Research Subject

Toward an ecological description of actions. —How does body movement specify the environment?— (Sasaki Group)

(1) Goal and summary

1. Relationship between objects and actions

An animal's actions are occured in the environment. Actions and the surroundings always go together and are not isolated from each other. Actions are closely interrelated to the environment.

As an example, the recent study on reaching shows that an infant's action of trying to reach an object undergoes qualitative changes during the one year after birth so that the relationship between reaching and objects will become closer[1]. A five-month old infant tries to reach an object with its both hands in 60objects – 3.7cm in diameter $\times$ 8.1cm in height; large objects – 8cm $\times$ 19cm). However, in the case of a 7-month old infant trying to reach an object with both its hands, 30% cases involve small objects and 70% cases large objects. In the case of an 11-month old infant, 30% involve small objects and 90discern the environment with greater sensitivity. Other than the description of the cases where an infant uses its both hands, this study shows that the angle between a thumb and a forefinger the infant widens to reach an object close to the size of the object. This shows that part of the nature of a target object is embodied in actions at different levels as improvement in an infant's skill in reaching an object.

As described above, it is relatively easy to compare an infant's action of reaching an object with the environment by means of a one-dimensional formula such as the size of an object. What is generally known as the "affordance perception research" pursued in the 1980s points out that the question of whether a person can see the possibility of performing a certain act by measuring the width of his/her shoulders or the width of an aperture or an opening the person is trying to pass through or the length of his legs and the height of the difference in level the person is requested to climb without using his/her hands (i.e. whether a person can pass through a narrow space without turning his/her shoulders around or climb a height without having a fall) is invariably interrelated to the size of the body used for such action[2].

The great significance of this type of study is indisputable. However, an action is movement of the body of an animal which could either be stiff or lithe. Accordingly, it would be difficult to generalize all these qualities merely on the basis of a "size" and it should even be more difficult to enumerate the qualities of the environment required for an action. Then, what methods are available to specify the relations between such action and the environment? The author challenged this difficult subject by making several attempts. Set forth below is part of the results of such attempts.

From the 19th century through the 20th century, a number of studies were made and discussions conducted by and among the psychologists over the matter of how the relationship between the environment and an action can best be described. In this report I would like to introduce some of these discussions by way of finding a linkage between the two.

2. Eggs

Case 1: An egg-shell protects the chick inside the shell from its outside enemies and sharp weather changes. When the chick becomes big enough, it has to crack the shell open with its bill not yet hard enough. The shell of an egg is a substance produced by evolution as constraint by such natural requirements and it is a unique object which is hard and brittle at the same time. In order to break the surface of a raw egg with a hand by hitting it against something, it is necessary to make the surface come in contact with an object and because the person performing such action has to deal with the unique qualities of such hardness and brittleness, the person faces the unique difficulty of such action.

We record 7 egg-cracking instances involving patient M at a rehabilitation hospital over a period of 10 months[3]. M was 42 years old at the time of our initial observation. M had a fall 6 months earlier and suffered an injury in the head. At first it was difficult for him to walk by himself and used a wheel-chair.

What was taken most seriously by those involved in M's medical treatment was that any action made by M was hardly based on his own intent. This was evident, for instance, from his inability to move in an orderly and smooth fashion; i.e. he failed to navigate a simple course and got lost on the way from the rehabilitation treatment room to his hospital bedroom or he was unable to complete the process of getting dressed, having meals or washing his face or hands in an appropriate manner. M showed signs of apraxia attributed to difficult planning of such movements and he was therefore diagnosed with the "higher order brain dysfunction"

As part of M's daily physical movement training program he began to make eggrolls. Before he succeeded in cracking an egg, he had to hit the egg against the edge of a steel cooking bowl about 23 times on the average (Fig. 1). For comparison, 8 healthy adults were observed while they were cracking eggs in a similar setting. They succeeded in cracking an egg after 2 to 7 hits, or after 4 hits on the average (Fig. 2). This shows that M had to hit an egg about 6 times more than in the case of such healthy people.

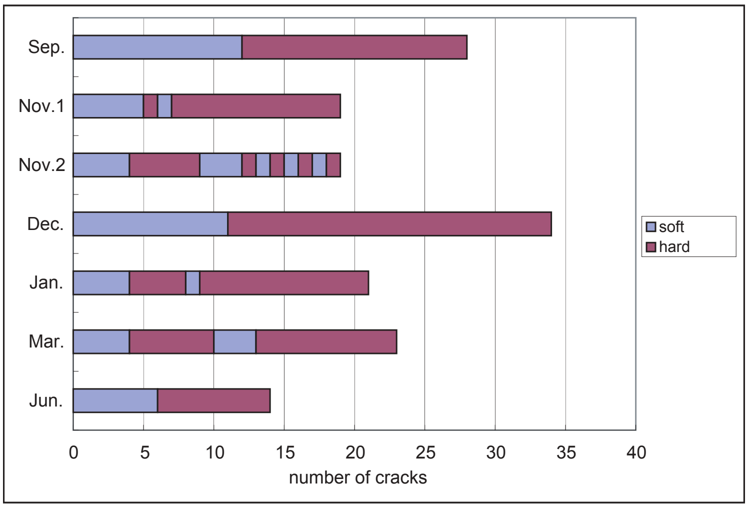

Figure 1: A sequence of movements by M cracking an egg.

