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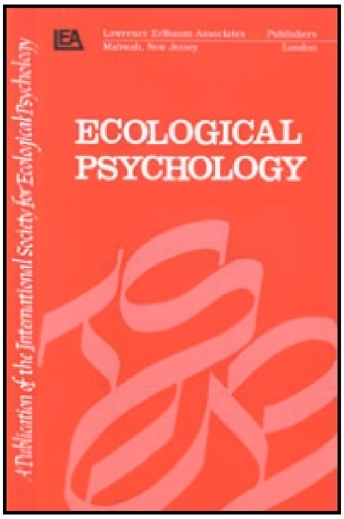

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Spoon Handling in Two- to Four-Year-Old Children

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A method for the study of tool use is presented from the perspective of an ecological approach to perception and action. It is argued that the essence of tool use lies in the maintenance of a specific relation between the organism + tool complex and the environment. Control over the tool is subordinate to this aim. It is proposed that perturbations of the tool–environment relation reveal the essential dimensions of organism + tool complex. A simple experiment is reported in which children (n = 43) from 2 to 4 years of age were asked to use (1 of 6) spoons to transport rice from 1 bucket to another. Perturbation of the tool–environment relation was introduced by manipulating the geometrical configuration of the spoons. The results indicated that all children indeed controlled the relation between tool and environment. They varied their grip such that the functional act of scooping was preserved. Hence, they perceived the new spoons in terms of its functional properties, its *affordances*. In

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addition, it was found that the relative occurrence of successful and unsuccessful transport attempts was contingent upon the configuration of the spoon. The control problems posed by one spoon in particular were such that, when using this implement, five children failed to transport any rice. A highly rigid handling mode was evident during many of the transport attempts undertaken using this spoon. The results further exemplified that failures in tool use, following perturbations of the tool–environment relation, are concommitant with the adoption of rigid handling modes and the selection of maladaptive grip configurations.

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The majority of our routine interactions with the environment rely upon a high degree of manual dexterity. Although the phylogenetic origins of prehensile specialization remain abstruse, it is clear that the present morphology of the hands affords an astounding variety of functions. Furthermore, the ability to pick up and manipulate objects or use these objects as tools considerably extends our facility to interact with the environment. Despite the fact that the human prehensile system, by virtue of the opposable thumb, is more adapted for tool use than any other species (Jouffroy, 1993), surprisingly few studies are devoted to tool use and its development in young children. As a consequence, insight is needed in the core properties, that is, the affordances of tool use and methods to study children's discovery and exploitation of those affordances. In this article we present a method for the study of tool use. We take as our starting point the ecological approach to perception and action. Hypotheses stemming from this method are subsequently tested in a simple experiment.

In spite of the fact that the study of tool use has only received scant attention, definitions of tool use do exist. Beck (1980; see also McGrew, 1993) defined tool use as "the external deployment of an unattached environmental object to alter more efficiently the form, position or condition of another object" (p. 10). According to Connolly and Dalgleish (1989), tools, in their capacity as devices for working on something, "serve as extensions of the limbs and enhance the efficiency with which skills are performed" (p. 985). Goodall (1986) argued that in tool use "an object must be held in the hand (or foot or mouth) and used in such a way as to enable the operator an immediate goal" (p. 536). According to Gibson (1979/1986, see also Reed, 1988) tools " ... are objects that can be temporally attached to our bodies, so as to increase our capacity for action" (p. 40). A common theme is that tools can be attached to the body to extend the capacity for action.

However, to be used as a tool, the function of the implement has to be discovered; it has to be discovered what a tool affords to the user (Gibson, 1979/1986). The function, or affordance, of the tool is determined by its possible relation with the environment. The emphasis on the relation between the tool and the environment or target that is worked upon is emblematic of the ecological approach to perception and action (cf. Gibson, 1979/1986; Reed, 1988; Smitsman, 1996; Tamboer, 1989). From this perspective, the organism and environment are taken to be inseparable, and studies of tool use need to take this reciprocity as starting point of inquiry. Studies predicated on the assumption that the implement and the environment constitute separate entities potentially turn the action of tool use into a cognitive means–end problem for the organism (e.g., Bates, Carlson-Luden, & Bretherton, 1980; Brown, 1990; Connolly & Dalgleish, 1989; Parker & Gibson, 1977; Piaget, 1954). Furthermore, from the ecological perspective, the demarcation between the organism and environment is not fixed but is subject to shifts; detached objects from the environment can become part of the action system of the performer (e.g., Katz, 1925; Smitsman, 1996) thereby extending the capacity for perceiving and acting, namely, change the dynamics of the movement system (Van der Kamp, Steenbergen, & Smitsman, 1993).

