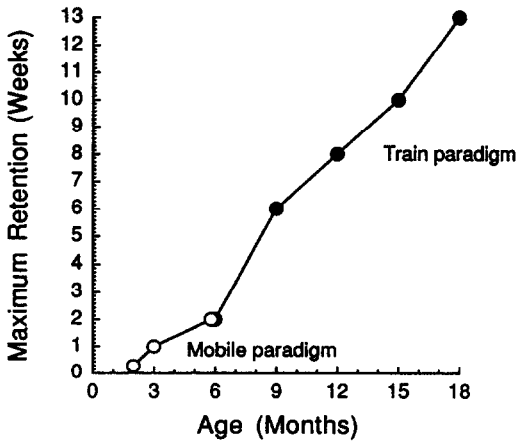
Figure 10. The maximum duration (in weeks) of retention exhibited by infants over the first 18 months of life. Infants were trained under standardized conditions with task parameters calibrated to yield equivalent immediate retention; independent groups were tested in increments of 1 week until they exhibited a baseline level of performance for 2 consecutive weeks. Two-, 3-, and 6-month-olds were trained and tested in the mobile conjugate reinforcement paradigm (*open circles*); 6-, 9-, 12-, 15-, and 18-month-olds were trained and tested in a miniature-train paradigm (*filled circles*). Long-term retention at 6 months was identical irrespective of task. (*From Hartshorn & Rovee-Collier, in press.*)

Shore, 1987) and the reenactment paradigm (Hudson, 1994; Sheffield & Hudson, 1994).

So much for capacity. Next, consider economics. As we saw earlier, infants learn what pays off. If the cost of learning exceeds the benefit of doing so, then they will not learn it. If the benefit exceeds the cost, they will. Thus, newborns will not learn to kick to move a mobile, but they will learn to suck at a high rate to turn on a recording of their mother's voice. Even after they have been behaviorally liberated from energetic constraints, however, infants will continue to behave economically. For example, 3-month-olds initially learn to move the mobile by kicking both feet. After playing the game for 30 minutes or so, however, they begin to kick the foot without the ankle ribbon less often, even though there is no specific contingency for doing so—the mobile will move whether one or both feet move, as long as the foot with the ankle ribbon moves (see Figure 11).

We were surprised when we first noticed this response differentiation because infants were thought to be bilateral at this age. Yet, like college undergraduates, infants expend the minimum amount of effort necessary to produce a desired outcome. In the preceding case, they reduced their energy cost by decreasing the activity of the second leg. Morrongiello subsequently demonstrated that when control of the mobile was shifted to the other foot, its kick
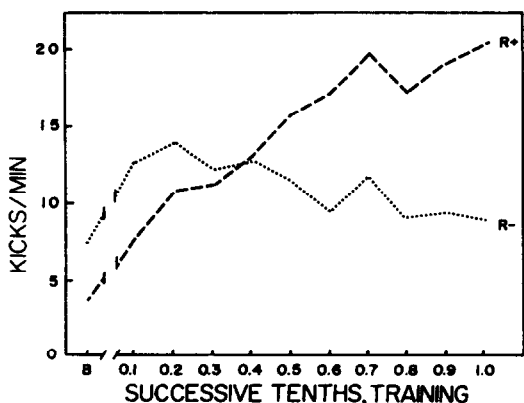
no indication that memory changes qualitatively with the appearance of language (K. Nelson, 1989). In addition, the degree of brain maturation is *not* the rate-limiting step in infant memory. Although this figure shows that 2-month-olds remember for only 2 days, they will remember for 2 weeks—just like 6-month-olds—if their same total training time is distributed into three 6-minute sessions instead of the standard two 9-minute sessions, shown here. Likewise, 3-month-olds typically remember for approximately 1 week; yet, they will remember for at least 6 weeks—just like 9-month-olds—if they are simply exposed to a brief reminder on two different occasions (Hayne, 1990). The standardized retention function shown here is not unique to my particular paradigm. Similar durations of retention have been reported with paradigms that are vastly different, including the deferred imitation paradigm (e.g., Bauer &