What was common between M and those 8 healthy people was that they did not crack

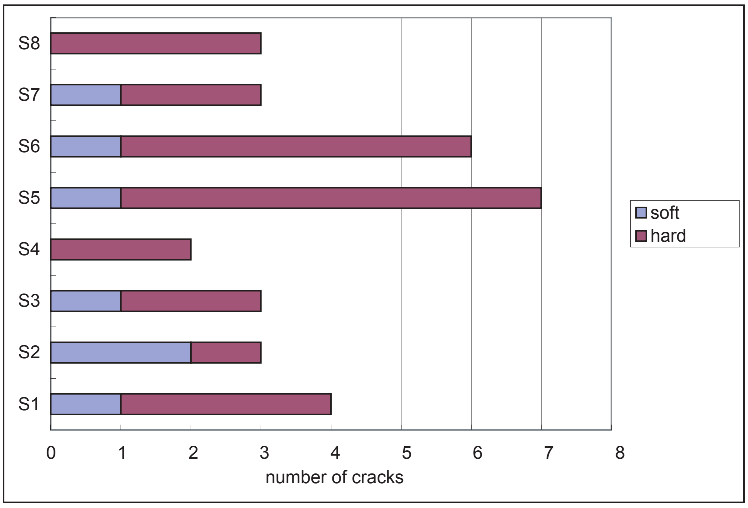

Figure 2: A sequence of movements to crack an egg by eight adults.

an egg with a single hit. In order for an egg to be cracked, more 2 hits had to be made. Close observation of the scenes on the video leads us to believe that there are 2 kinds of hits required for cracking an egg. Healthy people seemed to measure the hardness of an egg first by hitting the egg softly against a bowl once or twice and then to crack the egg with several "hard hits" after that.

In showing the hitting process employed by healthy people, Fig. 2 separates soft (exploring) hits from hard (cracking) hits. Fig. 3 introduces only one example. However, it shows the different levels of frequency distribution between soft hits and hard hits; i.e. in the case of soft hits there was relatively a larger frequency distribution of the power of the low frequency composition than in other zones and in the case of hard hits, there was the roughly equal distribution of power throughout the entire frequency range. These findings were obtained by isolating each hitting sound and using the power-spectral analysis. This type of acoustic analysis had given its endorsement to the results of observation of the video that the hits required for cracking an egg can be distinguished into two different kinds.

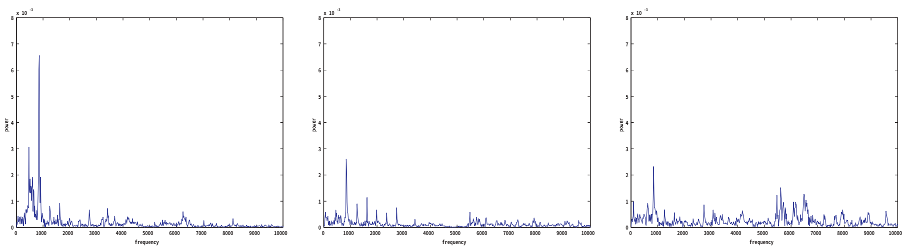

Figure 3: S3's sound spectrums of cracking an egg.

Fig. 1 shows M's 'long hitting process'. M's hits are classified into soft hits and hard hits based on the same standards as in the case of healthy people. In M's case, however, the difference between these two kinds of hits is not so clear as of healthy people. Fig. 4

shows the frequency distribution pattern of the 8 hits made by M starting with his first hit in November. A clear distinction between the two kinds of hits is not adequately shown. On this day M kept cracking eggs relatively with soft hits all occasion. Fig. 5 shows the results of analysis of the 8 hits made by M on the observation in June. As opposed to the November, a clear distinction will probably be made in June between the 5 soft hits and the 6th and other subsequent hard hits. This two data suggest that a chain structure of hits required for cracking an egg was captured during the 7-month period of M's egg-cracking process; i.e. hits were soft at first to gradually become harder as was the case with the healthy group of people. As referred to above, it was pointed out that M had a problem in planning his movements. As far as the practice of egg-cracking is concerned, M could successfully plan his act of cracking an egg by distinguishing between soft hits and hard hits and with the formation of a chain structure of the 2 classified hits.

