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The Planning of Tool-to-Object Relations in Young Children

ABSTRACT: *This study investigated the way young children used a cane for displacing an object. In the experiment, 11 children with an average age of 32.3 months were asked to pick up a cane (hooked stick) that was located and orientated differently on each trial. With this cane they had to displace a target-object towards a free-to-choose goal location. The way the children used the cane for transporting the object was not determined by its starting location and orientation relative to the object. In fact, the children preferred enclosing the object in the hook, irrespective of the starting configuration. This contradicts a prediction that follows from an earlier study by Van Leeuwen et al. (1994). Final location of the target object and hand use was influenced by preferences as well as constraining task variables. © 2006 Wiley Periodicals, Inc.* Dev Psychobiol 48: 178–186, 2006.

Keywords: *planning; tool use; young children; motor preferences*

Although tool use has recently seen a revival in the interest of developmental psychologists (see e.g., Bongers, Smitsman, & Michaels, 2004; McCarty, Clifton, & Collard, 1999, 2001; Lockman, 2000; Smitsman, 1997; Van Leeuwen, Smitsman & Van Leeuwen, 1994; Want & Harris, 2001), as yet it remains unclear by what mechanisms young children learn how tools modify their action system with respect to a certain task. What children have to discover in tool use, is that the body's inadequacy for a task in some of its dynamical, geometrical, and/or perceiving-acting abilities can be resolved by using a hand-held object with suitable properties (Smitsman, 1997; Smitsman & Bongers, 2003). They have to learn that the intended goal (e.g., food in the mouth) can more effectively and efficiently be attained after their action system has been modified with an appropriate object (e.g., a spoon).

The functional relationship that exists between the tool-object and the target-object, which fundamentally constraints the possibilities for tool use, has been labeled *topology* (Smitsman & Bongers, 2003; Smitsman, Cox, & Bongers, 2006; see also Wagman & Taylor, 2004), or tool-environment interface (Wagman & Carello, 2003; Wagman & Taylor, 2004). The term topology expresses that, for tool use to be successful, the dynamical, geometrical, and perceiving-acting properties of the tool in some way have to match the properties of the target-object, within the context of a certain task. This means that it is not the tool in isolation that predicts its usability, but the way it adapts the actor's bodily means in relation to the target-object and the goal. Specifically, the topology comprises a set of relative parameters, like relative size and shape, and relative distance and orientation, which are defined for the tool + target-object system as a whole (Smitsman et al., 2006). They are *relative* parameters because they describe a tool property relative to its corresponding target-object property. To clarify this, consider, for example, the way a screwdriver is shaped at the tip (or the size of the tip for that matter) to fit into the inversely shaped head of the screw.

The topological relation between a pair of objects, and the set of relative parameters this entails, holds all the potential degrees of freedom for the tool-using possibilities. Therefore, to discover if an object is suitable as a tool for operating on another object to attain a certain goal, a child has to be sensitive to these relative parameters. Moreover, in order to use the tool adequately it means that the child has to learn to actively regulate the values of the relative parameters, within the constraints set by the task. This means that the child's actions have to directed at controlling the parameter values, for example, changing the relative distance by bringing the tool closer to the target-object. Note that for any specific tool, some

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parameter values are fixed (e.g., for relative size and relative shape), which means that not all potential degrees of freedom are always free for the actor to regulate. These fixed parameters have a constraining influence on the tool-using possibilities. Summarizing, the child has to find out if it can be done as well as how to do it by discovering the topological relation and by regulating its underlying set of relative parameters.

One of the findings from the famous primate studies performed by Köhler (1925) is that the discovery of this topological relation, called insight is facilitated by perceptual factors of the spatial layout, like tool-target proximity and orientation. Richardson (1932), Bates, Carlson-Luden & Bretherton (1980), and more recently Van Leeuwen et al. (1994) further developed Köhler's pioneering work. Bates et al. state, contrary to Zhukova (1960), that a child has to see the tool and target-object as two distinct objects that in some way fit together. Their emphasis is on the discovery of the causal relations that hold between the two objects when they are connected (see also Want & Harris, 2001). They argue that the facilitating effect of the spatial configuration is as a reminder of the possible connection.

