

# When a Toddler Starts Handling Multiple Detached Objects: Descriptions of a Toddler's Niche Through Everyday Actions

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Using the *Akachan* Movie Database (Sasaki et al., 2006), a movie database of infants' niches, this article considers the issue of what *is* around the development of action in early childhood and its implications on behavioral flexibility and nesting of actions. A toddler's activity of repeatedly gathering toy blocks into a container, observed over the period of 10 months at home, was extracted from the database for the analysis. In the activity, 42 toy blocks, their container, and its lid—"detached objects" according to J. J. Gibson's (1979/1986) term—were around the toddler, giving a variety of meanings to the toddler's actions. Longitudinal study of the setting found that there was a range of postures employed in the activity, and the change of postures across the periods reflected the meaning of the layout of surfaces surrounding the activity. Along with the change of postural variations, the emergence of novel action coordination was observed in which an invariant spatial relationship between the detached objects and the toddler was maintained in such a way to facilitate the act. The close relation found between the meaning of the environment and behavioral flexibility and nesting of actions in the activity supports the proposition that such properties of action are the symptoms of functional coupling to the ecological resources available in a situation.

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What *is around* when actions develop in early childhood? Although the question appears to be straightforward, one rarely finds this question addressed in the literature of child motor development. In the last couple of decades, it has been increasingly emphasized that actions are always embodied and embedded, that is, always performed by an animal with certain body dynamics and always performed in an environment with certain opportunities and constraints (Adolph & Berger, 2006; Bertenthal & Clifton, 1998). As such, in order to understand the development of motor action, one must know something about what there is in the environment, as the functional outcome of action is bound to the properties of the surrounding environment (Adolph & Berger, 2006). Surprisingly, however, very few studies have attempted to describe what *is* in the natural environment where the development of action in early childhood actually takes place.

Consider, for instance, studies on the development of manipulation skills in infancy. Piaget (1952), who regarded prehension as one of the first forms of deliberate action, studied the development of the act of grasping of his three children. The description of what surrounds the action that appeared in the study was mostly limited to the objects he presented to his children: his hand, a rattle, a cloth doll, a package of tobacco, a cigarette lighter, a tobacco pouch, a roll of tinfoil, a pencil, and so on. In Piaget's account, grasping begins as movement "without any interest in the objects themselves" (Piaget, 1952, p. 120). With this premise, Piaget's emphasis was more on the process of externalization and objectification of objects as opposed to the properties of objects themselves that may afford, support, constrain, motivate, and invite actions.

Likewise, most of the studies on the development of the act of reaching have little to say about what is around the development of manipulation in infancy (e.g., Thelen et al., 1993; von Hofsten, 1989). In Thelen et al.'s study, for instance, infants were supported by means of a broad torso strap in a specially constructed infant seat that allowed free arm movement, and headrests were provided for young infants with poor head control. Small, attractive, graspable toys were presented to the infants at midline, shoulder height, and just at the distance of their extended arms (Thelen et al., 1993). What *is* around the infants here was so simplified that the study focused on the transition of movement kinematics and underlying mechanisms of infants' reaching rather than the resources used in the natural environment. Despite its remarkable finding that the process of learning to reach can take multiple paths depending on infants' intrinsic dynamics, the study does not address the opportunities and constraints of the environment. The following example of Reed (1989) might be relevant to clarifying what has been overlooked in these studies:

Consider, for example, a toddler who wants to engage in activity at a play table, perhaps manipulating blocks or a puzzle. She brings her tiny chair or stool over

to the table, sets it up, and begins to play. But she has not noticed that she has placed the chair a relatively great distance from the table surface. . . . At any rate, she quickly discovers that she “cannot reach” all her toys well enough to play. She gets frustrated and perhaps even complains that she “can’t do it.” . . . Indeed, the toddler in this story cannot do it. But what exactly is it that she cannot do? . . . Casually, we might say that “she cannot reach.” Yet reaching is precisely what the child can do. What she cannot do is set up the situation so that she can use her reaching skills effectively. (pp. 19–20)

As Reed (1989) implies here, in our daily lives the functional outcome of reaching—bringing a hand to an object—does not distinguish movements of arms from postural adjustments or from anything that contributes to the goal. The success of the action depends not only on the child’s bodily capabilities but also on what is around her that can be used to achieve the goal.

This article, by taking into account what is in the natural environment, attempts to present a view that allows a different way to look at the development of action in early childhood. The purpose here is twofold: to lay out the issues concerning what is around action and to report on an observational study based on the *Akachan* Movie Database (Sasaki et al., 2006)—a movie database of infants’ niche—to address the issues raised. First, the theoretical background underlying this research is discussed, more specifically, the problems raised by Köhler (1917/1959) as well as J. J. Gibson’s (1979/1986) ecological approach. The article then introduces the *Akachan* Movie Database and reports on the study based on the database.

## KÖHLER’S PROBLEMS

Köhler’s study of chimps in the early 20th century was among the first to point out that leaving out the environment can give rise to serious confusion regarding animal behavior (Köhler, 1917/1959). In the study, Köhler presented facts that contained at least two problems: (a) how multiple subordinate actions are organized into a coherent act that reflects a situation and (b) how an action can take different routes without changing its meaning.

One of the chimps, Tschego, for instance, was brought into the situation where a box was placed in a barred room against the bars, and outside the bars opposite the box bananas lay on the ground. They could be reached easily if the box were moved or even knocked over. Tschego did nothing but stretch and grope toward the bananas while seated on the box for nearly 2 hr. But when some other young chimps were introduced and gathered closely around the bananas, Tschego gripped the box, jerked it backwards, stepped up to the bars, and took the bananas. Tschego was again led into to the same situation on the following

day. This time Tschego seated herself beside the box and seized the box, tripped it over backwards into the room, and took the bananas. It took barely a minute for Tschego to achieve the objective, but the movement by which she disposed of the box “was quite different from that of the day before: she did not repeat the innervations of yesterday” (Köhler, 1917/1959, p. 59).

With such facts, Köhler (1917/1959) refuted Thorndike’s (1911) idea that the adaptive behavior to a situation arises out of connections among meaningless units made by the subsequent rewards from success. According to Thorndike’s account, the structure of the situation in itself has no power to guide the behavior of an animal. A chimp cannot know whether the box she happens to touch is relevant to taking bananas before actually getting them, for at this point there is no opportunity yet for reward to work at all. If a chimp happens to move the box, there is no way for her to tell whether the direction in which she is moving the box is appropriate or not. When several subordinate actions that do not yield immediate success, such as moving a box, are required to achieve a goal, it is too unlikely for these subordinate actions to be arrayed accidentally to form a sequence of acts to achieve a goal. Thorndike’s theory does not provide an account for “roundabout behaviors,” the coherent organization of several subordinate actions to the surroundings to achieve a goal, which Köhler’s chimps were observed to be able to perform.