Figure 11. Mean kick rates of reinforced (R+) and nonreinforced (R–) feet during baseline (B) and over successive tenths of training (vincentized scores) of 3-month-olds. (*From Rovee-Collier, Morrongiello, Aron, & Kupersmidt, 1978, Experiment 2.*)
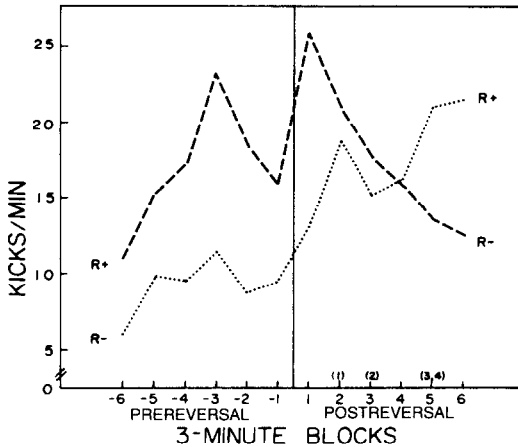
Figure 12. Mean kick rates of reinforced (R+) and nonreinforced (R–) feet over successive 3-min blocks preceding and following a switch of the mobile to the second (previously empty) mobile stand. Both legs were connected by an ankle ribbon to an overhead mobile stand, but the mobile was hung from only one of them. Data from the 4 infants (of 5) who successfully mastered the reversal are shown; the numbers in parentheses indicate the successive blocks at which each infant first exhibited the reversal behaviorally. (From Rovee-Collier, Morrongiello, Aron, & Kupersmidt, 1978, Experiment 2.)

frequency increased, and kicks of the original foot decreased (see Figure 12). Moreover, infants learned this reversal more rapidly than the original response differentiation, again in the absence of an experimenter-imposed contingency (Rovee-Collier, Morrongiello, Aron, & Kupersmidt, 1978). Thus, what young infants will and will not learn is determined by the economics of learning it.

I began this presentation by asking the Why question: *Why* do infants remember what they do for the length of time that they do, and *why* do they forget what they do? This leads to a consideration of *infantile amnesia*. Little more than a decade ago, scientists thought that infants' memories were highly transient, and infantile amnesia was attributed to this (Moscovitch, 1984). When researchers found that infants could encode, store, and retrieve information after relatively long periods of time, however, it became patently clear that the earlier account of infantile amnesia was wrong. Many of us then attempted to

account for infantile amnesia by appealing to changes in context between encoding and retrieval, a developmental shift from visual to linguistic encoding, changes in the brain mechanisms thought to be responsible for long-term memory, and so forth. None of these attempts has proven satisfactory.

Over time, I have come to view the question of infantile amnesia, "Why do adults not remember events from early childhood—before the age of 3 or 4?" as being much like the question, "Have you stopped beating your wife lately?" That is, *the basic premise of the question is wrong*. I propose that *adults actually can and do remember what was experienced early in life*, particularly if they have periodically re-experienced it in the meantime. Moreover, I think that adults use much of this long-maintained information on a regular basis.

One reason adults think that they cannot remember their early memories is that they have lost access to the particular memory attributes that represent when and where they first encoded a particular memory; as a result, they cannot pinpoint the *origin* of these memories. This does not mean, however, that the memories did not originate early on. In fact, our research has shown that the memory attributes which represent place information are quite fragile: They are "washed out" if the memory is retrieved in a variety of different contexts (Amabile & Rovee-Collier, 1991; Rovee-Collier & DuFault, 1991). They are also "washed out" even if the memory is repeatedly retrieved in the original context, if the retention intervals are long enough. Hitchcock, for example, found that a memory which was forgotten, reactivated in the original context, and then forgotten again was already context-free by the second time it was reactivated (Hitchcock & Rovee-Collier, 1996).

The second reason adults may fail to identify a memory as having originated early in life is that its *content* has probably been updated—perhaps many times—to reflect more recent circumstances. This reason is addressed in detail below.

Rule 4. There is a Logical Relation Between Learning and Memory.

Twenty years ago, Bob Bolles (1976) wrote that there is a logical relation between learning and memory: Were it not for learning, members

of the animal kingdom would have nothing to remember; and were it not for memory, they would never be able to learn in the first place. As the infant's niche changes, what the infant learns also changes. From this, it follows that the infant's memories must change as well. This occurs, for example, when the behavior that is appropriate in a given situation at one age becomes inappropriate at another. However, the infant need not relearn everything anew. It is, in fact, much more economical to simply update a prior memory than to acquire a completely new one. And, such updating is more likely to occur more often when organisms are young and in periods of rapid change than when they are older.