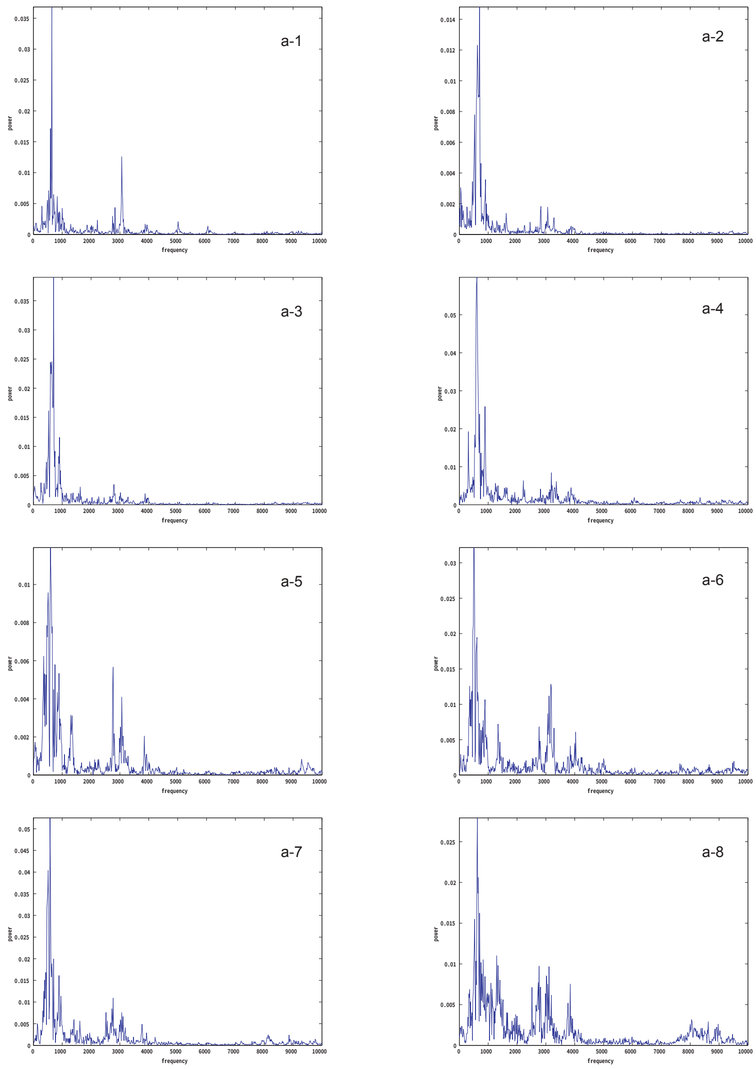

Figure 4: Sound spectrums from M's Nov.1 egg cracking trial.

The method of describing an egg-cracking practice as a number of hits seems to have succeeded in capturing a fragment of the change in M's practice. This method may rep-

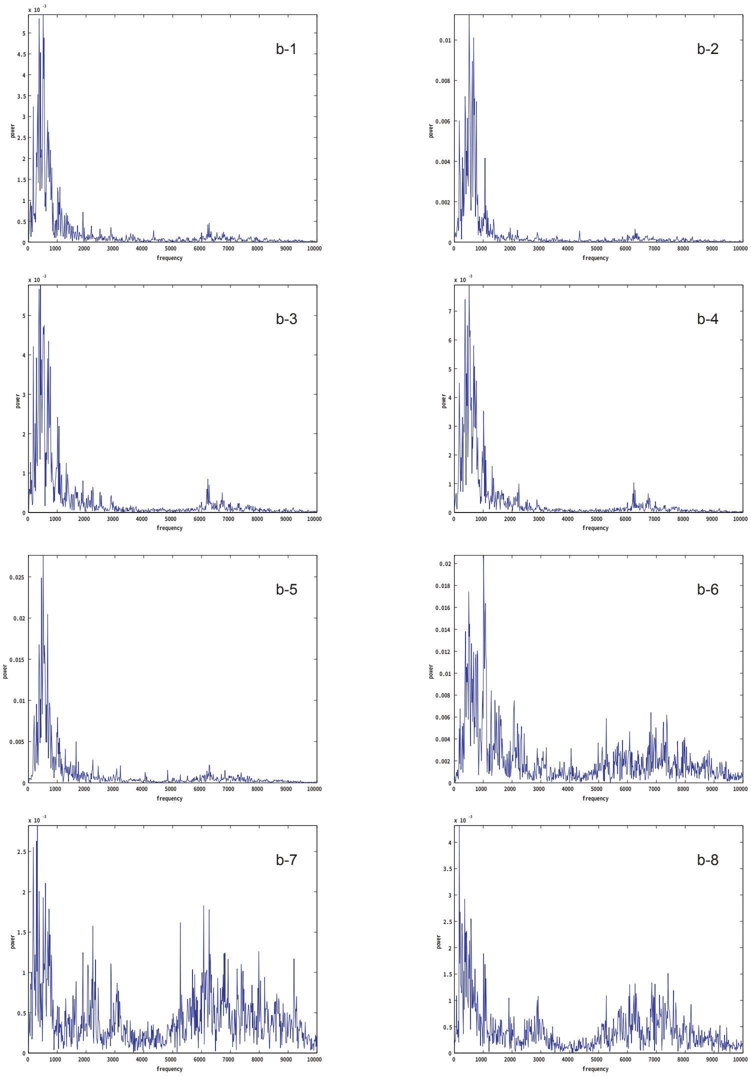

Figure 5: Sound spectrums from M’s June egg cracking trial.

resent a more general point of view than description of not only this example case but the relationship between an object and an action. It is as described below:

(1) An action interrelated to an object may be identified as a number of movements to contacts with the object.

(2) A number of movements can be differentiated in accordance with the ways in which they interact with objects.

(3) A chain structure of differentiated movements may be called an action.

(4) A chain structure of movements comprising an action may undergo changes in its order structure following its repetitious encounters with an object.

Theory 1: Bernstein's dexterity: One constituent part of the theoretical structure which describes an action as a chain of movements may be related to Berstein, N.A., a Soviet physiologist, who pointed out in early-20th century that enormous degree of freedom unique to an animal's movements is the central problem of its movement control[4]. He defined such an action as the embodiment of a series of movements which jointly resolve the task of movement. He advanced the theory that the goal of an action is to find a movement which provides a way to the solution of problems under any and all circumstances and he particularly referred to the structure of an action equal to the level as dexterity. Bernstein thought that any movement as a constituent part of an action is connected to each other in accordance with the significance of a task to be resolved and that therefore a chain of movements have a possibility of change and that repetition of an action will cause a suitable change in the composition and structure of a chain of movements. This structure explains the background against which a suitable change occurred in a chain of hitting movements made by M in his attempt to crack an egg.

Bernstein gave one more characteristic of an action; i.e. an action goes with an object. An action is not merely comprised of a chain of movements. More than anything else it is linked to a specific object in the surroundings. In order to satisfy the requirement with an object, it is required that movements used as a unit to describe a chain of movements comprising such an action result from direct connections with an object. The foregoing egg-related case shows a person holding an egg in his hand and hitting the egg against an object harder than the surface of the egg (a cooking bowl in the video) softly at first and strongly later. This hitting act was necessitated by an encounter with the unique surface of an egg. In describing the relationship between an object and an action, it is necessary that there be an encounter between the two and that the movements generated under the restrictive circumstances created by an object be discovered as a unit for description of a chain of movements comprising the action.