Moreover, according to Thorndike’s account, once some response to a situation is made, the recurring response has to take on the same movement. Even if, by chance, a chimp managed to put together several separate actions to succeed in taking the bananas, and a response were formed to the situation, then the chimp should respond to the same situation in exactly the same way as before. But, as we have seen, that was not the case. The manner in which the chimps moved the box out of the way varied both between and within individuals. What remained invariant was not the movement but rather the meaning of the action, namely, the removal of the obstructing box. Thorndike’s theory does not provide an account for the flexibility of animals’ actions, the ability of animals to achieve the same goal by alternate paths.

Although it has often been misunderstood, Köhler (1917/1959) never used the concept of “insight” as an explanatory principle. As Koffka (1935) rightly emphasizes, insight was introduced to Köhler’s work in order to establish the reality of one type of behavior and its irreducibility to another type. Köhler himself explicitly stated that “here we have only to exclude the idea that the behavior of the animal is to be explained by the assumption according to which the solution will be accomplished without regard to the structure of the situation, as a sequence of chance parts” (Köhler, 1917/1959, p. 170). Essentially, what Köhler did was to present facts containing new problems. And among the problems posed were that of the organization of actions and that of behavioral flexibility, which will be addressed later in the current study.

## GIBSON'S REALISM

The necessity of taking into account what is in the environment to understand the way of life of animals is nowhere better illustrated than in the ecological approach of J. J. Gibson (1979/1986). J. J. Gibson realized that a comprehensive theory of perceiving the environment required a commensurate description of the environment (Mace, 2005). To describe the ecological level of reality, as opposed to the realities of physics (e.g., particles, atoms, and the radiation of energy), J. J. Gibson established a triad of medium, substances, and surfaces that separate the substances from the medium. The medium for terrestrial animals is air, which is insubstantial and thus permits locomotion. Substances vary in substantiality, and the surface of a substance has a characteristic texture and layout. The fundamental ways in which surfaces are laid out have an intrinsic meaning for behavior, unlike the abstract concepts of physics (J. J. Gibson, 1979/1986). The layout of surfaces constitutes what they afford for animals; for example, an object that has its opposite surfaces separated by a distance of less than the span of the hand allows for grasping.

Furthermore, the layout of surfaces is specified by the pattern of energy in the environment. Lights from the sky and other light sources are scattered at surfaces and reach a steady state in the medium where light is ambient at all points. Ambient light to a point is inevitably structured by multiple reflections from surfaces in such ways to specify the layout of surfaces of the environment. Because the structure of ambient light surrounding a point is unique to that point, the structure also specifies the point of observation at the same time. There are an infinite number of potential points of observation in the medium, some of which are occupied by an observer with eyes, others of which are not occupied. But any observer can put their eyes at one of these points of observation and thereby see (J. J. Gibson, 1974). The fact that there is optical information specifying both the layout of surfaces and the point of observation does not depend on whether or not the point is occupied by a perceiver.

The layout of surfaces provides both utility and dangers. If there is information in the energy array that specifies them, then it follows that the meanings of the environment can be discovered by extracting that information. J. J. Gibson's (1979/1986) theory implies that values and meanings are external to the perceiver, and what there is in the environment is the basis of animals' functional activity.

## AKACHAN MOVIE DATABASE

Sasaki et al. (2006) created the "Akachan (infant) Movie Database," the world's first movie encyclopedia of infant niches. In the *Akachan* Movie Database, the

everyday behavior of 2 male infants born in fall 2001 is captured from their birth to 3 years of age. The recording was conducted at home on a weekly basis by the family of each infant. Other than the caretakers videotaping the babies' behavior, no specific tasks were imposed on the babies, and controlling the environment around them was avoided. Nine hundred forty movie clips were extracted from 160 hr of recorded material. Each movie clip was labeled with several keywords, 879 in total, and given a brief description. The movie clips are searchable by keywords, the names of the infants, and their ages. Users of the database can actually observe both the multiple affordances at two homes and the development of action of the 2 infants taking place at these settings at the same time.

The *Akachan* Movie Database is the first attempt to describe longitudinally with movie clips the niches of infants and what there is in the natural environment where infants develop their daily skills. It captures the behavior of the infants together with the features of the environment surrounding the 2 babies' lives, such as the objects with which they establish their actions or places where these actions occurred. Users are permitted to search the database with keywords that refer to features of the environment such as "ground" or "step." In the database, the meaning of substances, surfaces, places, objects, and events of the environment are described not by abstract measures such as dimensions but by the actual actions of the 2 babies.

### LONGITUDINAL STUDY OF A TODDLER'S ACTIVITY OF GATHERING TOY BLOCKS

Out of 160 hr of movie materials collected for the *Akachan* Movie Database, a particular setting in the environment was selected, and the movie clips where a child spontaneously engaged in a particular activity were extracted.

In the database, a set of toy blocks frequently appeared in movie clips of 1 baby from 14 to 24 months of age. The baby, from the very beginning, spontaneously engaged in the act of putting the blocks into the container, which eventually became the act of gathering scattered blocks in the container. All the scenes where the baby engaged in the act of gathering blocks in the container were extracted for close examination. Instead of controlling and setting a uniform condition that allows comparison between multiple participants, it was decided to extract and select recorded movie clips of 1 baby where a particular functional outcome was achieved.

#### Detached Objects

In the specified setting, 42 toy blocks, their container, and its lid—"detached objects," according to J. J. Gibson's (1979/1986) term—surrounded the baby.

The baby kept manipulating these multiple “detached objects,” transporting them from one place to another, rearranging them over and over. To make clear the subject matter, Gibson’s “detached objects” are briefly defined before going into the detail of the method of the study.

J. J. Gibson (1979/1986) tentatively made a list of the layout of surfaces with special use meaning. Among them is the “detached object,” the layout of the surface completely surrounded by the medium. A detached object does not share its surface with the substratum and can be detached from the ground and transported without breaking the surface. The meaning of a detached object is radically different from that of an object attached to the substratum. A tree can be held on to or climbed, whereas fallen detached branches of a tree cannot support an animal’s body. Instead, fallen branches can be transported, gathered in one place, and combined to make another meaningful surface layout, such as a raft, or used as an extension of the body, such as a rake. You can grab a strap in a train to stabilize your body, whereas a bag with a strap can be grabbed and be moved around.

A handheld detached object can be used as a tool. A flat object of moderate size and weight can be used as a tray. An elongated object allowed Köhler’s chimps to pull a banana beyond their reach (Köhler, 1917/1959). J. J. Gibson (1979/1986) commented, “When in use, a tool is a sort of extension of the hand, almost an attachment to it or a part of the user’s own body, and thus is no longer a part of the environment of the user. But when not in use, the tool is simply a detached object of the environment, graspable and portable, to be sure, but nevertheless external to the observer” (p. 41).