In terms of the action problem the children have to solve, the issue remains unresolved however. For any given two objects of fixed size and shape (we shall omit the addition *relative* in front of the topological parameters from now on), their spatial configuration (i.e., their distance and orientation) concerns information about the actions that need to be performed to reach a goal. From this it follows that the tool a certain object can be, emerges from the activities that it affords on a target-object. For example, because of the concave shape of its bowl, a spoon affords scooping, but only by penetrating the food's surface and subsequently retrieving it (i.e., regulating distance), while holding it in a suitable orientation. Van Leeuwen et al. (1994) have argued that it is these activities that determine the discovery of tool functions. Interestingly, this view redefines the problem of insight in tool use into ''discovering that it can be done by discovering how to do it,'' in which the latter knowledge varies between different tasks.

In Van Leeuwen et al. (1994) study, children between 8 months and 3.8 years of age were asked to use a cane with a curved part (hook) on one end and a straight part (handle) on the other end. The task involved pulling a desired target-object nearby. The object was placed out of reach on a table in front of them. The task started with placing the cane also on the table, in different positions and orientations relative to the object (i.e., different topologies). The handle always pointed towards the child and was within reach. The different topologies formed the starting configurations in the experiment. In some configurations the hook already enclosed the object, while in others the child needed to displace and/or rotate the cane so that the object could be pulled nearby. According to the authors, these configurations differed in complexity because of the different number of transformations (i.e., translations and rotations) the children needed to temporarily integrate in the planning, before they could use the cane for pulling the target-object within reach. For instance, in the most complex configuration the child needed to rotate the cane, displace it to the side and downwards, before its hook surrounded the target-object appropriate for pulling. According to their model, this complex configuration required the temporal integration of a sequence of four transformations, three to get the cane in the appropriate position and orientation, and one for pulling the target-object nearby.

Results agreed with what the authors predicted: Children that were intermediately successful in retrieving the target-object (i.e., between 33% and 66% of all trials across the different configurations) were more likely to solve the problem when less transformations needed to be integrated, according to the model. Remarkably, this group consisted of both younger and older children, and performance was similar between them. The general conclusion of the researchers was that it is the temporal integration of necessary transformations that determine children's discovery and planning of tool functions.

This conclusion raises a number of questions. One question is whether it is solely the starting configuration that determines if and how the cane will be used and where the object will end up. If the cane is already in the hand, for example, it may be difficult to define a starting configuration at all. When the hand is active, the cane will be moving relative to the target-object. This means that its (perceived) function changes if the complexity of the configuration changes due to this movement. A peculiar implication of this is that the cane can switch from being a tool object to being a nontool object, just by rotating it in the hand, for example.

Related to this is the fact that there is not just one way to use the cane that will effectively displace the object to a desired location. Which ones will be more efficient than others depends on a number of things. One very important factor is where the goal is located with respect to the tool and the target-object. In Van Leeuwen et al. (1994) task enclosure as *the* tool function of the cane is dictated by a goal location that requires the object to be inside the hook to succeed. For a goal location to the side of the table, sweeping the object using the cane as a stick will be just as effective. For pushing an object further away, the outside of the hook will be more suitable. Thus, the particular topology that a child chooses is determined by many other factors besides the starting configuration, such as the shape of the tool and target-object and the goal location.

More fundamentally, it is questionable whether the required transformations form the basic units for planning functional relations between objects in tool use. This disconnects (i.e., disembodies) the ‘‘knowing how to do it’’ from the action system and effectively turns it into mental operations on objects and on the trajectories between these objects in space. It could just as well be the other way around: Functional relations are the basic units themselves and the necessary trajectories follow from the relation a child chooses to realize. This hypothesis takes into account the flexibility that is available in the movement apparatus. Given this flexibility it may be more sensible to plan in terms of relations between objects, and exploit the flexibility to achieve these relations under varying circumstances.