3. Socks

The biggest problem in describing an object-related action is perhaps how to identify a structural unit of an action.

Theory 2: Holt's Specific behavior: This was a subject of discussion at the outset of the 20th century. E.B. Holt who succeeded James, W in the field of pragmatism criticized the main stream of psychology in the 19th century for placing the focus on elementary senses and actions under the influence of physiology and urged the necessity of instituting a new unit of analysis for a reform of psychology[5]. He proposed that such unit be called "wish" as used by Freud, J earlier. The word "wish" was defined to mean "a course of action with regard to the environment which the machinery of the body is capable of carrying out". And wrote "This capacity resides...not so much in the matter of which the body is composed, as in the forms which this matter assumes when organized". Holt theorized that the "body" is within the form chosen when it is structured. In line with this theory Holt tried to find the first characteristic of the unit "wish" in the structured organization of the body. The second characteristic was placed on the fact that the structure of the body goes through changes while maintaining the connections with the environment. Holt called a movement with these two characteristics "specific behavior." Holt gives the following example of "specific behavior" as a model case.

"A small water-animal has an eye-spot located on each side of its anterior end;each spot is connected by a nerve with a vibratory silim or fin in the opposite side of posterior end; the thrust exerted by each fin is toward the rear. If,now, light strikes one eye,say the right, the left fin is set in motion and the animal's body is set rotating toward the right like a row boat with one oar. This is all that one such reflex arc could do for the animal. Since, however, together are now two, when the animal comes to be turned far enough toward the right so that some of the light strikes the second eye-spot(as well happen when the animal comes around facing the light), the second fin, the right side, is set in motion, and the two together propel the animal forward in a straight line. The direction of this line will be that in which the animal lies when its two eyes receive equal amounts of light. In other words, by the combined operation of two reflexes the animal swims toward the light, while either reflex alone would only have set it spinning like a top. It now responds specifically in the direction of the light, whereas before it mere spun when lashed." Holt introduces a model case of the circumstances under which the composite structure of "senses and movements" induces a certain behavior based on an object in the environment and Holt calls such behavior "specific behavior". He defined a "Specific behavior" as "a course of action which the living body execute or is prepared to execute with regard to some object or some fact of its environment".

Case 2: The subject involved in the second example case is K, a patient in his early twenties with an injured cervical spinal cord injury. In an accident he suffered the dislocation of the 5th place of his cervical spinal cord, had broken bones and was paralyzed from his shoulders down. He was observed for the first time in 1998. During the one-year period of rehabilitation after the accident, he regained the capacity of performing several kinds of actions such as moving from a wheel-chair to his bed, changing postures using bed shelves, making forward and backward movements by supporting the upper part of his body with his own hands on a flat mattress. However, he still needed help at the time of excretion and changing his clothes. Sometime in September, 1998 he started practicing putting on his socks and his motion pattern for the period of 6 months including the day was video-taped and analyzed. Loop-shaped strings were sewed into the openings of his socks. He was able to maneuver by sticking his two thumbs in the openings like hooks.

K had a lithe body as one of his characteristics. At his first attempt, he was able to fold himself in two at his waist, put the upper part of his body on both of his thighs, and brought his both hands close to the tips of his toes. He was able to maintain this posture for 8 minutes. When he tried to place one of his legs on the other leg with both of his hands, he could not do it very well. At the therapist's instructions K raised the back of his bed so that the upper part of his body would be at a raised level. With this posture he was able to put on a pair of socks on his feet. The amount of time spent for one foot was 7 minutes and the total amount spent for both of his feet was 15 minutes.

Video tapes were made for the months of September, October and December, one for each month and 2 video tapes in March of the following year bringing the total number of the tapes to 5. The amount of time spent for one foot on the last occasion was 2 minutes compared with 15, 15, 7 and 5 minutes for the earlier attempts. Based on the definition that the “movements” required for putting on socks on both feet are “to change the position and direction of each part of the body such as both hands, both arms, waist which can be moved even slightly,” the number of such movements was counted. The results were 690, 967, 585, 175, and 217 for the respective months. The number of movements made by healthy university students counted on the basis of the same standards was about 15. This shows that a series of movements made by K were enormous particularly during the initial period of his practice.

When putting on socks, an infant or a person with impaired legs first needs to sit on the floor or a chair or otherwise place their buttocks against the wall for the purpose of stabilizing the posture and then bring both legs, one at a time, close to the hands, and widen the openings of the socks. In order to perform this act, they have work something which is difficult to handle with the toes of their feet located the farthest from their hands compared with the other parts of the body. In order to bring the tips of their hands close to the toes of their legs, they have to bend their whole body forward with the likelihood that their head will move, cause their body to lose its balance and have a fall. This means that the act of putting on socks involves difficult operation using the tips of their hands while bending their body forward and adjusting their posture while expecting the possibility of a fall. There are 3 required elements for the act of putting on socks: (1) subtle adjustments of one’s posture to prevent a fall, (2) formation and maintenance of a bending posture, and (3) handling of socks with hands.

A socks-related action is largely classified into 3 different groups. The movements made by K each month and counted earlier were classified into 3 groups of actions as required for completion of the act of putting on socks. The first is “adjustment of the posture of the body,” and the second is the formation of a “bending posture.” namely, “to bring legs near the tips of hands in order to let the hands approach the legs” and the third is “slipping the tips of the toes in the socks” and “pulling up the socks by hand.” Each of the 3 groups of actions performed to put on socks is hereinafter referred to as “sub-action.” Fig. 6 shows the distribution pattern of the sub-actions of the 3 groups of actions performed by K until he finished putting on socks (horizontal bar) during the 5 months period (vertical bar). The black spot in Figure 6, related to actions, shows the sub-actions performed by K on his own, and the gray spot shows a series of sub-actions performed by K simultaneously.