Moreover, a portable detached object can be put side by side with another object. Detached objects can be rearranged to modify a surface layout to explore and discover the new meanings in the environment. E. J. Gibson (1997) recollects that in one of her experiments, she handed a colored golf ball to a child and then exchanged it at the end of corridor to keep a young walker walking. Portable objects add a new meaning to the locomotion of an animal, more than just going from one place to another. Detached objects offer an opportunity for an animal to transport them to a new place and to modify the layout of surfaces so as take advantage of existing substances and surfaces of the environment.

Since ancient times, exploring new meanings through modification of the surface layout has been one of the most fundamental acts in our lives. Tidying up, for instance, is such an activity. In a metalogue by Bateson (1972), a daughter asks her father why things in her room get in a muddle. Both father and daughter agree that things do not get muddled up if nobody touches them. The father asks the daughter when she calls her paint box, dolls, books, and various detached objects “tidy,” and it turns out there are very few places that are tidy for each item. The father concludes that the reason things get in a muddle is “just because there are more ways which you call ‘untidy’ than there are ways which you call ‘tidy’” (Bateson, 1972, p. 5). The metalogue is meant to explain the concept of

the second law of thermodynamics, but it also illustrates how fundamental the act of tidying up is for humans who use multiple detached objects for various purposes in a semienclosed space.

Detached objects have special meanings for animal behavior. In the following study, a baby's behavior over a period of 10 months expressed a variety of meanings in these detached objects in complex everyday situations.

## General Method

The participant in the current study is a male toddler, Daiji, one of 2 children who participated in the *Akachan* Movie Database. Daiji has no known sensory or motor impairments and is from a Japanese, upper middle-class family.

When Daiji was 14 months old, a set of toy blocks was introduced to him. The set consisted of 42 blocks, a container, and its lid (Figure 1). From the very beginning, Daiji spontaneously transported the blocks, often into and out of the container. Within a couple of weeks, Daiji started reaching for scattered blocks on the floor and transported them into the container consecutively (Figure 2). In the movie clip when he was 18 months of age, after playing with the blocks, Daiji succeeded for the first time in gathering all the blocks on the floor into the container.

Out of 160 hr of video recording collected for the *Akachan* Movie Database, all the scenes where Daiji picks up blocks on the floor and puts them into the container more than twice in succession were extracted. There are 10 such scenes: (1) 14:17, (2) 15:0-1, (3) 15:0-2, (4) 18:29, (5) 23:14-1, (6) 23:14-2, (7) 24:9-1, (8) 24:9-2, (9) 24:9-3, (10) 24:9-4 (month:day-serial number within the same day). Due to the nature of the video materials used, the intervals between the scenes are not of equal length.

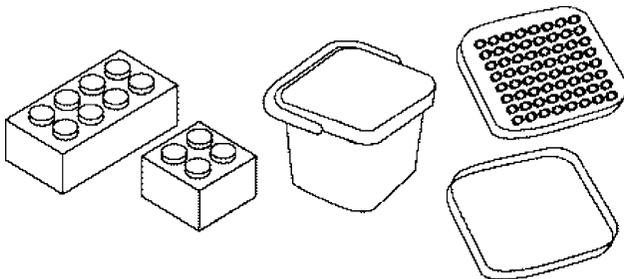


FIGURE 1 Toy blocks set consisting of 24 large blocks (64 mm  $\times$  32 mm  $\times$  20 mm), 18 small blocks (32 mm  $\times$  32 mm  $\times$  20 mm), and their container (opening: 160 mm  $\times$  160 mm, depth: 160 mm) with a detachable lid (wider surfaces: 175 mm  $\times$  175 mm, depth of the edge 20 mm).



FIGURE 2 A scene from 15:0–1.

The duration of each scene was measured. The beginning of each scene was defined as Daiji's action of touching the first block to put into the container. All 10 scenes started from the initial condition where no block is in the container. The ending of the scene was defined as Daiji's action of releasing the last block into the container before quitting the act. A brief description of each scene is provided in Table 1. Though not in their entirety, all of the 10 clips are included in the *Akachan* Movie Database, which can actually be viewed by anyone who has access to the database.

## STUDY 1: POSTURE

With respect to the persisting features of the environment, an animal's behavior consists of postures and movements (J. J. Gibson, 1975). Posture is the behavior of maintaining an orientation to the environment, and movement is the behavior of changing that orientation. For example, consider ocular behavior, which consists of stabilization of the eyes to the ambient optic array and occasional quick jerks from one stabilization to a new one (J. J. Gibson, 1974). The former is defined as "posture"—keeping one's eyes oriented to persisting features in the environment, often with compensatory rotation of eyes during the displacement of head. The latter is defined as "movement"—changing the orientation of the eyes and establishing a new relation to the environment. Note that both posture and movement involve active achievement of an animal in the environment. In our daily behavior, postures and movements are nested within one another at multiple levels. Standing, for instance, is an upright posture made up of

TABLE 1  
Brief Descriptions 10 Scenes

Age (Month:Day)	Duration	No. of Blocks Gathered	Notes
14:17	55 s	6 (including other toys)	The first time Daiji was observed to gather multiple blocks and toys into a container
15:0-1	49 s	9/42	
15:0-2	48 s	7/42	
18:29	92 s	42/42	The first time Daiji was observed to succeed in gathering all blocks into a container
23:14-1	113 s	42/42	
23:14-2	114 s	Container: 21, Lid: 14/42 (7 left on the floor)	Daiji gathered blocks both in a container and on a lid separately
24:9-1	127 s	42/42	Daiji started using a lid as a tray to transport blocks
24:9-2	136 s	42/42	
24:9-3	169 s	42/42	
24:9-4	76 s	25/42	The recording was stopped halfway before Daiji finished gathering all blocks

small compensatory movements, whereas walking is a movement that involves keeping an upright posture (J. J. Gibson, 1975). Following J. J. Gibson, posture is defined in the current study as dynamic relations between an actor and the environment, actively maintained by an actor and involving nested movements at various levels.

## Method

In the aforementioned 10 block-play scenes from 14 to 24 months of age, the underlying persisting postures while the toddler was engaged in gathering blocks were classified into five postures: sitting, kneeling, standing, squatting with locomotion, and squatting without locomotion (Figure 3). "Sitting" was defined as his body being supported by his buttocks on the floor. "Kneeling" was defined as his body being supported by his knees with his buttocks off the floor, often with a hand on the floor. "Standing" was defined as his body being supported by his feet on the floor with his legs straight. And "squatting" was defined as his body being supported by his feet on the floor with his legs bent.