This paper presents an experiment that was designed to shed more light on the issues raised above, by investigating *whether* and *how* 2-year-old children use a cane for displacing an object. In the experiment a target-object was placed in front of the child in the middle of a round table (see Fig. 1). At the start of every trial the cane was randomly placed in one of four different locations on the table: on the near or far side of the table, either left or right from the child’s midline. The handle always pointed towards the child and was within reach. On each location the hook was oriented either towards or away from the object. The task for the child involved using the cane to displace the object to a free-to-choose goal location in a groove that fully surrounded the table.

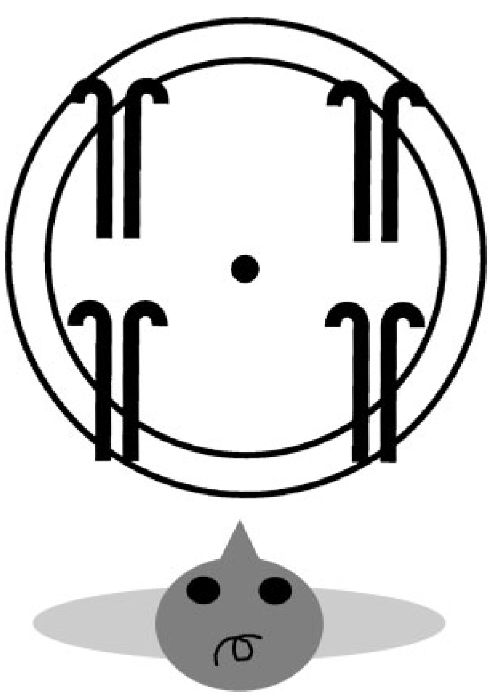

FIGURE 1 The eight different starting configurations of cane and target-object on the table. In each trial one of these configurations was randomly presented to the child.

Three action variables were monitored in the experiment: topology, end-position, and hand choice. Topology was measured to give us insight into which tool-to-object relation the children realized during task performance. End-position was defined as the target-object’s final location after displacement, giving us the goal the children chose for the object. Finally, by also monitoring the hand the children used for grasping the tool with and subsequently for displacing the object, we hoped to shed some light on how they deployed their bodily means in performing the task. A general aim of this study was, therefore, to unravel children’s tool-use behavior in terms of these three action variables.

Because in Van Leeuwen et al.’s (1994) study children of a large age range participated (8–44 months), their conclusions are applicable to the 2-year-old children in this experiment. Moreover, in their study there were children of this age that either used or refused to use the cane. Children that refused to use the cane in their complex configurations might use it in this study, because the free-to-choose goal location always enables them to perform the task very easily. Children that used the cane in all configurations of their study were expected to do the same in this study, but they too will be likely to solve the problem in the easiest possible way.

If starting configurations determine the discovery of tool functions, as Van Leeuwen et al. (1994) argue, in this experiment one would predict the topology to directly follow from the cane’s starting location and orientation. For successful task performance, in principle, only two transformations have to be integrated for all eight starting configurations: A translation of the cane towards the target-object followed by a translation of the cane that displaces the object to the side. This means that the cane will be used as a stick in case its hook points away from the object in the starting configuration, and as a hook in case its hook point towards the object. In fact, Van Leeuwen et al. reported stick use in comparable configurations. In the simple movements just described, the object is pushed away in a straight line until it falls into the groove. In the same line of reasoning, therefore, one would expect the object’s final location to be directly opposite to the cane’s starting location. A deviation from this pattern would imply that the necessary transformations are secondary to establishing a functional relation between actor, tool, and target-object.

METHODS

Participants

In this research, the data of 11 children with an average age of 32.3 months and a standard deviation of 3.2 months were used for further analysis. This group contained five girls and six boys. Two participants were excluded from the analysis because they were considerably younger than the rest of the group (21 months old). The children were recruited from a children's day-care center near the Dutch city of Nijmegen. Parents were written about the experiment and granted their permission. It was verified in advance that the children were willing and able to participate in the experiment. From verbal inquiry of the day-care employees we concluded that most children were right-handers. Handedness was not assessed separately because we know of no suitable and reliable test for this age group. Moreover, both direction and strength of handedness are not yet fully developed at this age (see e.g., McManus et al., 1988).