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Hence, merely implementing an environmental object into one's action system is not enough for an object to become a tool. To find out what it is that makes an object a tool, we need to focus on the activity of tool use itself rather than internal cognitive mechanisms (e.g., Berthelet & Chavaillon, 1993; Connolly & Dalgleish, 1989; Greenfield, 1991; Parker & Gibson, 1977). When the activity itself is brought into focus we see the essence of tool use. The core feature of tool use entails that manipulation is directed at the relation between implement and environment. A fundamental consequence of this assumption is that the end-effector within a tool-use action is displaced from the hand to the implement. Thus defined, tool use implies a shift in the boundary between organism and environment (cf. Smitsman, 1996). During object manipulation, an action is performed on a detached object from the environment, whereas in tool use, an action is performed with a detached object in the environment (i.e., a tool) on something else from the environment. Grasping an object has a different affordance when a functional relation between the grasped object and another object forms the goal (tool use), compared to when the object itself forms the goal (object manipulation).

To study tool use we need to begin with a description of the action to be performed. More precisely, it is necessary to examine the required relation between the tool and the environment. The specific character of this relation specifies the type of tooling action that is performed, for instance, hammering and cutting. To examine whether the affordance of the tool is indeed perceived and maintained, manipulations of the tool–environment relation need to be introduced that vary relevant but noncrucial features of this affordance (cf. Reed, 1996). If, despite these manipulations, the functional relation between tool and environment is still established this presents clear evidence that the functional properties of the object, namely, its affordance, is perceived.

If a person is indeed performing a tool-using action, instantaneously, the underlying dynamics of the prehensile system are changed, which forms the basis for the emergence of new action possibilities and the loss of existing ones. A second question concerns the constraints upon the reorganization of the action system during tool use. Of particular interest is the question of whether the principles that underlie tool use are the same (generic) principles that apply to the learning of complex skills. For example, it has been postulated that the initial stages of skill acquisition may be expressed as the freezing of mechanical degrees of freedom (Bernstein, 1967; for examples, see Steenbergen, Marteniuk, & Kalbfleisch, 1995; Vereijken, Van Emmerik, Whiting, & Newell, 1992).

The study of tool use requires a description of the required relation between the tool and the environment, and an outline of the contingent changes in the composition of the tool–organism complex. Perturbations of the tool–environment relation reveal the limits under which tool use may proceed. In addition, adaptations in the handling of the tool resulting from perturbations may reveal the essential dimensions of the organism + tool complex.

An exploration of the limits of tool use has been provided by Van Leeuwen, Smitsman, and Van Leeuwen (1994). They asked young children to displace an object by means of a hook. An object together with a hook were placed on a table in different configurations. For the children to use the hook, they had to perceive that the hook indeed afforded hooking, namely, that a particular relation between hook and object needed to be established to use the hook as a tool for displacing the objects. Van Leeuwen et al. manipulated the complexity of the affordance structure by varying the relative positions of the hook and the target. The results showed that more complex affordance structures resulted in a larger number of performance failures. In these instances, the particular relation between hook and object that afforded hooking was not realized. According to Van Leeuwen et al. this was due to a lack of appreciation of a high level affordance structure created by the tool–target–actor relation.

If, on the other hand, an affordance is realized in the face of perturbations, the adaptations in the handling of the tool that results may provide insight into the control principles underlying tool use. For example, Bruner (1969, 1973) suggested that restriction of the movement of the joints and the use of the power rather than the precision grip (Napier, 1956) in manipulating objects reflects means by which the infant effectively reduces the degrees of freedom in the process of mastering tool use. The consequence of using a robust power grip as compared to a more flexible precision grip is that the former does not permit intrinsic movements, that is, movements of the individual fingers for controlling the spoon (Elliot & Connolly, 1984; Landsmeer, 1962). In contrast, a precision grip is more difficult to control because more degrees of freedom are involved in this grip compared to a power grip.

Recently, Connolly and Dalgleish (1989, 1993) described changes in spoon use during feeding in infants aged from 1 to 2 years. During this period, children tend to reduce the number of grip configurations expressed (e.g., type of grip, position of the hand on the spoon). When filling the spoon they showed a shift from movements of the shoulder to movements of the wrist joint and an increasing use of elbow and shoulder flexion during transport of the spoon to the mouth. Movement trajectories also became more fluent and the number of errors was reduced. The adaptations, which occurred with increasing age,

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permitted greater precision and flexibility. One behavioral consequence was reduced spillage, hence, optimization of performance outcome. These results suggest an initial freezing and subsequent unfreezing of available degrees of freedom and support the concept of proximo–distal organization of coordination (cf. Steenbergen et al., 1995).