Updating memories to reflect changing circumstances does not mean the loss of the original memory. We have found that the updating process can either *replace* one of the original memory attributes or supplement them (Boller, Grabelle, & Rovee-Collier, 1995; Boller & Rovee-Collier, 1992, 1994; Boller, Rovee-Collier, Gulya, & Prete, in press; Muzzio & Rovee-Collier, 1996; Rovee-Collier et al., 1994; Rovee-Collier, Borza, et. al., 1993; Rovee-Collier, Greco-Vigorito, & Hayne 1993). Which of these occurs depends on the age of the infant, whether the new information is central or peripheral to the original event, and the interval between encoding and updating. Not surprisingly, the shorter the interval, the more likely is the new information to supplement the old; the longer the interval, the more likely is the new information to replace the old.

Rule 5. A Rose By Any Other Name is Still a Rose.

Even if a memory that originated in infancy or early childhood has undergone so many transformations that it is no longer recognized as such, it is still the same early memory. An analogous scenario is played out as an infant is transformed into a child or young adult—slight changes in the infant from one day or week to the next are not noticeable, but if a person has not seen the child for awhile, the change is quite obvious—in fact, the person may not recognize the child at all! Yet, the child is the very same individual who once was the infant. In short, *those seeking to explain infantile amnesia are trying to explain a phenomenon that does not exist.*

"It's a poor sort of memory that only works backwards," the Queen remarked. (Lewis Carroll: *Alice's Adventures in Wonderland and Through the Looking Glass*)

The function of memory is reflected in this remark made by the Queen of Hearts to Alice. The Queen was describing the advantages of having a memory that works both ways—in the future as well as in the past. In fact, as records of our past experiences, our memories function as the data base that informs our present and future behavior (see also Bruner, 1964). Today, I have argued that the time has come to move beyond the search for *mechanism* and consider the *function* of infant behavior. I have also argued that answers to the Why question will ultimately rest on an evolutionarily based understanding of the infant's ecological niche. Although I have focused on early learning and memory, this is only one small piece of the puzzle.

Currently, the field of infancy is fractionated into highly specialized areas such as face recognition, attachment, play, symbolic development, sensory and motor development, categorization, imitation, spatial learning, object search, perceptual development, language development, emotional development, social development, and so forth. Each of these areas is an important piece of the puzzle and was originally obtained by asking the What question. The Big Picture of this puzzle, however, will emerge only when *all* of its pieces are fit together. As researchers in these areas of specialization and others, we have now arrived at a point in our science where each of us can begin to ask the Why question and contemplate how our own, separate pieces might fit into the puzzle to yield the Big Picture. In this way, we can begin to achieve an understanding of infant behavior and development that is broader, richer, and more integrated—as well as a greater sense of community—than the current situation permits.

Shifting the focus from What to Why should not be taken to mean that we should stop asking What. In fact, asking the Why question will lead to many new What questions that we had not before thought to ask. Also, although some of our initial Why answers may turn out to be less than satisfactory, we still must see how the pieces fit together so that we can determine what pieces we are still missing. In the process, the notions that we entertain and the hypothe-

ses that they generate can open entirely new avenues of inquiry. In short . . . *it's time to get this baby off the ground and see if it flies.*

THE FAR SIDE By GARY LARSON
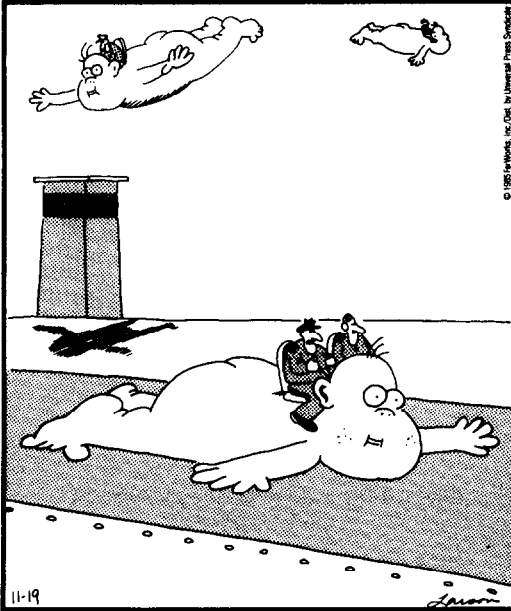
"Fuel ... check. Lights ... check. Oil pressure ... check. We've got clearance. OK, Jack—let's get this baby off the ground."

Figure 13. THE FAR SIDE © 1985 FAR-WORKS INC./Dist. by UNIVERSAL PRESS SYNDICATE. Reprinted with permission. All rights reserved.

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