While Daiji was in a sitting or kneeling posture, the position of his buttocks or knees remained at one spot, and he shifted his posture either to a squatting position or to a standing position when he moved around. While Daiji was in



sitting (27%)



kneeling (3%)



standing (7%)



squatting without locomotion (32%)



squatting with locomotion (31%)

FIGURE 3 Classification of posture and the proportion of total duration of each posture.

a standing position, he was almost constantly locomoting. When Daiji was in a squatting position, sometimes his feet remained in the same position for a long time, while at other times he locomoted with his legs bent and changed the position of his feet on the floor. To reflect such differences in his squatting posture, the squatting position was further classified into two postures: "squatting without locomotion," where his feet remained in one place more than 9 s, and "squatting with locomotion," where his feet changed positions within the interval of 9 s. 9 s was set as a threshold between a mobile posture (standing, squatting with locomotion) and an immobile posture (sitting, kneeling, squatting without locomotion) because the maximum duration of Daiji's standing on the same spot was 9 s. In other words, when Daiji was in a "standing" or "squatting with locomotion" posture, he was constantly moving without staying at one spot for more than 9 s.

All underlying postures while Daiji was engaged in gathering blocks fitted into one of the five postures mentioned earlier. The duration of each posture was measured in each scene, and the proportion of the duration of five postures in the 10 scenes was calculated by three raters, Tetsushi Nonaka, and two naïve graduate students with no prior knowledge of this research who were seeing the video clips for the first time. We assessed interrater reliability by calculating the intraclass correlation coefficient among the three raters. The two-way mixed model with measures of consistency was selected for the calculation of the intraclass correlation coefficient.

## Result

The average measure of the intraclass correlation coefficient among three raters was 0.996, indicating that three raters were in almost perfect agreement. Taking into account the extremely close correlation between the raters, the mean proportion of the duration of five postures in 10 scenes among three raters was calculated and presented in Figure 4.

Sitting was the dominant posture in the first four scenes from 14 months to 18 months of age, except in one, Scene 15:0–2. After 23 months, the proportion of sitting dropped to below 15%. Kneeling appeared only in the first four scenes, with its proportion constantly below 20%. Standing was always below 10% except in 15:0–2. And squatting became the dominant posture after 23 months, in which sum of durations of squatting with and without locomotion was constantly above 85%. However, squatting with locomotion was never observed in the first four scenes.

With the first appearance of squatting with locomotion at 23 months, the dominant posture shifts from sitting to squatting. The proportion of squatting with locomotion further rises in the last two scenes in 24:9, whereas squatting without locomotion drops to below 30%.

## Discussion

One interesting result is the classification of posture itself. In the 10 scenes, Daiji was never observed to lie down in a supine or prone position, but his posture always fitted into one of the five defined postures, in which his head and upper body are held upright. When Daiji was gathering blocks, his head and upper body always remained upright, which presumably played an important role in exploratory activity such as looking around. In other words, there was a certain invariant ecological relation maintained throughout the scenes. Under such invariance, there was also a variation of five postures, according to the classification adopted here.

By taking a look at what there was in the setting where such postural transition of the toddler occurred, it was clear that there was a certain layout of surfaces in the environment around where the toddler was gathering the blocks. First, the blocks, their container, and lid were always placed on the floor, which was sufficiently large to allow for the locomotion of the baby. These multiple detached objects—blocks, a container, and its lid—were typically scattered on the floor of the room (Figure 2). This situation required the toddler to move about to gather the blocks. In addition, as the blocks and the container were placed on the floor and the container was only 160 mm in height, the toddler needed to maintain a low posture to be able to transport the blocks on the floor to the mouth of the container. In sum, when gathering the blocks, there were certain motor problems arising from the layout of the surfaces surrounding the action, requiring the toddler to cover the extended area to reach the scattered objects as well as to keep a low posture to handle the objects on the floor. Whereas the flat, extended floor in the room allowed for the locomotion of the toddler, the detached objects allowed the transportation while in locomotion.

In a sitting and kneeling position, the toddler could keep a low posture while erecting the head and upper body upright. However, horizontal locomotion was not possible in these postures. According to our classification, when an object was out of reach while in a sitting posture, the toddler would either have to change his posture to move toward the object or give up reaching for the object. The latter, however, should not have happened after 18 months of age when Daiji learned to gather all the blocks on the floor.

In a standing posture, the toddler was almost always on the move. The posture offered an opportunity for the toddler to locomote across a wide area while erecting his head upright. In this posture, however, his hands and head were far from objects on the floor. In 15:0–2, Daiji was observed bending his body down while still standing on his feet with knees straight, still “standing” according to our classification, so as to drop blocks into the container. But he did not succeed and the blocks fell out of the container. It is likely that the reason “standing” did not appear so often is that the vertical transportation between the floor and the mouth of a container was unstable when the toddler was standing.

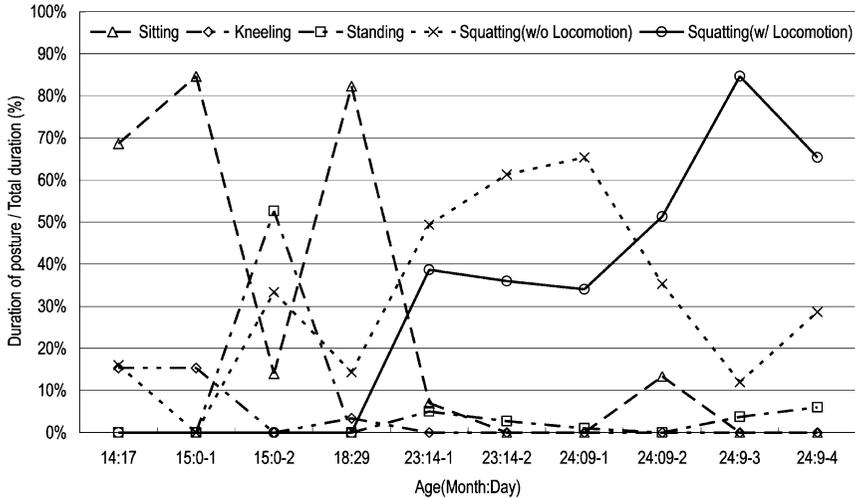


FIGURE 4 The proportion of the duration of five postures.

In a squatting posture, the toddler could keep a low posture while supporting his upper body erect. In addition, the squatting posture allowed the toddler to locomote while maintaining a low posture.

Figure 4 shows that Daiji's dominant posture shifted from sitting to squatting, which presumably gave him opportunities to cover a wide area as well as to stay close to the objects to be handled. To be sure, the layout of surfaces was not the only constraint, but Daiji's physical maturation should also have constrained the actions used. However, his physical maturation per se cannot *cause* such postural development. The change of proportion of five postures and its relation to the layout of surfaces suggest that the emergence of new variations of posture reflected the meaning of the surface layout surrounding the activity.

## STUDY 2: HAND USE IN REACHING

### Method

In the same 10 scenes where Daiji gathered blocks on the floor into a container, the frequency of hand use (left hand, right hand, and both hands at once) when reaching for blocks on the floor was counted. The proportion of the frequency in each scene is shown in Figure 5.