In the longitudinal study of spoon use, Connolly and Dalgleish (1993) noted that developmental progress was characterized by a shift from a grip position close to the bowl to a position at the top of the stem, which occurred by the end of the second year. This observation suggests that in spoon use, this may be one of the essential dimensions of the organism + tool complex along with a change in grip configuration.

Our experiment was conducted to investigate the influence of perturbations of the tool–environment relation upon the action of tool use. Children from 2 to 4 years of age were asked to use (1 of 6) spoons to transport rice from one bucket to another. For a spoon to afford scooping, a concavity (bowl) is necessary to hold the substance, and attached to this bowl a handle is needed with which the spoon can be grasped. In normal spoons the axis of the handle continues into the bowl. Still, for the spoon to be used as a tool for transporting substances it is not mandatory to have this feature. Therefore, we varied the relation between the bowl and the handle, thereby introducing a perturbation in the tool–environment relation. If the children indeed perceived the spoon in terms of its functional properties (affordances), adaptations in the handling may be expected that accommodate the function of the spoon. Consideration was given to circumstances in which the perturbation induced by this manipulation resulted in a situation in which the scooping tool could no longer be used as a spoon. In addition, contingent changes in the pattern of tool handling were examined. We also sought to examine whether changes in task performance were concommitant with freezing and unfreezing of mechanical degrees of freedom.

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METHOD

Participants

Children were recruited from two children's day care centers in the city of Amsterdam. Data obtained from 43 participants (18 girls and 25 boys) ranging in age from 24 months to 46 months (mean age 36.2 months, *sd* 6.7 months) were used for further analysis. It was verified initially that all children were able to adopt a mature precision grip for eating when using a "normal" spoon (e.g., Connolly & Dalgleish, 1989). Had this not been the case, then no variation in grip patterns could be expected because only power grips were possible.

Apparatus and Experimental Materials

Six spoons were used as tools in this experiment. The stem of each spoon was 12.5 cm in length and was 1.2 cm at the widest point. The bowl, which was oval in shape, had a long axis of 6 cm and a short axis of 4 cm. The essential difference between the spoons was in the geometrical relation of the bowl to the stem. One spoon was of the conventional variety, whereas the remaining five spoons were adapted to introduce a bend at the intersection of the bowl and the stem (see Figure 1).

The children were seated comfortably at a table, upon which were placed two transparent baskets measuring 21 cm in length, 14 cm in width, and 2.5 cm in height. One basket was filled with dry, uncooked white rice and was placed 25 cm in front of the child. The other basket was empty and was placed 10 cm in front of the child. Experimental sessions were recorded on videotape.

Procedure

All experiments were conducted at children's day care centers between 10 a.m. and 11:30 a.m. During each experimental session, two experimenters and one employee of the day care were present. Testing was conducted in a room that was separate from the day care group. Toys were arranged on the table, and soft children's music was played in the background. When the child was seated comfortably at the table, they were asked to carry rice from the full to the empty basket, using one of the six spoons. When 1 min had elapsed, another spoon was offered to the child. The order

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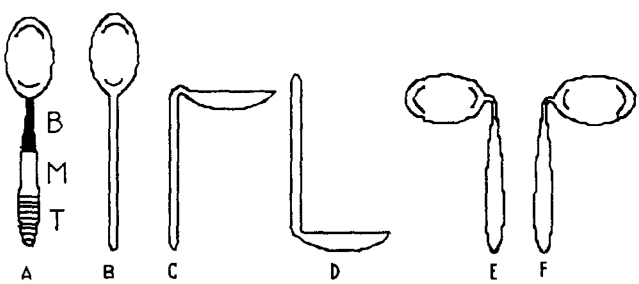

FIGURE 1 Schematic representation of the six spoons used in the experiment. The classification scheme for grip position is indicated on Spoon A: T = top position, M = middle position, and B = close to the bowl.

of presentation of the six spoons was randomized over children. Each child was required to use the entire range of spoons. One complete experimental session lasted approximately 10 min.

Data Reduction

The following dependent variables were obtained from the video record.