In September in which the first video tape was made, at least 2 kinds of sub-actions were performed simultaneously. The video tape made in October shows that K was able to perform his sub-actions unaided. In this month 3 kinds of sub-actions were performed at the same time. Namely, body posture adjustment, bringing the legs close to the hands and then readjustment of the body posture. Further, in order to put on socks K alternated rhythmically the body posture adjustment with adjustment of the location of the legs. In December each sub-action was performed in order and all sub-actions were performed in

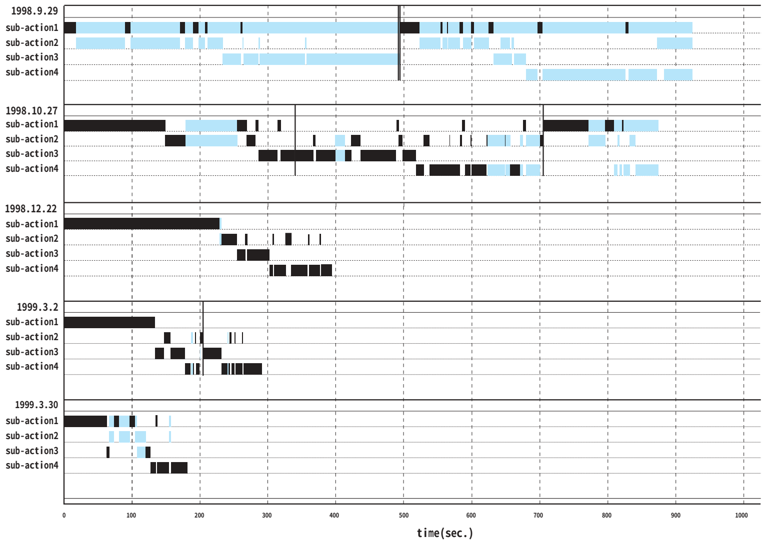

Figure 6: Organization of putting on action processes by a cervical spinal cord injury person.

stageslike manner. In March the process of phased performance gave way to a composite of sub-actions as observed in September. Particularly conspicuous in the last video tape made in March is the simultaneous performance of such sub-actions or the performance of a composite of sub-actions. Perhaps this shows one of the characteristics of a person who has become skillful in putting on socks.

The foregoing analysis shows that K restructured the meaning of a chain of actions or a composite of actions referred to as sub-actions each time he put on socks. Given the fact that the structure of a chain of movements which vary from occasion to occasion embodied after all the action of putting on socks, it can be concluded that K's actions were extremely flexible as demonstrated by the fact that K's socks-related actions were the structure of sub-actions which can freely change the way to form a composite.

The rearrangement which occurred to the structure of sub-actions which formed K's action of putting on socks may be referred to as “development.” The number of movements made by K to accomplish the act of putting on socks and the amount of time spent for the purpose decreased considerably during the 6-months period. The structure of his actions underwent not only a quantitative change but a qualitative conversion (mixed actions = phased or staged performance of actions = simultaneous performance of actions). A change in the structure of sub-actions clearly reflects the “development” which occurred to the actions[6].

Theory 3: Gibson's posture: The idea of describing Holt's wish as specific behavior was partially handed down to Gibson, J.J. who studied under Holt at Princeton University. Gibson proposed a new unit of the environment related to an animal's actions in ”The ecological approach to visual perception”[7]. What has been adhered to by psychologists in the past was an ”stimulus” which imposed the receptive cells of sensory organs. However, Gibson made an issue of ”information” extracted from the body comprising a broader system for perception. Information, for instance, is an enduring structure of energy involving simultaneously both animals and the environment existing in the place where there is a flow of energy surrounding animals like optical flow. Gibson says that information implicating the environment and animals at the same time has ”specificity.” According to Gibson, specificity means direct relations between the environment and animals without the need for mediation. For instance, the move of animals is controlled by optical flow without the need for mediation. As a result of evolution and the development, what has been achieved by an animal’s actions is the reciprocity with the environment and it is the specificity of information what has led to its. Gibson referred to the body unit which specifies information as a ”posture.[8]” A posture means the body’s orientation to the environment. For example, a standing posture is formed based on information obtained by visual system and haptic system. All postures assumed for orientation involve the use of the entire system and the various parts of the body such as the head, body, and limbs and made up of numerous subtle corrective movements. Namely, a posture is the generalized state of changes for orientation of the body and a movable consolidation seeking connection to surrounding information. A posture resembles a unit with movements and the sensory perception defined as a structure by Holt put together. Gibson uses this posture as a unit for actions. Any change of a posture for orientation or achievement of an objective involving movements is an action per se. The structure of an action comprised of this posture has one characteristic. For instance, as shown by a case where a person maintains his/her standing position when making a move, an action is performed based on a basic posture orientation against the macro structure (ground and horizons) of the environment. A structure formed with different postures integrated into such unchangeable base is an action. An action is a moving unit with one posture transformed into another posture. A posture is reciprocally implicated with the levels of the environment in which it orients itself. An action comprised of postures therefore orients itself simultaneously to the levels of different environment. Gibson called ”nesting” to the way in which postures are formed like this. Nesting is a state where a number of units comprise the whole without clear boundaries. The question of which part of an action is a standing posture would be difficult to answer because it would be difficult to separate a standing posture from organized action. However, it goes without saying that a standing posture connotes a moving action and forms the basis of such action. Holt’s definition of specific behavior and Gibson’s theory on the posture-related nesting action may represent a point of view which expands on the example case of putting on socks by linking an action to an object as another way to describe the case such as:

(5) There are cases in which an action is comprised of a composite of a chain of movements involving the whole system. This chain of movements is called a sub-action. Each of sub-actions is organized under a number of object assigns to the action and it resolves them.