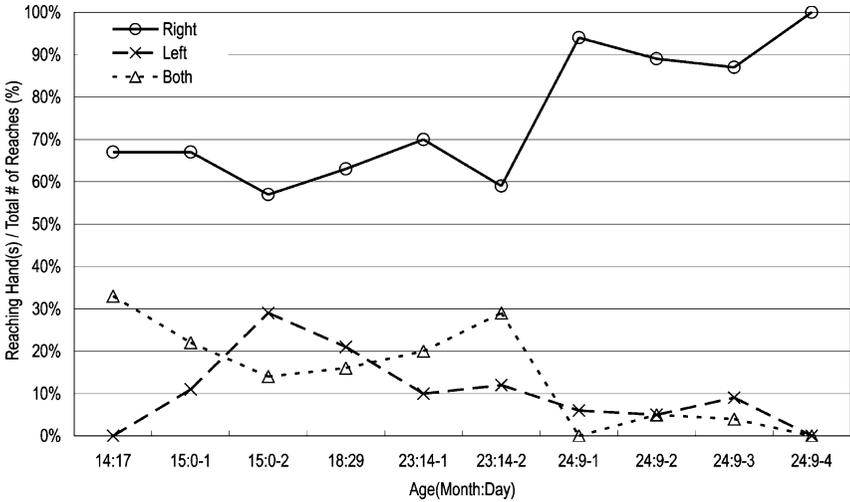


FIGURE 5 The proportion of the frequency of hand use in reaching for blocks.

### Result and Discussion

Right-hand reaching was preferred throughout the scenes. The proportion of right-hand reaches was especially high (constantly higher than 85%) in the four scenes at 24 months.

Considering that the blocks scattered on the floor were not always placed at his right hand, such high frequency of right-hand use must have been accompanied by some kind of adjustment of the spatial relation between the toddler and the objects. For, even if one has a strong hand preference, some postural adjustment is needed to use the preferred hand to reach for an object placed on the other side. The high proportion of right-hand reaches, especially in the scenes at 24 months of age, indicates that the toddler was obtaining certain relations to the layout of surfaces that allowed reaching for blocks with his preferred hand.

To examine how the toddler obtained the opportunity to reach with his preferred hand, four scenes at 24 months, in which the proportion of his right-hand use was especially high, are looked at in more detail in the following section.

### STUDY 3: THE ARRANGEMENT OF DETACHED OBJECTS

When the toddler was 24 months old, a new way of gathering blocks into the container was observed. The toddler first gathered blocks on the lid and then proceeded to use the lid as a tray to transport blocks into the container (Figure 6).

Apparently, the toddler was absorbed in this new way of gathering blocks, as even after all blocks were gathered, he emptied the container and did it over and over (four times in a row, hence, 24:9-1, 24:9-2, 24:9-3, and 24:9-4).

As the toddler gathered blocks in this manner, every time he locomoted to transport blocks on the lid to the container, the spatial relationship between objects and the toddler naturally changed. After having moved the lid to dump blocks into the container, the toddler would come back to the pile of blocks and would start picking up blocks in a new position (Figure 6).<sup>1</sup>

## Method

The position of objects in relation to the toddler was closely studied. Daiji transported the lid to pour blocks into the container 31 times in total, which divides each period into 32 segments. The spatial relationships in these 32 segments between the toddler, the lid, the blocks, and the container are examined and depicted (Figure 7).

### Result 1: The Spatial Relationships Between Objects and the Toddler

Spatial relations observed in the 32 segments between Daiji, the lid, the blocks, and the container are depicted with the toddler in the center. It turned out that all arrangement patterns that appeared during the act fit into one of seven patterns depicted in Figure 7.

In the scenes at 24 months of age, the most frequently observed actions of handling detached objects were as follows: (a) transporting blocks on the floor onto the lid (125 times), (b) transporting the lid to the container (32 times), and (c) transporting blocks on the floor directly in the container (12 times). The most frequent action by far was the transportation of blocks from the floor onto the lid. It was noted that the objects immediately involved in that particular action were the blocks and the lid, and considering this fact, the spatial relationships between the blocks and the lid in relation to the toddler (i.e., excluding the container) were reexamined. The dotted circles in Figure 7 indicate the relation of these objects in relation to the toddler.

In terms of these objects involved in the most frequent action, a certain spatial relationship between the objects and the toddler can be seen to consistently appear. In 30 out of 32 segments, the lid was placed on the left side of the blocks. From the toddler's point of view, the lid was almost always placed on the left,

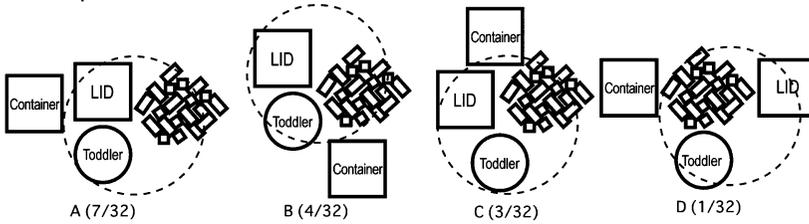
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<sup>1</sup>In addition to the movement of the lid and the self, the toddler was observed to move a container three times in total, two of which happened when picking up blocks that had fallen out of the container in the manner shown in Figure 9.



FIGURE 6 Change of the spatial relationship between objects and the toddler by moving the lid.

## The lid placed on the floor



## The lid held by hand

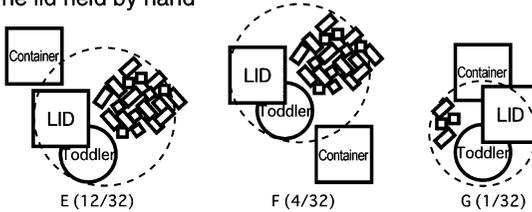


FIGURE 7 Seven spatial relationships appeared in 32 segments of four scenes in 24 months.

and the blocks were placed on the right side. The lid was, probabilistically, just as likely to be placed in any other position as the left side of the toddler. But, in fact, there was an invariant relationship between the toddler, blocks, container, and lid where the blocks were positioned on the right and the lid was on the left of the toddler. It sounds reasonable that the blocks are easily reached with the right hand when they are on the actor's right-hand side. The increase of right-hand reaching in this period is consistent with the frequent appearance of such relationships between the objects and the toddler.

Such increased specificity of the relation between the toddler and the layout of the objects suggest that the toddler was exploring the environment for an opportunity to handle the blocks and modifying the layout of surfaces to make available such an opportunity. As well as transporting the lid to carry blocks, the transportation of the lid was controlled to maintain an opportunity for handling blocks with a preferred hand. The property of the lid as a "portable" detached object offered the toddler opportunities to modify the layout of surfaces to further explore for and acquire affordances for gathering blocks.

## Result 2: Serial Order of the Appearance of the Spatial Relationships

The serial order of the appearance of the seven spatial relationships is shown in Figure 8. Each alphabetical letter corresponds to the spatial relationship depicted in Figure 7.