Materials

The tasks were performed at a red-round table with a diameter of 62 cm. The height of the table could be adjusted to the waist-height of the children. There was a ring-shaped groove in the table at 3.0 cm from the edge, all-around, 5.0 cm wide and 2.6 cm deep. The bottom of this groove was painted blue. The whole groove acted as a possible location towards which the children could transport the target-object. It left a large disk with a diameter of 46 cm in the middle of the table. The cane was 37 cm long with a width at the hook of 7.0 cm. It was constructed by bending one end of an 8.0-mm thick, solid blue aluminum rod (mass: 58 g) into a hook shape. Using this cane, the children had to displace one of four small wooden target-objects. The target-objects were disks of 1.3 cm in height and 2.5 cm in diameter. They were painted white with a black edge on the top and the bottom and with a yellow side. To make these objects more appealing to the children, there were small animals painted on them—a duck, a swan, a frog, and a fish.

Procedure

All the experiments were performed at the day-care center, in a specially appointed, separate room. During each session an employee of the day-care center was present in the room together with the experimenter and the child. When the child was at ease in the room she was invited to sit down on a little chair at the table, with the experimenter sitting on her left side and the employee on her right side. The cane and the target-objects were shown and the child was allowed to explore these objects and the table for a while. During this phase the experimenter explained that the disks were little animals that would like to go to the water (the blue groove in the table), but that they were to little to do this on their own. The child was then asked to help the animals get to the water by using the cane. The experimenter made it very explicit that it was allowed to bring the target-object anywhere in the blue groove. After this, the experiment started by first placing one of the target-objects on the table at a clear distance from the child (just behind the nearest half of the table). Then the cane was placed on the table in one of the eight possible starting configurations displayed in Figure 1. These configurations arose from combining lateral cane-position (on the left or on the right of the child), proximal-distal cane-position (near or far from the child) and hook-orientation (away from or towards the target-object). A total of 16 trials (2×8) were presented to the child in a completely randomized order. After each successfully performed trial, the experimenter removed the object from the groove and gently retrieved the cane from the child. A new object was chosen at the child's wishes and a new trial was started. The duration of one complete experimental session was 10–20 min.

Response Scoring

Three-dependent variables were assessed from the videotaped sessions, viz. hand choice, topology, and end-position. The variable *hand choice* was scored for two distinct phases of the task, because switches of the tool between the hands could occur in the time interval after the tool was picked up and before the actual start of the object's displacement. The period of time between the start of the trial and the child's grasping of the tool, that is, the period in which the child chose how to pick up the tool, is defined as the *grasping phase*. The period of time between the start of the target-object's transportation with the tool and the first arrival of the object at its end-position is called the *transporting phase*. The values that were possible for hand choice were left, right, or both, where the latter value was assigned to the behavior of both hands grasping or touching the tool.

The tool-to-object configuration that the child uses for transporting the object is called *topology*. It provides us with valuable information about how the children used the cane. The position where the object contacts the cane can in principle be anywhere on the surface of the cane, making it a continuous variable. However, for the sake of reliable scoring with enough distinguishable power there were three values constructed for this variable, which are shown in Figure 2. Enclosure (Fig. 2a) was defined as the configuration in which the object was always inside the hook or touching the hook very near to the inside. The tip of the hook was scored as enclosure too. Exclosure (Fig. 2b) was defined as the configuration in which the object was positioned at the outside of the hook, or touching the hook very near to the outside. Stick-use (Fig. 2c) was scored when the cane was clearly used as a stick, that is, when the target-object touched the handle part of the cane including its tip.