(6) All sub-actions resolve all task simultaneously and in parallel to each other an object assigns to the actions.

(7) Among the sub-actions is the orientation action with the head and the body playing the central role and it provides the basis to other sub-actions (Gibson named it ”the basic orientating system”).

(8) The characteristic of one action may be described as the time series layer structure comprised of a number of sub-actions.

(9) An action undergoes quantitative and qualitative changes when encountering an object repetitiously. Qualitative changes may be described as the restructuring or reorganizing of sub-actions.

4. Desk Surface In our studies earlier, no reference was made to any changes of an object which may have occurred in the process of an action. Needless to say, the surface of an egg continued to change its shape by coming into collision with an object. Socks continued to change their shapes because of being handled. How are changes caused to such an object related to the progress of an action?

Case 3: At the time of cracking an egg, the patient introduced as M in Case 1, used the dining table in the daily activity training room of Rehabilitation Hospital. Other than a bowl and eggs there were scattered on the table all kinds of things (a kitchen knife, chopping board, chopsticks, soy sauce, sugar and many others with the total number ranging from 5 and 13) to be used for all kinds of cooking including the cooking of eggrolls. Before M cracked an egg against the bowl, M changed the position of things on the table each time. The number of things moved by M for their relocation was counted prior to the first collision between an egg against the bowl. As shown in Fig. 1, counting was carried out each month and the numbers were 6, 4, 9, 11, 13, 8, 23 respectively showing an upward trend. The number of times relocation was made, which ought to be affected by the number of things placed on the table, was also counted and the numbers were 7, 5, 11, 13, 13, 13, 13 respectively. The frequency of relocation for the 4th and subsequent attempts came out equal. The ratio of relocation frequency to the number of things was larger in the latter half.

These findings suggest that in the case of M, relocation of a number of things on the table is a required condition for the opening of the act of cracking an egg albeit in gradual steps (analysis are now in progress on the subject of what M was trying to accomplish by changing the places of things). As referred to in the comments in Case 1, as the months went by, a series of collisions taking place in the process of M's attempt to crack eggs began to show a structure comparable to that observed among healthy people. This change evidencing an improvement in the egg-cracking action corresponds to increased relocation frequency. This suggests the possibility that increased relocation frequency is connected to the formation of a structure related to the egg-cracking action which immediately follows the relocation action. The possibility was hinted at that egg-related actions are closely related by nature not only to a time series structure beginning with a collision of an egg against the bowl but to the structure involving the space between the egg and all kinds of things placed around the egg. One of the changes occurring to an object-related action can be observed in the sequential structure as we have been observing, and the foregoing analysis shows the possibility that such change may be reflected in an action-related object and relocation of things around the object.

Case 4: There is another case indicating that the movements involved in an egg-cracking action are restricted not only by an object involved in the action but also by a number of things around the object. It is a case involving the movements of a hand for making a small choice known as "microslip" (minor corrections of hand movements).

It was Reed & Schoenherr who first wrote about this phenomenon in 1992[9]. They observed a university student making coffee. They identified 4 kinds of microslips. The first microslip — the student extended his hand toward an object, stopped immediately before touching the object (for about one third of a second) and resumed his action and grabbed the object (hesitation). The second microslip — he began to extend his hand to grab object A, changed the direction of his hand and grabbed object B near object A (trajectory change). The third microslip — he changed the direction of his hand and slightly touched something he was not aiming at (meaningless touch). The last microslip — he first shaped his hand to grab a cup by the top and suddenly changed the shape of his hand to grab the cup by the handle (hand shape change).

The following are the results of the microslip-related studies made in the past: (1) people of wide strata of age groups from 7 to 75 engaged in heated discussions over coffee were observed making several microslips during one minute without exception; (2) the larger the number of things on a table, the larger the number of microslips made; (3) the number of microslips is small under the circumstances where a person who is going to perform a certain action is not forced to do so with the placement of surrounding things pre-arranged but is allowed to change freely the way in which such things are placed before he gets on with his action or the person is allowed to repeat the action any number of times with the surrounding things placed the same way.

Detailed analysis of microslips shows that such microslips do not appear uniformly throughout the whole process of an action but polarized in specific areas of an action. For instance, the action of making coffee consists of a series of the following actions: (A) to scoop pulverized coffee from a container; (B) to put sugar into a cup from a sugar container; (C) to pour hot water into the cup; (D) to stir the content of the cup. When a person makes a cup of coffee, it is inconceivable that the person does action (D) before he does the other actions. Except for such a case, the objective can be accomplished by changing the order of the 4 sub-actions any way you want. Meanwhile, the action of putting pulverized coffee into a cup from a container, one of the lower part actions, which comprises the whole structure of coffee making, is comprised of a series of movements such as holding a spoon, scooping pulverized coffee from a container, putting the coffee into a cup and placing a spoon on the table. However, the action of making coffee at this level cannot be accomplished except in this order. Namely, a series of actions required for making coffee involving the "higher" level actions of A, B, C and D allow for a broad range of freedom of choice but the action of making coffee involving "lower" level actions of A,B,C and D performed separately allow only for a narrow range of freedom. In other words, the progress of a series of actions at a "lower" level is severely restricted by an object. According to the results of these observations, microslips occur easily between the joints of "upper part level" actions from A to D rather than those of "lower part level" actions. They show that microslips tend to occur where there is a possibility of the formation of links between the process of an action and a number of things[10].