1. The functional use of the spoon: Is the affordance perceived? To find out whether a spoon indeed afforded scooping, it had to be established for each of the scooping attempts whether the concave side of the spoon was facing up, in which case the functional property of the spoon as tool for scooping and transporting rice was perceived. If the spoon did not afford scooping to the children, it might be expected that the spoon was held with the convex side facing up or otherwise.
2. The total number of scooping attempts in each 1-min interval. A scooping attempt was the act of bringing the spoon into the rice, followed by an effort to load the spoon. If no rice was subsequently transported, the attempt was denoted unsuccessful. Successful attempts were defined as loading the spoon with rice, transporting the rice to the second bucket, and emptying the spoon into this bucket, regardless of the amount of rice transported. Thus, the total number of scooping attempts was the sum of the successful attempts and the unsuccessful attempts.
3. The type of grip employed (see Figure 2). The grip patterns were classified on the basis of the number of individual digits that were used. The classification was chosen to be consistent with the existing literature on grip patterns and tool use (Connolly & Dalgleish, 1989; Napier, 1956). Grips were categorized on a ordinal scale ranging from the robust power grips (Type 1: Fist, no individual fingers controlled; Type 2: The opposing thumb is used), to the more flexible precision grips (Type 3: Opposing thumb on spoon, forefinger pointing up; Type 4: Thumb and forefinger used to control the spoon).

The reason to limit all available grips into this ordinal scale is that grips ranged from rigid, in which only few degrees of freedom of the prehensile system are used, to flexible (mature) grips, in which more degrees of freedom of the prehensile system are actively involved in the control process. It could therefore be tested whether freezing degrees of freedom occurred as an initial solution to the control problem. The classification accounted for 94% of all the grip patterns observed in the experiment. The remaining grips were scored as Type 5. These grips included adult clenched grip, digital palmar grip, and interdigital grip (see Connolly & Dalgleish, 1989, 1993).

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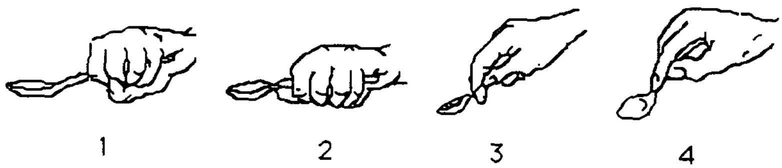

FIGURE 2 Schematic representation of the categorization of grip patterns. Grips 1 and 2 were classified as power grips, and Grips 3 and 4 were classified as precision grips (see text for details).

4. The position on the stem at which the spoon was held: top, middle, and close to the bowl (see Figure 1).

The reliability of the scoring of each dependent variable was evaluated by having the data obtained from five participants scored by two independent observers (first and second author). Interreliability for the total number of scooping attempts was 98%. In addition, measures of kappa (Cohen, 1960) for type of grip and position on the stem, assessed on the basis of 140 scooping attempts, were .90 and .76 respectively.

RESULTS[1]

Did the Spoons Afford Scooping and Transporting Rice for the Children?

The primary aim of this study was to examine the functional organization of tool use in the face of perturbations of the tool–environment relation. To establish the integrity of our experimental manipulations, it was necessary to establish that, in all conditions, the children attempted to use the tool in a goal-oriented fashion. For a spoon to be used as a device for scooping and transporting substances, it should be inserted into a substance with the concave side facing upwards. We verified that all of the children included in this study indeed tried to control this relation. In all instances they brought the scoop into the rice with the concave side facing up. We concluded, therefore, that in all instances the spoon afforded scooping and that the use of the spoon as a tool was indeed possible. Henceforth, for all spoons, children perceived the functional properties of the spoon, in spite of the differences in geometrical layout.

[1]A preliminary analysis failed to indicate the presence of any main effects or interactions attributable to age. All children were able to use the spoon as a device for transporting rice, and all were capable of manipulating the spoon with a precision grip.

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Success of Tool-Using Action

To examine the contribution of spoon type to the success in scooping,[2] data were pooled over participants, and the number of scooping attempts was analyzed using a 6 (Spoon: A, B, C, D, E, F) × 2 (Scoop Outcome: Successful vs. Unsuccessful) chi-square procedure. It was clear that the number of successful scooping attempts far exceeded the number of unsuccessful attempts, $\chi^2(5, N = 43) = 219.75, p < .005$ (Figure 3). The majority of scooping attempts resulted in the transfer of rice between buckets. Inspection of Figure 3 also shows that there were more successful than unsuccessful scooping attempts for all spoons other than for Spoon C. The control problems posed by Spoon C were also emphasized by the observation that, for this spoon, 5 children failed to transport any rice.