End-position served as a measure for the movement trajectory of the target-object. It was scored as the object's

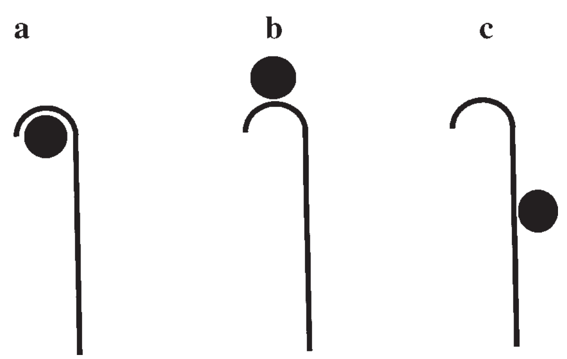

FIGURE 2 Examples of the three topologies: (a) enclosure; (b) exlosure; (c) stick-use.

location when it (first) arrived in the groove, regardless of possible further displacements of the object after that. For this, the groove was divided into four parts, relative to the child: near left, near right, far left, and far right. End position was assessed using a computerized procedure. A marker on the target-object was recorded, relative to a set of reference markers, by means of a video-digitizing system.

RESULTS

One observer scored the variables topology and hand choice for all subjects. A second observer scored about one third of the sessions (four subjects). Interobserver reliability was calculated for this portion of the data, revealing an agreement of 96% for hand choice ($\kappa = .93$) and 94% for topology ($\kappa = .86$). In all cases the primary observer's scoring was used in the analyses.

Because each starting configuration was presented to the children twice, in a completely randomized order, the data was inspected for possible effects of repetition. It was concluded that no systematic effects were present. Therefore, only the data of the first presentation of each condition was used in the analyses, resulting in a total of 88 trials. In none of these trials children used both hands for grasping the cane or for transporting the object.

Hand Choice

In the grasping phase, where the children made the cane part of their action system, as well as in the transporting phase, where the children actually displaced the target-object towards the groove, there appeared to be slightly more overall use of the right hand (55% and 66%, respectively). For each individual child the proportion of right-hand use was calculated for both phases of the task separately. *t*-tests revealed that in both phases the proportions of right-hand use did not significantly differ from a test value of .5.

The percentages of right-hand use in both phases of the task, for each of the eight different conditions, are presented in Table 1. A 2 (phase) × 2 (lateral cane-position) × 2 (proximal-distal cane-position) × 2 (hook-orientation) repeated measures ANOVA was conducted on the hand-choice data. The analysis yielded a main effect for lateral cane-position, $F(1,10) = 29.307$, $p < .001$. This effect revealed that the children predominantly used the ipsilateral hand, that is, they grasped and used the tool with the hand on the same side as the cane's starting position. Furthermore, there was an interaction effect between phase and lateral cane-position, $F(1,10) = 7.368$, $p < .05$. The nature of this interaction indicated that the ipsilateral effect of lateral cane-position on hand use was stronger in the grasping phase than in the transporting phase. This means that between the two phases, children, to some degree, switch the cane between the hands. No main effects were found for proximal-distal cane-position and hook-orientation. Interestingly, there was a lateral cane-position by hook-orientation interaction, $F(1,10) = 15.802$, $p < .01$. This effect was such that, for both lateral cane-positions, when the hook was directed away from the target-object, the contralateral hand was used relatively more often, than when the hook was directed towards the object.

Table 1. Percentages of Right-Hand Choice in the Two Phases of the Task

		Grasping	Transporting
LCP—Right	PDCP—Near		
	HO—Away	82%	73%
	HO—Towards	100%	91%
	PDCP—Far		
	HO—Away	82%	82%
	HO—Towards	91%	91%
LCP—Left	PDCP—Near		
	HO—Away	36%	64%
	HO—Towards	9%	36%
	PDCP—Far		
	HO—Away	27%	55%
	HO—Towards	9%	36%

To analyze these results further, a 2 (lateral cane-position) × 2 (proximal-distal cane-position) × 2 (hook-orientation) repeated measures ANOVA was performed for each of the two phases separately. This yielded a main effect of lateral cane-position in both phases of the task, $F(1,10) = 33.835$, $p < .001$, in the grasping phase, and $F(1,10) = 11.228$, $p < .01$, in the transporting phase. The interaction effect between lateral cane-position and hook-orientation was also significant in both phases of the task, $F(1,10) = 13.913$, $p < .01$, in the grasping phase, $F(1,10) = 9.412$, $p < .05$, in the transporting phase. To elucidate this interesting finding, the percentages of right-hand use in both phases of the task, as a function of lateral cane-position and hook-orientation, are shown in Figure 3.