As mentioned previously, seen in terms of the objects involved in the most frequent action (i.e., excluding the container), A, B, and C are identical (presented as white letters) where the lid is placed on the floor on the left side of the toddler and the blocks. Similarly, E and F are identical (presented as black letters) where the lid is held by the left hand with the blocks on the right side of the toddler. The difference between the patterns presented as white letters and black letters is that the lid is placed on the floor in the former, whereas the lid is held by the left hand in the latter.

Figure 8 shows that there was a difference between the first two scenes (24:9–1, 24:9–2) and the last two scenes (24:9–3, 24:9–4) in the spatial relationships that tended to recur. In the first two scenes, there was a strong tendency for the patterns presented as white letters to recur, and once the pattern was acquired, it was retained successively as the toddler transported the lid with the blocks. In the last two scenes, there was a strong tendency for the patterns presented as black letters to recur.

In the study of posture (Figure 4), there was an increase of the proportion of squatting with locomotion in the last two scenes. Daiji was very mobile in 24:9–3 and 24:9–4, in which “the lid held by hand” (black letters in Figure 8) tended to recur. Daiji’s increased mobility in the last two scenes may be explained by the change in environmental constraints when the lid was attached to his hand. The lid, when attached to his hand, became an extension of the toddler’s own body and moved as the toddler moved, offering an opportunity for the toddler to locomote as he gathered blocks on the lid.

### Result 3: Emergence of New Spatial Relationships

Figure 8 also shows when these seven spatial relationships first appeared. In Figure 8, the circled letters indicate the first appearance of each spatial relationship. The patterns C and D appeared at the beginning of Scenes 24:9–1 and 24:9–2, when the toddler started gathering blocks into an empty container. The patterns A, F, and G first appeared right after some blocks fell out of the container when Daiji poured the blocks from the lid into the container.

It is interesting to note that new patterns often appeared when picking up the blocks that had just fallen out of the container. Figure 9 is an example of the acquisition of the new pattern A on such an occasion. Here, when the child poured blocks into the container, one of the blocks fell behind the container. He then moved the container away and placed the lid on the left next to the pile of blocks and acquired the new spatial relationship, A.

When any blocks fell out of the container as he dumped them, Daiji almost always picked them up immediately. There is no clear explanation as to why he did so. What is known is in such situations, the position of the fallen blocks constrained the toddler’s act of reaching. For, unlike the situation where



FIGURE 9 The acquisition of the new spatial relationship A after a block fell out of the container.

the toddler was allowed to pick up any blocks on the floor, he reached for the blocks that had fallen at a particular spot on the floor. In the face of such a change in constraints, the toddler was often observed exploring and acquiring spatial relationships between himself and the layout of surfaces (blocks, lid, and container) that made possible the goal-oriented action of putting the blocks in the container.

### Summary of the Results

Daiji spontaneously gathered blocks on the floor a number of times from 14 to 24 months of age. The summary of the data is as follows: (a) When Daiji gathered blocks, his head and upper body were always held upright. Under such invariance, there was a certain range of variation of postures—sitting, kneeling, standing, squatting with and without locomotion. (b) Daiji's postural change across the periods showed specificity to the layout of surfaces surrounding the task. (c) As Daiji became more mobile, the portable detached objects allowed the toddler to explore and acquire affordances through the modification of the layout of surfaces, which was reflected in invariant spatial relations between the objects and Daiji in the task.

## GENERAL DISCUSSION

In this study, the experimenters avoided controlling in advance the environment surrounding the toddler. Instead, situations where a toddler spontaneously engaged himself in the particular task of gathering blocks were selected afterward from the recorded materials. The data allowed for an examination of the environment supporting the development of action, which arguably has several important implications that supplement the current knowledge of early childhood development.

### The Meaning of the Environment Described by Actions

The observed postural progression of a toddler by no means resembled the general description of the development of postural control in the first 2 years of life after birth (Figure 10). The contrast between Figure 4 and Figure 10 implies that postural development in isolation from its environmental context is a fiction and that such "general" progression of postural development also could be the expression of normally occurring experiences of children in the natural human environment.

The toddler's activity of gathering blocks was afforded by blocks—graspable detached objects that allow transportation, and a container—the semienclosed

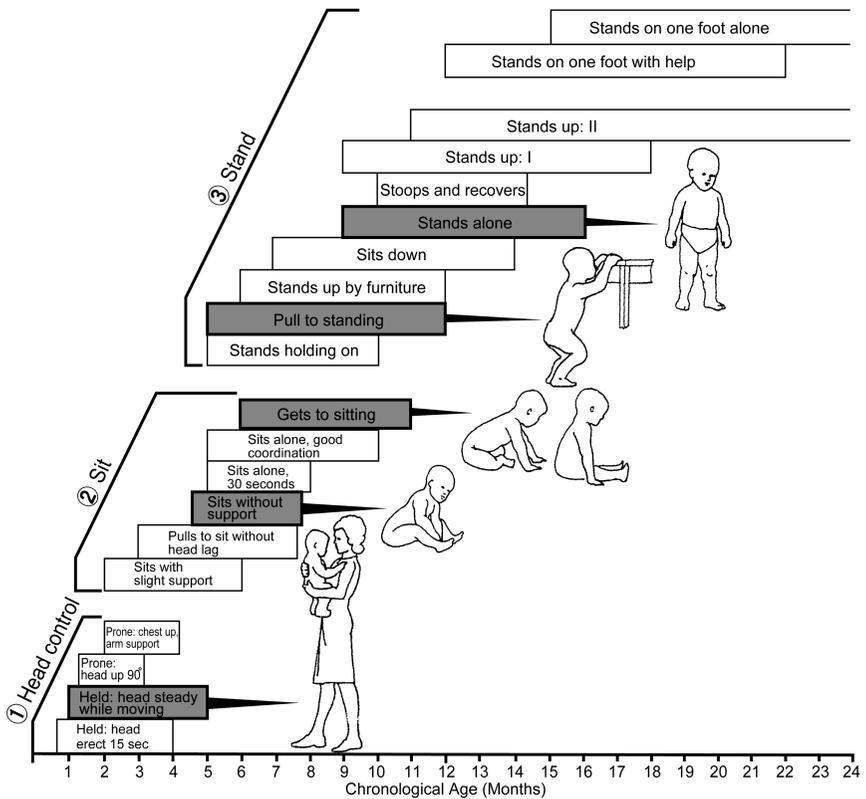


FIGURE 10 General progressions of change in postural control (adapted from Keogh & Sugden, 1985, p. 32).

layout of surface that allows blocks to stay inside. The fact that the activity was repeated over a course of 10 months illustrates the motivation that such objects had given to reaching, locomotion, and other motor actions that made up the task. Scattered graspable, portable blocks invited the toddler to reach for them, and the success of the action depended on posture and the relation between the objects and his body. The toddler almost always kept a low posture, and later locomotion was nested in a low posture in the mobile squatting posture. Such postural control and locomotion allowed the toddler to achieve the spatial relations that allowed for reaching and the transport of the blocks into the container. The toddler's postural change over the periods reflected the meaning of the layout of the multiple detached objects surrounding the activity, scattered across the horizontally extended floor. Interestingly, the squatting posture, whose increase during the activity was observed, has been almost entirely neglected in the

literature of child motor development despite the fact that it is a ubiquitous posture while resting, working, and playing all over the world except Western countries (Roussel, Bril, & Nonaka, 2007).