The manner in which the number of successful and unsuccessful attempts varied with grip type was assessed using a 2 Scoop Outcome (successful, unsuccessful) × 5 (Grip: 1, 2, 3, 4, 5) chi-square procedure. Data were pooled across spoon type and over all participants. As inspection of Figure 4 reveals, the grip most frequently adopted during successful attempts was a Type 4 precision grip, in which the thumb

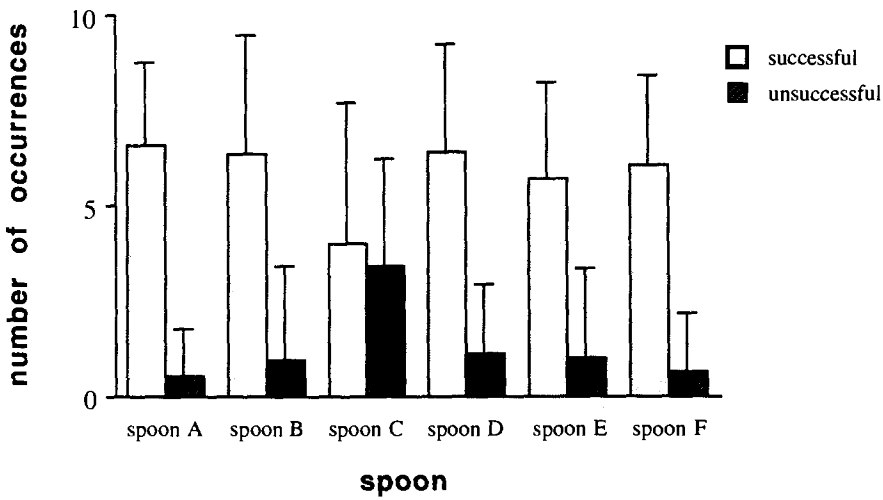

FIGURE 3 The distribution (mean number occurrences per participant) of successful and unsuccessful attempts observed for each type of spoon. Error bars represent the corresponding standard deviations.

[2]Note that success in scooping is referred to as either scooping with some rice as opposed to scooping without any rice. Hence, no refinement in scoring was made with respect to the amount of rice transported.

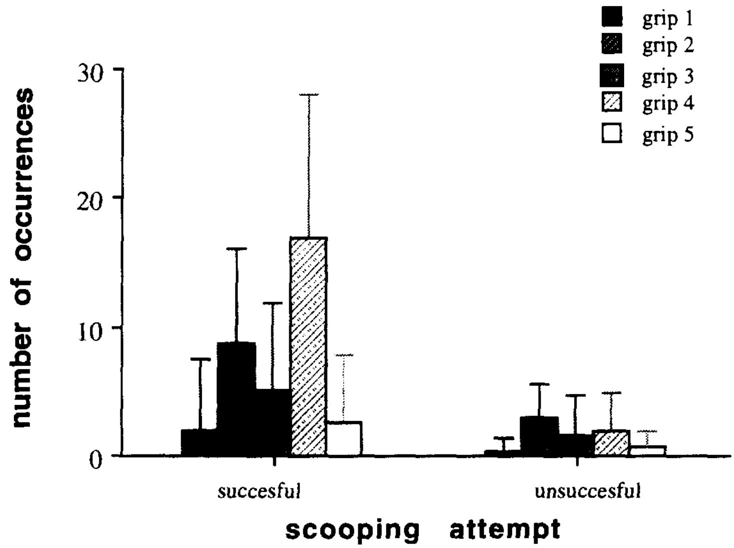

FIGURE 4 The observed distribution (mean number of occurrences per participant) of successful and unsuccessful scooping attempts expressed as a function of grip type. Error bars represent the corresponding standard deviations.

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and forefinger were used to control the spoon, $\chi^2(4, N = 43) = 37.25, p < .005$. The next most frequently occurring grip was a Type 2 power grip, in which the opposing thumb was used. In contrast, during unsuccessful attempts there was a uniform distribution of grip types.

The relative occurrence of successful and unsuccessful attempts was also examined as a function of grip position using a 2 (Scoop Outcome: Successful vs. Unsuccessful) × 3 (Position: Top, Middle, Blade) chi-square procedure. Data were again pooled over all participants. As Figure 5 indicates, during successful attempts the spoon was more often grasped in the top and middle positions, $\chi^2(2, N = 43) = 18.02, p < .005$. In contrast, during unsuccessful attempts the spoon was more frequently grasped close to the bowl in the blade position.