Topology

In 79% of the trials the children enclosed the target-object in the hook, in 15% they used an exclosure topology, and in 6% they transported the object by using the cane as a stick. By combining the exclosure and stick-use topologies, an overall category of nonenclosure topology is formed. This makes the difference between hook use (enclosure topology; 79%) and nonhook use (none-nclosure topology; 21%) most apparent. A 2 (lateral cane-position) × 2 (proximal-distal cane-position) × 2

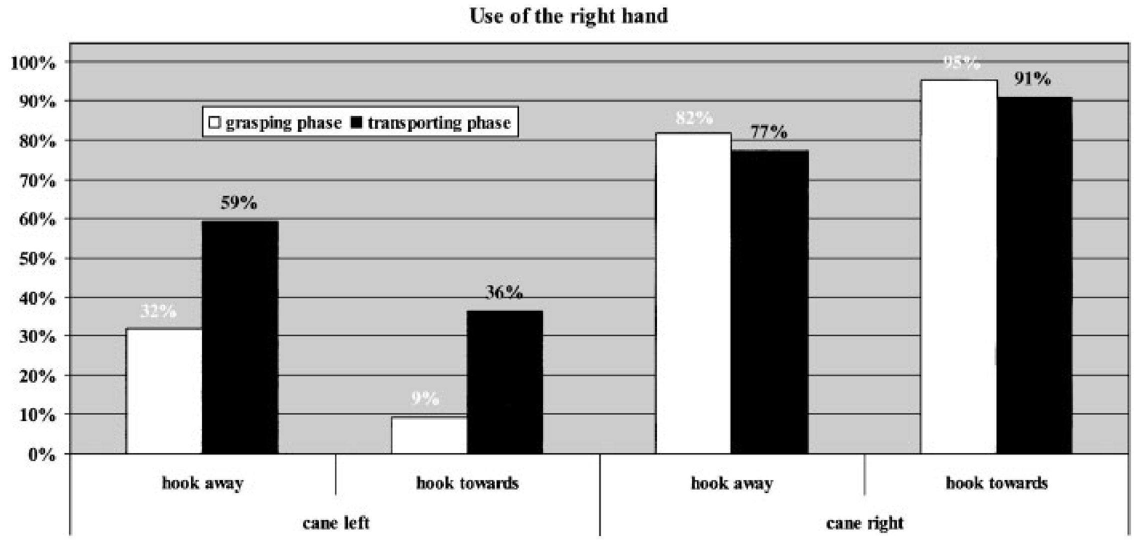

FIGURE 3 Percentages of right-hand use in both phases of the task as a function of lateral cane-position and hook-orientation.

(hook-orientation) repeated measures ANOVA on the topology data in this latter form (i.e., hook vs. nonhook) yielded no effects of the independent variables. Therefore, it can be concluded that the way the cane was used for transporting the object was not determined by the starting configuration of tool and target-object.

End-Position

Figure 4 shows the scores of each of the four end-positions (near left, near right, far left, and far right) in percentages. The target-object's final location was left free to choose, and the children almost always chose to move the object closer to them. With respect to the laterality, there appeared to be a clear preference for right-sided end-positions. For the purpose of analysis, the end-position data were pooled into two categories: lateral (left/right) end-position, and proximal-distal (near/far) end-position.

A 2 (lateral cane-position) $\times$ 2 (proximal-distal cane-position) $\times$ 2 (hook-orientation) repeated measures ANOVA was performed on the lateral end-position data and on the proximal-distal end-position data separately. This analysis yielded no significant effects of the independent variables on proximal-distal end-position. This is most