These observations of microslips indicate that an action proceeds as the action of choosing a number of things. An action yields part of its character not only to an object of ultimate use in the environment but to the things placed contiguous to the object. The progress of an action is restricted by the way in which things are placed. An action is in and of itself a changed form of body movements, but at the same time it is the work of correcting the environment it finds itself in. As shown by the examples cases relating to eggs and socks, an object changes an action but an object changes in the process of an action. Both actions and objects change their forms in the course of their interactions and are subject to mutual restrictions. The foregoing results may be outlined as follows:

(10) An action is restricted by the way in which a number of things to be used are placed and by the way in which a number of things around the things to be used are placed. Simply stated, an action is restricted by the way in which the surrounding things are placed.

(11) By observing the changes or corrections of the way in which things are placed or minor corrections of an action (microslips), the level of restriction of an action by an object/environment may be clarified.

There was a patient with the right side of his body paralyzed due to cerebral infarction. Prior to the stroke she was right handed. There was an occasion when she had to spend several months trying to get better at eating a dried horse mackerel with his left hand, and the author, together with some others, made an attempt to describe the changes occurring to his act of loosening and "picking" the flesh of the fish as well as the changes occurring to the flesh of the horse mackerel during the period of such several months[11]. When a simple tunicate changes its form in a complex way through an action, the way in which the elements of a gradually loosened object are placed begins to restrict the action. Change in the structure of a series of collisions required for cracking an egg and "nesting" involved in the act of putting on socks falls into this category.

The subject of this Section is entitled "Desk Surface" because the surface of a desk is one of the places where it can be observed that the changes of this type of action and those of an object proceed in close relationship with each other. However, where there is enough space to put things here and there and to relocate them any way you want, an action relocates things and begins to make careful choices of things.

5. Scattered Objects on Ground and Surroundings

Case 5: Before his death, Charles Darwin, evolutionist, published a book on earthworms after spending 40 years collecting relevant data[12]. In his later years the book was highly evaluated on the ground that Darwin had made a great contribution in the field of geology by demonstrating an earthworm's ability to form topsoil(vegetable mould). In Chapter 3 he observes an earthworm digging a hole in the ground to make a tunnel for his residence and protecting the hole from the cold and keeping the hole from getting dry. We will take up Darwin's record as the last example case on the attempt to describe an action-related object. The action of "closing up of tunnel" is outlined as follows:

Darwin starts by collecting several hundred leaves carried into the hole of an earthworm out in the field. He studied the question of which part of the leaves went into the hole first. As for leaves of an ordinary shape with pointed ends, 80% went in from their pointed ends, 9% from the base (joints between leaves and branches), 11% from the center of leaves. This means that an earthworm was capable of using certain spots of leaves for carrying the leaves into a hole with a high rate of certainty that the use of such spots will help him accomplish his purpose with ease as is obvious even to us. A change in the shape of leaves was followed by a change in the percentage of each part of leaves used for accomplishment of its purpose. For example, as for oval-shaped leaves of a golden chain tree with the ends of leaves and the base (both ends) not so sharp, 63% were from the ends of leaves and 27% from the base and 10% from the center of leaves. As for leaves of a golden chain tree, the percentage of using the base was larger than the percentage of using sharp-pointed leaves. When leaves of other kinds of trees were observed, all kinds of leaves shared something in common; i.e. an earthworm's choice was motivated by the ease with which it could perform the task.

As leaves shaped differently from any other leaves of an ordinary shape, leaves of a pine tree with two needle leaves united at the base were observed. It was observed that an earthworm placed outside in the open in winter, practically with no exception, used the base where two needle leaves were joined together. It may be said that the way the earthworm acted was appropriate because if the end of either side of leaves had been used instead of the base, the end of the other side of leaves would have stuck at the mouth of the hole. However, an earthworm kept indoors in a warm breeding pot, when given 42 needle leaves by Darwin, used the ends of those needle leaves to carry into a hole as many as 16 needle leaves which ought to have been a difficult thing to do. Darwin writes that in a warm place with a high humidity level an earthworm acts slovenly. Darwin observed the same earthworm by leaving it outdoors throughout several evenings and giving it 72 needle leaves. Darwin found out that the earthworm had carried the leaves into a hole by using only the base. This demonstrates that the shape of leaves and the climatic condition work together to restrict an earthworm's action.

Darwin further observed the leafstalks of leaves fallen off. For observation purposes he extracted from a holes several hundred leafstalks of clematis of about 2 to 5 inches in length. On a well trodden hard gravel road, leafstalks for which the hard ends of those leafstalks were used were 5 times as many as those for which the non-hard base was used. However, as for the leafstalks from the ground of soft lawns or flowerbeds, the ratio of the leafstalks for which hard ends were used to those for which soft base was used was below 3:1. The ratio of the hardness of the ground to the softness of leafstalks restricted the earthworm's action.

Darwin extracted and examined several hundred leafstalks of an ash tree an earthworm feeds on. The ratio of the ends to the base used in this case came out equal. Most part of the leafstalks for which the base was used had been nibbled. It was found out that to carry leaves into a hole, an earthworm uses the base when eating and uses the ends when closing a hole. In the case of leaves of an ash tree, an earthworm changed their particular spots depending upon the way in which they were used.

For further observations Darwin prepared artificial leaves using paper. For preparation of such paper "leaves," 303 triangular sheets of paper were cut out from rather hard stationery with two sides equally measuring 3 inches in length, 102 sheets with the base measuring 1 inch in width, 183 sheets with the base measuring 0.5 inch in width. When these paper "leaves" were placed outside at night, 59%, 25% and 16% were from the ends, the central part and the base respectively with respect to the triangular sheets with a wider base, and 65%, 14% and 21% from the ends, the central part and the base respectively with respect to the triangular sheets with a narrower base. As for 63 sheets of paper carried into a hole in a warm room, the respective percentages were 44%, 22% and 33%. In both cases of paper "leaves" and natural leaves, the percentage of each particular spot used was based on the degree of ease with which an earthworm was able to perform his task. Furthermore, the climatic condition of the atmosphere affected such percentage at the same time in both cases.