Ten months after the toddler started gathering blocks, a new meaning of the lid was discovered. The lid, a detached object with two parallel extended flat surfaces being close together relative to their dimensions, allows for the placing of multiple objects on top if the wider surfaces are held horizontal. The toddler kept the wider surfaces horizontal by either placing it on the flat floor or holding it with his hand. He gathered blocks on the wider surface of the lid and then transported it to pour the blocks into the container, taking advantage of its portability and flat extended surface.

At 24 months, there was an increase of the proportion of mobile posture as the toddler started holding the lid while gathering blocks. The lid, when attached to his hand, offered an opportunity for the toddler to locomote as he gathered blocks on the lid. In addition, the lid was used to obtain a spatial relation that facilitated gathering blocks, which was reflected in an invariant spatial layout maintained during the activity. And a novel action coordination in which a lid was used as a tray to transport blocks into a container reflected the new meanings the toddler discovered in his surroundings.

### Ecological Foundations of Flexibility

Daiji's actions, despite having the same functional outcome, were by no means cast in the same mold as each other. Instead, flexibility was observed at various levels of his activities.

Specifically, a considerable variety of subordinate activities was observed that set up the spatial relation between the objects and the body to achieve an invariant functional outcome of gathering blocks. As previously discussed, the toddler became increasingly mobile while maintaining a low posture. The specificity of postural variation to the layout of surfaces showed evidence of exploration of opportunities for the handling of objects placed in a certain arrangement on the floor. In addition, when the toddler began taking advantage of the portable, flat lid to gather blocks as he moved about, the position to put down the lid was selected in such a way to facilitate reaching for blocks with his preferred hand. Here, postural adjustment and modification of surface layout share an equivalent function in that they were both adjusted to maintain an opportunity for handling blocks on the floor. The difference lies not in the overall function but rather in the ecological resources used to achieve the functionally equivalent outcome. The former, postural adjustments took advantage of the flat extended floor that allowed locomotion to acquire certain spatial relations, whereas the latter also utilized portable detached objects that allowed for the modification of the layout of surfaces in relation to the toddler.

Such flexibility cannot be attributed to toddler's intrinsic property alone but must also be an expression of the environmental resources available in the situation.

In Köhler's (1917/1959) observation of the behavior of chimps who obtained an object fastened at a height from the ground, various parts of the environment shared the same affordance. The chimps discovered the same meaning in a box, a ladder, a table, stones, iron grills from the windows of the cages, tins, blocks of wood, and coils of wire, all of which "were indiscriminately collected and employed as ladders or footstools—objects which in the practice of chimpanzees are almost identical functionally" (p. 45).

Furthermore, just as a variety of layouts of surfaces afford the same goal, a variety of actions are made possible by the same surface layout of the environment. A toddler could reach for blocks on the left with his left hand or move around to reach for them with his right hand. The portable lid was used to obtain a spatial relation that facilitated reaching with his preferred hand as well as to transport the blocks as a tray. Köhler's (1917/1959) chimps used a stick as a rake, a vaulting pole, a missile, and as material to make a longer stick by combining it with another stick. In the case of Daiji, as well as of Köhler's chimps, upon the achievement of a specific function, both multiplicity of the environment and flexibility of action were found. Such equivalence of function is both the property of action and the property of the environment.

Regarding behavioral variability in motor development, Adolph and Berger (2006) listed the different styles of belly crawling in infancy, asking what was to be made of such variability. They went on to introduce the current conceptualizations of behavioral variability: variability as the loss of stability around phase transition, variability as a generator of an information-rich array of possibilities, and variability as both an active search for alternatives and as an impetus for exploration. Yet no remark was made on the multiple ecological resources on which behavior is based.

Behavioral flexibility, the variability of behavior to achieve a functional outcome, arguably reflects the range of ecological resources available in a situation that can be used to achieve the goal. Just as with natural selection, a function does not distinguish an animal from the environment but selects behavior of the animal-environment system that suffices to fulfill the function. As such, we cannot truly understand behavioral flexibility without taking into account the multiple ecological resources that are incorporated into the achievement of the goal. Rather, considering the fact that animal behavior is bound to and constrained by the properties of the environment at the outset, flexibility of behavior has its origin in the multiplicity of the ecological resources that provide a range of opportunities of action. Crawling, for instance, is made possible by what surrounds a baby, and its variability should reflect the ecological resources available in the unique situation of the baby.

In the literature of motor control, there is a widely known phenomenon called anticipatory postural adjustments. When a person is engaged in a goal-directed manual task, evidence of preparatory adjustments to compensate for the perturbation of balance can be observed in the muscles involved in postural control prior to the activation of muscles involved in the focal arm movement (Lee, 1980; Massion, 1992).

In early childhood, before 15 months of age, infants rarely show anticipatory muscle activations of the trunk and neck to prepare to reach when they are placed in an infant chair with the back of the chair and frontal bar for support or placed on a flat surface (van der Fits, Otten, Klip, van Eykern, & Hadders-Algra, 1999). However, some 9-month-olds sitting on the knee of a parent showed consistent anticipatory muscle activity of the trunk extensors during reaching (von Hofsten & Woollacott, 1990, as cited in von Hofsten, 1993). These results, as well as the data from the current study, support the view that anticipatory adjustments of action reflect the environmental resources available in a situation as well. When a toddler gathered blocks, he not only adjusted his body but also adjusted the position of the lid in a prospective manner to allow for reaching of the objects. By looking only at bodily movements in a controlled and narrowly focused setting, the ecological foundation of such functional adjustment can be easily overlooked. It has been frequently suggested that such adjustments are not uniform, like a reflex, but assume considerable variation in the muscles activated and the temporal sequencing of muscle activity (Lee, 1980; Reed, 1988). It is likely that the observed anticipatory postural adjustments in these studies reflect the experiment's laboratory setting and that the flexible adjustment of posture too is a symptom of functional coupling to the range of ecological resources available in a situation.

### Ecological Foundations of the Nesting of Actions

While gathering blocks in a container, Daiji kept an upright upper body posture, looking around, often locomoting, adjusting the positions of objects, reaching for objects and transporting them. All of these streams of activity continually overlapped and were organized into the overall act of gathering blocks into a container. As previously discussed, Köhler (1917/1959) raised the problem of how various activities are organized into a unified act to refute the view that animals are blind to the meaning of the environment. The current study's data suggest that such organization of action is closely related to the opportunities and constraints of the environment.