These data suggest that the adoption of particular grip configurations (type and position) enhances accommodation to perturbations of the tool–environment relation (spoon type). More specifically, children varied their grip pattern to preserve the functional relation between tool and environment, thus maintaining the affordance of the spoon as scooping device. Conversely, infants' failure to successfully execute the task when using Spoon C may have been concomitant with the selection of maladaptive grip configurations.

To further assess these possibilities, the adaptation in grip configuration for only the successful attempts are examined in the following section. Hence, the 5 children that were not able to transport any rice with the spoon were not included in this analysis, resulting in a group of 38 children (15 girls and 23 boys) ranging in age from 24 to 46 months (mean age 36.8 months, *SD* 6.7 months).

Evidence for Adaptation in Handling the Spoon

A series of chi-square tests were conducted separately for each spoon type. In each analysis, data were pooled over all participants. To control for the potential inflation of Type I errors resulting from multiple comparisons, alpha was assigned as .005.

In the first set of analyses, the relative occurrence of grip type was assessed for each spoon type. All six analyses were significant, (α = .005); chi-squares ranged from $\chi^2(4, N = 38) = 110, 80$ for Spoon F to $\chi^2(4, N = 38) = 239.65$ for Spoon D. The analyses indicated that Spoons A, B, D, and E were grasped most frequently with a precision grip of Type 4 (Figure 6). Spoon C was most frequently gripped with a power grip of Type 2, whereas Spoon F was more frequently handled with grips of Type 2 and 4. In short, Spoons A, B, D, and E were handled almost exclusively with a precision grip, whereas during scooping attempts conducted with Spoons C and F, a power grip was also prominent.

In the second set of analyses, the relative occurrence of grip position was assessed for each spoon type. These analyses yielded a similar pattern of results and all were significant, (α = .005). That is, for scoops made using Spoons A, B, D,

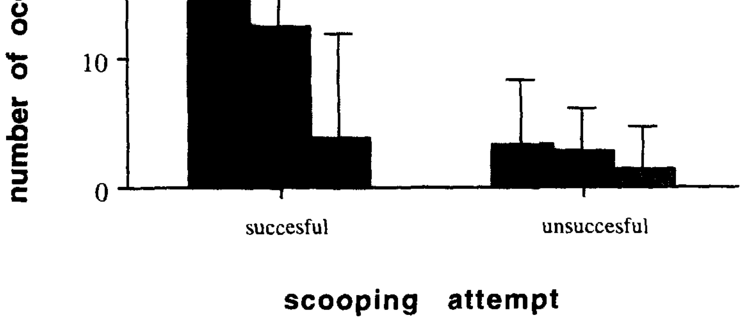

FIGURE 5 The observed distribution (mean number of occurrences per participant) of successful and unsuccessful scooping attempts expressed as a function of grip position. Error bars represent the corresponding standard deviations.

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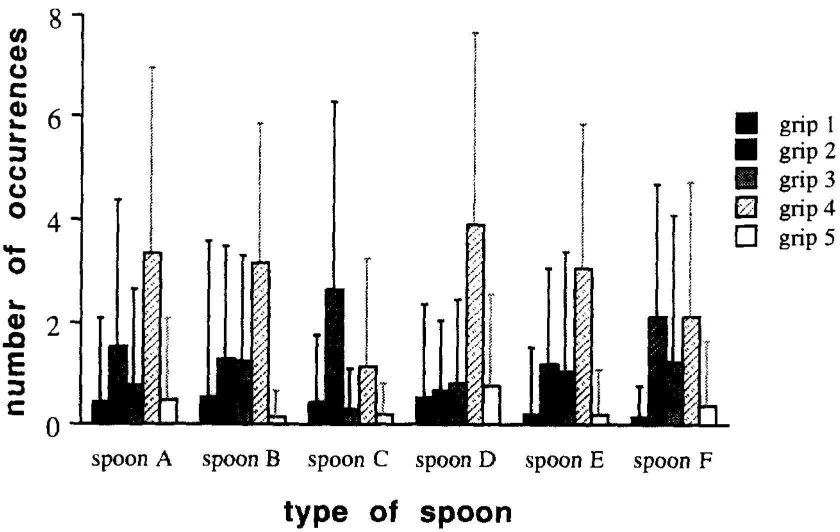

FIGURE 6 The observed distribution (mean number of occurrences per participant) of grip types expressed as a function of spoon. Error bars represent the corresponding standard deviations.