Due to limited space here, I have only been able to introduce part of Darwin's observations. Darwin persistently describes the diversity of the objects used by an earthworm in closing a hole. When there were no leaves, an earthworm piled up pebbles in the shape of a basket and even used an animal's fur. It discovered by chance that surrounding things have the quality of closing a hole and made use of such quality. At any rate an earthworm distinguishes in all kinds of things the quality of closing a hole and notices their particular parts which help it carry them into a hole with ease. Such ability of an earthworm is not only about the quality of such things but about the temperature and humidity of the atmosphere enveloping such things and the hardness of the ground.

As described above, Darwin attempts to describe the process of an earthworm's action of closing a hole. He once spent several evenings observing the scene in which the earthworm he kept carried pine tree leaves into a hole, and the results of his observation were: (1) it gathered so many leaves that it could not use them at the entrance of a tunnel; (2) it quickly pulled in the leaves as soon as it touched the base; (3) it stood straight to get hold of the base which happened to be stuck in the ground and folded all leaves in half to carry them into a hole. As a result of these observations he seems to have found out that he is unable to provide only one answer to the question of how an earthworm brings leaves into a hole. It is because the process of an earthworm's action of closing a hole varies depending upon the particular spots used. An earthworm's actions are more flexible and responsive to all kinds of things than you can imagine.

Any and all actions of "primitive" animal such as earthworms were driven by instincts in those days as they are today. It was even argued that some of their actions were based on their learning. Observation of the process of an earthworm' s actions, however, led to the denial of the strict " instinct" theory that releasing stimulus of an object to be used triggers a chain of reactions. That an earthworm distinguished foreign leaves it never encountered earlier just like it did domestic leaves did not support the "instinct" theory either. Further, Darwin conducted a series of experiments using sheets of artificial paper. After thoroughly checking for any wrinkles on the triangular sheets for which the ends of paper were used for bringing them into a hole (the part of leaves an earthworm takes hold of in its mouth gets wrinkled and smeared with its secretions) Darwin found no wrinkles and smears except for those at the ends of paper sheets and he confirmed that the ends of triangular sheets had been used for bringing them into a hole throughout the whole process. This means the when carrying the artificial paper leaves into a hole, the earthworm did not use a "trial and error" method by first letting the particular parts of such artificial leaves pass through a hole and choosing them if they fit the hole. It was also difficult to explain away an earthworm's actions simply on the basis of the "learning" theory. Other than the "instinct" theory and the "trial and error" theory was also discussed the theory "the geometric shape of a leaf" guides an action. However, the theory was also denied after the discussion resulted in the findings that a geometric shape as a parameter is inadequate to describe an earthworm's action of using an object.

While indicating that varied theories on the principle of such an action prevailing at the time cannot necessarily be affirmed, Darwin pursues his study of an earthworm's action by introducing some specific objects used by an action, Darwin may have described an earthworm's action of closing a hole by employing this method. If this method of describing an action by enumerating specific objects used is called "Darwin's method," then it is a method of describing an action as a collection of the qualities of objects the action distinguished and used. Except in certain cases Darwin seldom writes about an action per se. An action is implicated with the properties of surrounding objects it discovered and used as a result. By so describing the actions of a population of earthworms as a collection of the qualities of objects and the environment, Darwin showed the rare flexibility of an earthworm's action. Therefore, he drew the conclusion that an earthworm has "intelligence". Darwin's method is outlined as follows:

(12) To describe an action as the qualities of the environment and those of surrounding objects the action distinguished, discovered and used and as a collection of the compound thereof.

6. Conclusion

What a psychologist can observe are actions of animals including human beings, and what will change or remain unchanged around the actions. There is a certain solid relationship between an action and the environment and such relationship has encouraged a large number of people and helped him grow as a psychologist. If close attention had been paid exclusively to such relationship with an eye on detailed description, numerous successful results would have been attained. However, psychological studies have failed to focus on the aspect.

It is probably because of the belief that there is a gap between an action and the environment which cannot be bridged by an ordinary psychological method. Studies on the subject of actions based on the "information processing theory" generally conclude that an action is the expression of part of a perfect plan. The past principle of behavior has focused solely on a frail relationship (whether it generates remuneration or not) between behavior and the environment. Therefore, the focus of discussions has always been on the question of what is going to make up for the inadequacy of the relationship between such action and the environment. As a result, it has been believed that the emptiness between such action and the environment explains such relationship.

We wrote about the undertakings launched to search for a method of describing the relationship based on belief that an action is closely related to an object and the environment. Believing that an action is closely related to an object and the environment, the author has shown in this space that an action can be described as: (1) a series of movements coming into contact with an object; (2) as a layer of movements of the whole system dealing with an object; (3) as a change of the way things are placed and as slight movements of an action trafficking between objects; and (4) as a group of qualities of an object to be used in connection with an action. The qualities of the environment related to an action (called "affordance" by Gibson) are too particularized and diversified and mankind has not given verbal expressions to them all. Consequently, if any of such qualities has any meaning at all, it is the meaning related to an action alone and it is only through the action that the meaning can be conveyed. To describe an object by means of an action would be to open up the possibility of implicating the existence of the meaning at such level in the study of perception.

The discussions conducted in this report hint at the possibility that an object and the environment may provide a method of describing an action peculiar thereto for the study of perception.

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