The data presented in this article show that there were a variety of ecological resources that could be incorporated in the achievement of the same goal, and a variety of actions were made possible in the same environment. A range of

opportunities in the environment did not trigger a fixed response but provided room for action to be selected according to the situation.

Daiji's action revealed several selection pressures by doing. First, out of the range of opportunities offered by the environment, actions were selected to achieve certain functional outcomes for themselves. Daiji's posture during the act, for instance, was constantly selected to keep his head and upper body in a stable upright position in relation to the surface layout of the environment. Daiji's reaching actions were controlled to grasp blocks on the floor. Daiji transported the lid to carry blocks into the container.

Second, out of the range of opportunities, overlapping actions were selected in such a way as not to interfere with one another. When blocks were out of reach, the toddler never reached for them by lying down or giving up the stable upper body posture. Instead, reaching was always selected in such a way to keep his stable upright head posture, presumably to allow exploration and other concurrent activities. The lid was transported not just to carry blocks but also to obtain certain positional relations among objects that facilitated reaching with his preferred hand.

Third, subordinate activities were selected to not conflict with the overall goal. When the toddler put blocks on the lid, for instance, he could have done so either by transporting the blocks from the floor onto the lid or by transporting the blocks from the container onto the lid. The latter, however, conflicts with the overall goal of gathering blocks into the container and rarely happened during the act. Out of the range of opportunities, actions were selected not to conflict with the larger unit of action of which they are parts.

There are undoubtedly many more selection pressures upon the realization of one's actions, from social to cultural, and this study does not aim to be comprehensive. However, the study does clearly demonstrate that coherent nesting of a variety of functional activities is based on a variety of opportunities of actions offered by the environment.

## CONCLUDING REMARKS

This article argues that describing what surrounds and supports action is just as much an indispensable part of an explanation of the childhood development of action as are the descriptions of what children do. The longitudinal description of a child's spontaneous activity and what was around the activity illustrated that behavioral flexibility and nesting of actions in the setting were inextricably bound to the meaning of the natural environment of the child. The inseparable relation we found between the meaning of the environment and behavioral flexibility and nesting of actions provides support for the idea that such properties of action

are the symptoms of functional coupling to the ecological resources available in a situation.

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## REFERENCES

- Adolph, K. E., & Berger, S. A. (2006). Motor development. In W. Damon & R. Lerner (Series Eds.) & D. Kuhn & R. S. Siegler (Vol. Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (6th ed., pp. 161–213). New York: Wiley.
- Bateson, G. (1972). *Steps to an ecology of mind*. Chicago: The University of Chicago Press.
- Bertenthal, B. I., & Clifton, R. K. (1998). Perception and action. In W. Damon & R. M. Lerner (Series Eds.); D. Kuhn & R. S. Siegler (Vol. Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (5th ed., pp. 51–102). New York: Wiley.
- Gibson, E. J. (1997). An ecological psychologist's prolegomena for perceptual development: A functional approach. In C. Dent-Read & P. Zukow-Goldring (Eds.), *Evolving explanations of Development* (pp. 23–54). Washington, DC: American Psychological Association.
- Gibson, J. J. (1974). *Lecture at The Ohio State University, May 23*. Available from [http://www.av.trincoll.edu/ramgen/data2/ISEP/Gibson\\_OSU.rm](http://www.av.trincoll.edu/ramgen/data2/ISEP/Gibson_OSU.rm)
- Gibson, J. J. (1975). Note for a tentative redefinition of behavior. In E. S. Reed & R. K. Jones (Eds.), *Reasons for realism: Selected essays of James J. Gibson* (pp. 385–392). Hillsdale, NJ: Erlbaum.
- Gibson, J. J. (1986). *The ecological approach to visual perception*. Hillsdale, NJ: Erlbaum. (Original work published 1979)
- Keogh, J., & Sugden, D. (1985). *Movement skill development*. New York: Macmillan.
- Koffka, K. (1935). *Principle of Gestalt psychology*. London: Routledge & Kegan Paul Ltd.
- Köhler, W. (1959). *The mentality of apes* (E. Winter, trans.). New York: Vintage Books. (Original work published 1917 as *Intelligenzprüfungen an Menschenaffen*. Berlin, Germany: Springer.)
- Lee, W. A. (1980). Anticipatory control of postural and task muscles during rapid arm flexion. *Journal of Motor Behavior*, *16*, 135–170.
- Mace, W. M. (2005). James J. Gibson's ecological approach: Perceiving what exists. *Ethics and the Environment*, *10*, 195–216.
- Massion, J. (1992). Movement, posture and equilibrium: Interaction and coordination. *Progress in Neurobiology*, *38*, 35–56.
- Piaget, J. (1952). *The origins of intelligence in children*. New York: International Universities Press.
- Reed E. S. (1988). Applying the theory of action systems to the study of motor skills. In O. G. Meijer & K. Roth (Eds.), *Complex movement behaviour: The motor-action controversy* (pp. 45–86). Amsterdam: Elsevier Science B.V.
- Reed, E. S. (1989). Changing theories of postural development. In M. H. Woollacott & A. Shumway-Cook (Eds.), *Development of posture and gait across the lifespan* (pp. 2–24). Columbia, SC: University of South Carolina Press.
- Roussel, D., Bril, B., & Nonaka, T. (2007). Squatting as a flexible posture to adapt to environmental surface layout. *Fourteenth International Conference on Perception and Action Proceedings*, 81–82.

- Sasaki, M., Okura, M., Takahashi, A., Hayashi, K., Seki, H., Nishizaki, M., et al. (2006). *Akachan movie database*. Unpublished.
- Thelen, E., Corbetta, D., Kamm, K., Spencer, J. P., Schneider, K., & Zernicke, R. F. (1993). The transition to reaching: Mapping intention and intrinsic dynamics. *Child Development, 64*, 1058–1098.
- Thorndike, E. L. (1911). *Animal intelligence*. New York: Macmillan.
- van der Fits, I. B. M., Otten, E., Klip, A. W. J., van Eykern, L. A., & Hadders-Algra, M. (1999). The development of postural adjustments during reaching in 6- to 18-month-old infants. *Experimental Brain Research, 126*, 517–528.
- von Hofsten, C. (1989). Mastering reaching and grasping: The development of manual skills in infancy. In S. A. Wallace (Ed.), *Perspectives on the coordination of movement* (pp. 223–258). Amsterdam: Elsevier.
- von Hofsten, C. (1993). Prospective control: A basic aspect of action development. *Human Development, 36*, 253–270.
- von Hofsten, C., & Woollacott, M. H. (1990). Postural preparations for reaching in 9-month-old infants. Unpublished manuscript.