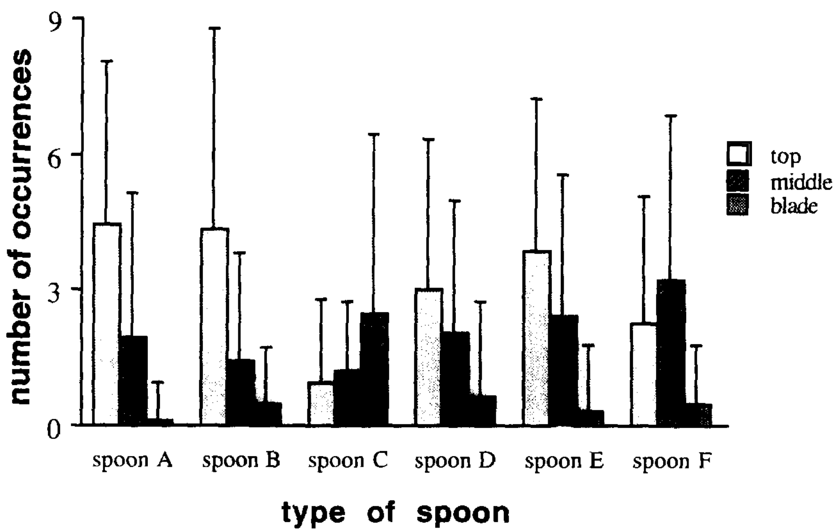

FIGURE 7 The observed distribution (mean number of occurrences per participant) of grip position expressed as a function of spoon. Error bars represent the corresponding standard deviations.

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and E, the top grip position was most frequently adopted (Figure 7). In contrast, when Spoon F was used, the middle grip position was employed more often than the blade grip position. During scoops made using Spoon C, all grip positions occurred with equal frequency.

The increased prevalence of power grips and the absence of a preferred grip position, associated with Spoon C, may have been indicative of adaptations to the control problems posed by this tool. On the other hand, it is possible that these modes of handling expressed intrinsic coordination tendencies. If this was the case, it might have been anticipated that there would be few changes in the mode of handling during a series of scooping movements.

To examine this question, the relative number of changes in grip and position within each 1-min collection interval was analyzed as a function of spoon type using the chi-square procedure. It was evident that the number of changes in grip type was not influenced by the spoon used, $\chi^2(4, N = 38) = 5, 32$. However, the number of changes in grip position was sensitive to the type of spoon, $\chi^2(2, N = 38) = 24.46$, ($\alpha = .005$). As Figure 8 shows, there were more changes in grip position when Spoon C was used, compared to the other spoon types.

GENERAL DISCUSSION

It has been argued that the essence of tool use lies in the control of a functional relation between the organism + tool complex and the environment. The specific

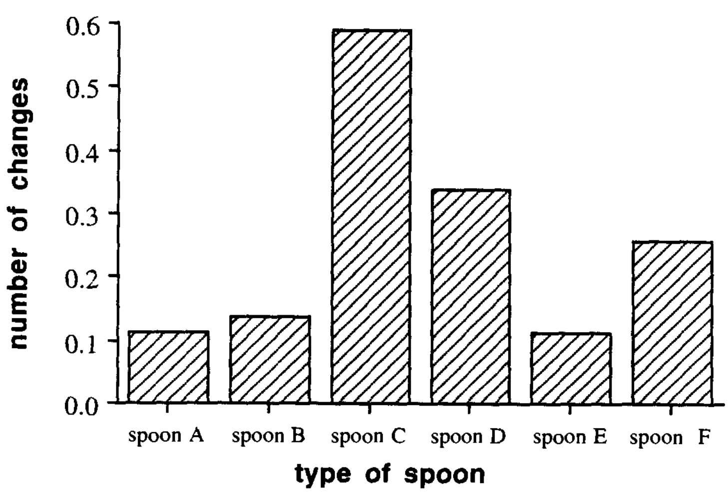

FIGURE 8 The mean number of changes in grip position observed for each type of spoon.

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character of this relation defines the type of tool-use action that is performed. As a corollary, it was assumed that perturbations of this relation, for example, those induced by changing some features of the tool without annihilating the affordance of the tool, will reveal the essential dimensions of the organism + tool complex.