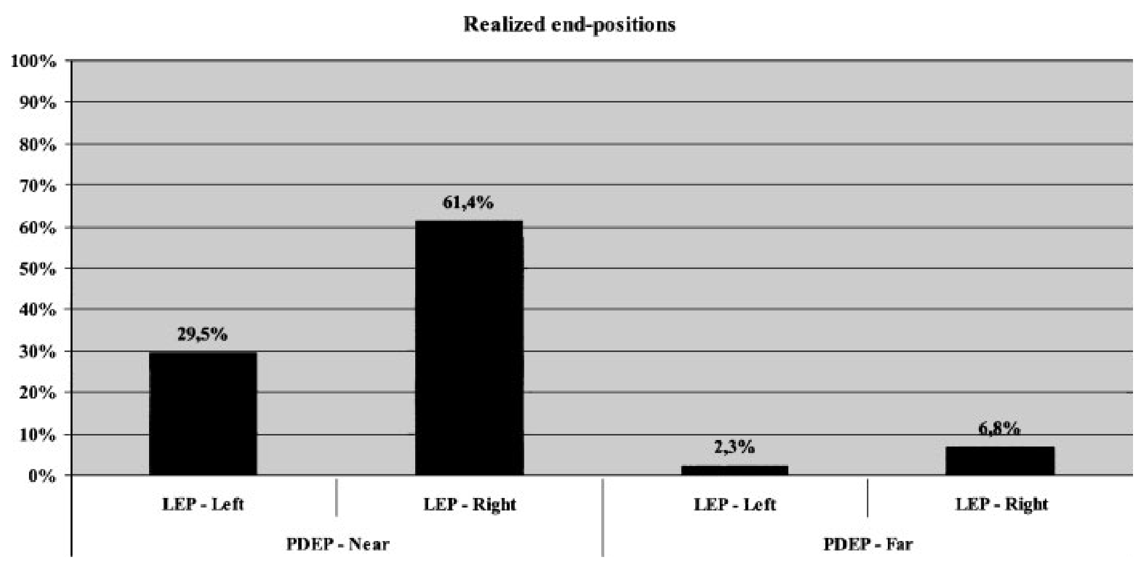

FIGURE 4 Percentages of realized end-positions for the four quadrants of the table. LEP is lateral end-position, and PDEP is proximal-distal end-position.

probably due to the fact that participants mostly brought the object towards them. For lateral end-position, there was a main effect of hook-orientation, $F(1,10) = 5.714$, $p < .05$, and an interaction effect between hook-orientation and proximal-distal cane-position, $F(1,10) = 5.714$, $p < .05$. This latter effect was such that when the cane was lying at the near end of the table, the object ended up on the right in 77% of the trials when the hook was pointing away from the object, whereas only in 59% of the trials when the hook was pointing towards it. When the cane was lying at the far end of the table, the object ended up on the right in 68% of those trials for both hook orientations.

Lateral end-position varied with the hand the children used to transport the object with. When the location was on the child's left side, in 96% of the cases this was done with the right hand, while only in 4% with the left hand. When the location was on the right side the percentages of right-hand use and left-hand use were almost equal: 52% and 48%, respectively.

Although no separate analysis of motor behavior was conducted, two types of movement patterns are conceivable for the near end-positions (about 91% of the trials). First, a *sweeping movement*, either with the right hand to the left side (32% of the trials) or with the left hand to the right side (33% of the trials). Second, a *pulling movement*, only performed with the right hand to the right side (35% of the trials), but never with the left hand to the left side (0% of the trials). These movement types are in correspondence with the preference that was found for end-positions to the right (68%).

DISCUSSION

The starting location and orientation of the cane played no role in determining the topology that was used in performing the task. This is inconsistent with Van Leeuwen et al. (1994) earlier findings. Although in this experiment there were different starting configurations akin to those used in their task, these did not affect whether and how the cane was going to be used. Contrary to Van Leeuwen et al.'s task, in this experiment children were allowed to bring the object anywhere in a groove, which fully surrounded the starting position of the object. Arguably, with such a free-to-choose goal location, a possible constraining influence of this goal factor on task performance was absent. Because of this, the most direct and easiest possible solution to the task was to move the cane from its starting location to the object and further, letting topology and end-position emerge from this. If children would have chosen to do so, hook-orientation must have had a significant effect on topology, viz. more nonenclosure (nonhook) topologies when the hook was initially oriented away from the object and more enclosure (hook) topologies when it was initially oriented towards the object. However, this was not what we found in our data. This shows that the tool-to-object relation was not the result of planning the simplest trajectory, which requires the least number of transformations to be integrated. On the contrary, it proves that the tool-to-object relation must have been a central part of the planning itself, and that the necessary transformations followed from that.

A notable feature of the children's behavior was the preference they showed for the type of movement that can be characterized as sweeping (defined by using the hand contralateral to the object's destination). Roughly over two-third of the transportations are executed in this way. One might argue that these movements are very simple translations in space, and that their presence, therefore, indicates that the children planned the easiest possible trajectory. Although controlling a movement trajectory is part of the task performance—it has to be in order to establish tool-object contact and to let the object arrive at its goal location—the large number of enclosure topologies indicated that these trajectories were constrained by the tool-to-object relation the children planned to use. Children did not just "sweep" from the tool's starting location to the object and further. Instead the sweeping movements were instigated after tool-object contact had been established.

Interestingly, sweeping was the only way in which the participants used the cane with the left hand, while for the right hand a considerable number of pulling movements (defined by using the hand ipsilateral to the object's destination) were observed too. Together this resulted in a considerable number of object transportations to the right side. If the larger part of the children were right-handers, which is in accordance with the day-care employees' verbal reports, the higher dexterity of the right hand enabled them to organize a more difficult and less comfortable (i.e., involving more degrees of freedom) movement like pulling. This indicates that biomechanical factors, in addition to the task-related factors, are an inherent part of the task performance (see e.g., LeConte & Fagard, 2004).

The strong ipsilateral effect of lateral cane-position on hand choice that was found is in agreement with the findings on reaching movements and tool use in children reported by others (see e.g., Harris & Carlson, 1993; McCarty et al., 1999, 2001; Van Hof, Van der Kamp, & Savelsbergh, 2002). In the grasping phase children used the hand on the same side as where the cane was lying for making the tool part of their action system. In the transporting phase, when the tool was already in the hand and visual input of lateral cane-position was no longer available, the effect was still present but weaker. Arguably, it is the result of perseverance in hand use between the phases.

On top of this ipsilateral grasping with respect to the cane's starting location, the choice for the hand to pick up the tool with was also influenced by the future topology the children intended to realize. They seemed to plan an enclosure topology, afforded by the hook of the cane, and adapted the actions that had to be taken accordingly. When the hook was directed towards the target-object, they made relatively more use of the ipsilateral hand. This enabled them to accomplish an enclosure topology quite easily, that is, with the least number of transformations. For the same reason, the contralateral hand was used relatively more often when the hook was directed away from the object. This not only shows that children were sensitive to the initial tool-to-object configuration, but more importantly, it shows that they were able to use this information to appropriately adapt their future behavior. So, although they seemed to perform the task with the least number of transformations for the hook, this was instigated by the topology they planned, not vice versa. By cleverly choosing the hand to pick up the cane with, they realized this in an easy and comfortable way.

In conclusion, a tool cannot have its tool-use ''meaning'' as a single, unattached entity in the world, but its existence as a tool is embedded in its relations with an actor, a target-object, and a goal (Smitsman, 1997; Van Leeuwen et al., 1994). Tools are affordances (Gibson, 1986) and therefore possibilities for actions. This study showed that in realizing the affordance a tool entails, children were focused on the relation between the tool and the target-object (i.e., the topology). Moreover, the realization of this topology was clearly coupled to the kind of action system a child recruited from the body (i.e., the choice of which hand to use). The viewpoint we like to propose, therefore, is that in learning the new possibilities tools afford for action, children have to discover how the relation between the actor and the tool becomes constraint by the tool-to-object relation. This statement is in accordance with research done by others (Bongers et al., 2004; Wagman & Carello, 2003), and certainly deserves further investigation.

Finally, learning to use tools necessitates planning and control of a number of action variables in order to effectively and efficiently attain a goal. The general aim of this study was to investigate how children begin to negotiate these demands tool use imposes on them. The design of the experiment provided an interesting approach to this issue. By looking at a set of coupled action variables and the way they constrain each other in different phases of a task, valuable insights can be attained on the development of future-oriented problem-solving and goal-directed behavior (cf. Claxton, Keen, & McCarty, 2003; Johnson-Frey, McCarty, & Keen, 2004; Willatts, 2004.

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