In this experiment, consideration was given to the handling of spoons by young children. Perturbations of the relation between the organism + tool complex and the environment were achieved by altering the geometrical relation of the bowl to the stem in a set of otherwise identical spoons. If the action of the children was indeed aimed at preserving the functional relation between the scoop and the rice, adaptations in the handling of the spoon may be expected to be aimed at preserving this relation. It was apparent from our results that when the children were required to use the spoons to transfer rice from one bucket to another, all of their attempts were indeed aimed at establishing the necessary relation between scoop and rice. This was evidenced by the fact that in all attempts, the concave side was facing upwards. Hence, despite the perturbation of the relation between tool and substance, they still perceived and tried to effectuate the affordance of the spoon as a device for scooping and transporting rice. Most of the attempts resulted in successful outcomes. However, when scooping attempts were conducted using a spoon in which the stem was perpendicular to the bowl (Spoon C), a large number of unsuccessful outcomes were observed. Indeed, for five children, the control problem posed by Spoon C was insurmountable and they were simply unable to use the spoon for transporting rice. A highly rigid handling mode was evident during many of the unsuccessful attempts undertaken using this spoon. The spoon was frequently held close to the bowl in a clenched (power) grip, with the consequence that compensatory movements of the individual fingers were restricted (cf. Landsmeer, 1962). Even during successful attempts completed using Spoon C (and to a lesser extent Spoon F), power grips located close to the bowl predominated. Together, these findings suggest that the adoption of a rigid handling mode arises as a direct consequence of the need to preserve the functional act of scooping, namely, maintaining the functional characteristic of the affordance of the spoon, and point to the (generic) principle of freezing degrees of freedom (rigid handling mode) as initial solution to the control problem.

It has been proposed that the problem posed for the central nervous system in achieving coordination is that of harnessing the potentially vast numbers of degrees of freedom comprised by a highly redundant musculoskeletal system (Bernstein, 1967). However, the redundancy of the musculoskeletal system can also be regarded as a source of flexibility. A balance must exist between the need to reduce the number of independent variables to be controlled and the requirement that there remain degrees of freedom that have the potential to vary in response to changing task demands.

The grip pattern observed for Spoon C was evidently stable. The number of changes in the type of grip was no greater than that observed for the other spoons. Nonetheless, this grip pattern afforded little flexibility, as the fingers could not be

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moved independently. Adjustments that may have occurred in other parts of the movement system were clearly not sufficient to ensure a fully functional movement pattern. Although the grip configuration was relatively stable, children changed the grip position more frequently when using Spoon C than when using the other spoons. These data suggest that in accommodating to the perturbation, the degree of freedom represented by the grip position was amenable to greater change than the degree of freedom represented by the grip configuration.

Obviously, we only examined the degrees of freedom encompassed by the grip configuration and the grip position. However, it is evident that accommodation to changing task demands may be distributed throughout the movement system. As an example, Connolly and Dalgleish (1993) showed that during the first 2 years, children show an increasing degree of elbow flexion when eating with a spoon. In prehension it has also been shown that when greater precision is demanded, compensatory adjustments encompass joints that are proximal to the shoulder and the elbow (Steenbergen et al., 1995). In future work, currently being prepared in this laboratory, distributed responses to perturbations of the tool–environment relation need be considered directly. It is also to be anticipated that outcome measures, such as the amount of rice transported in each attempt, will provide more sensitive means of determining the efficacy of various movement patterns than the binary classification of movement attempts (successful–unsuccessful) used in this study.

Recently, Mathiowetz and Wade (1995) showed that it is preferable in a practical setting to use a functional task for evaluating functional performance rather than a miming task. Participants in their study were required to eat with a spoon under three conditions: completely miming the eating task, miming the eating task by using a spoon, and actually eating with a spoon. Each of the tasks elicited unique kinematic patterns. Mathiowetz and Wade (1995) suggested that their results raise concerns relating to the content validity of the functional measurement tools used currently by therapists, especially in circumstances in which functional tasks are omitted from evaluation protocols. These findings also indicate clearly the importance in tool use of the relation between the implement and the environment. In a similar vein, it has been shown that children stop writing when their scribbling has no success, for example, when it doesn't leave a trace on the writing surface. These examples clearly show that if the relation between the tool and the environment is nonfunctional or meaningless (no trace to be made on the paper or no food to be scooped on the spoon), the tool use action ceases to exist.

Taken collectively, these studies clearly show that control in tool use is directed at the tool–environment interface; namely, there is a shift in boundary between organism and environment. There is a high practical value in this work, especially in the field of ergonomic design. Design of tools, especially for disabled persons, has to be aimed at facilitating the process of controlling the relation between tool and environment. Examples are spoons and scissors for right and left-handed people (cf. Valsiner, 1987). The therapeutic and practical significance of this theorizing demands further study. By extension, the results of this study, namely, preservation

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of the functional characteristic of the affordance despite variation in features of the affordance, indicate that perception provides information about both the meaning and use of affordances (Reed, 1996).

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