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Highlights

► First spontaneous success in using a tool appears at 18 months of age. ► Infants begin to benefit from a demonstration of a tool-use action at 18 months. ► Developmental steps are discussed in terms of attentional changes with age.
Brief Report

The emergence of tool use during the second year of life

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Abstract

Despite a growing interest in the question of tool-use development in infants, no study so far has systematically investigated how learning to use a tool to retrieve an out-of-reach object progresses with age. This was the first aim of this study, in which 60 infants, aged 14, 16, 18, 20, and 22 months, were presented with an attractive toy and a rake-like tool. There were five conditions of spatial relationships between the toy and the tool, going from the toy and tool being connected to there being a large spatial gap between them. A second aim of the study was to evaluate at what age infants who spontaneously fail the task can learn this complex skill by being given a demonstration from an adult. Results show that even some of the youngest infants could spontaneously retrieve the toy when it was presented inside and touching the top part of the tool. In contrast, in conditions with a spatial gap, the first spontaneous successes were observed at 18 months, suggesting that a true understanding of the use of the tool has not been fully acquired before that age. Interestingly, it is also at 18 months that infants began to benefit from the demonstration in the conditions with a spatial gap. The developmental steps for tool use observed here are discussed in terms of changes in infants’ ability to attend to more than one item in the environment. The work provides insight into the progressive understanding of tool use during infancy and into how observational learning improves with age.

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Introduction

Learning to use a tool is a critical step in human development, and there has recently been a growing interest in the emergence of this ability in infants (see Keen, 2011, for a recent review). To our

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knowledge, however, no study so far has systematically investigated how learning to use a tool to retrieve an out-of-reach object progresses with age. This was the first goal of the study presented here. A second goal was to evaluate at what age infants who fail spontaneously can learn this fairly complex skill from a demonstration given by an adult.

Tool use in human infants develops during the period from 8 to 24 months of age following a development described by Piaget’s (1952) sensorimotor Stages 4 to 6 (McCarty, Clifton, & Collard, 2001). At sensorimotor Stage 4 (8–12 months), where infants start being able to sequentially plan steps to attain a goal, the literature shows evidence for the beginnings of tool use. Infants are able to retrieve an out-of-reach object when no spatial gap disrupts the link between the tool and the toy, as when the toy is on a cloth, at the end of a string, or even inside and against the tool (Bates, Carlsonluden, & Bretherton, 1980; Brown, 1990; Piaget, 1952; see also Van Leeuwen, Smitsman, & van Leeuwen, 1994). At Stage 5 (12–18 months), infants begin to be able to combine and relate two objects together, the literature suggests that infants are still not able to use tools when there is a spatial gap (Brown, 1990; see also van Leeuwen et al., 1994, although these latter authors did not precisely specify the age range). On the other hand, infants may start being able to do the task with the spatial gap if they are given a demonstration by an adult (Esseily, Nadel, & Fagard, 2010; see also van Leeuwen et al., 1994). It is also worth noting some other studies that are related to tool use performed on children at this sensorimotor stage and that concern the development of the motor skill involved in using a spoon (Connolly & Dalgleish, 1989; McCarty, Clifton, & Collard, 1999). This behavior may be easier than many tool-use situations because the movement involved is directed toward the child (Keen, 2011; McCarty et al., 1999). It develops gradually over Stage 5 and involves diverse strategies where hand preference, trajectory control, and type of grasping play a role. Finally, at Stage 6 (18–24 months), where infants start to make plans that imply mental representations and transformations of objects, existing studies provide evidence that infants more fully understand tools. In conditions of spatial gap, infants are now even more easily able to profit from a demonstration by an adult (Chen & Siegler, 2000). During the later part of this period (from 24 months), conditions of spatial gap begin to no longer pose a problem for children even without a demonstration (Brown, 1990; Keen, 2011). Furthermore, infants are able to spontaneously choose the relevant tool among a choice of functional and nonfunctional tools (Brown, 1990; but see Chen & Siegler, 2000). Again, it is worth noting that at the beginning of the period from 18 to 24 months, the motor skills involved in spoon use are optimally planned as a function of hand position (McCarty et al., 1999).

From this quick overview of the existing studies, we see that the spatial gap between the tool and the toy seems to play an important role. Another interesting factor seems to be whether infants are able to profit from an adult’s demonstration. Unfortunately, existing studies are limited either to broad age group ranges (e.g., Brown, 1990; Chen & Siegler, 2000; van Leeuwen et al., 1994) or to a single small age span (e.g. Bates et al., 1980; Esseily et al., 2010 [for the rake task]), or in the case of the spoon (Connolly & Dalgleish, 1989; McCarty et al., 1999, 2001) they concern the progress of motor skill acquisition more than cognitive development itself.

Given the importance of tool use as a hallmark of human cognitive development, the lack of systematic age-linked studies is surprising. The aim of the current work was to fill this gap by systematically describing developmental changes in learning how to use a tool, spontaneously and after a demonstration, while varying the spatial gap between the tool and the toy.

Materials and methods

Participants

A total of 60 healthy full-term infants (20 girls and 40 boys) participated in this cross-sectional study. Five age groups of 12 participants were tested: 14-month-olds (13 months 28 days to 14 months 13 days), 16-month-olds (15 months 28 days to 16 months 9 days), 18-month-olds (17 months 26 days to 18 months 4 days), 20-month-olds (19 months 27 days to 20 months 10 days), and 22-month-olds (21 months 25 days to 22 months 5 days). Infants were recruited from a list of local families who expressed interest in taking part in studies of infant development. Prior parental consent was granted before observing the infants.

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Design and materials

The experimental apparatus was designed to assess at what age and in which conditions infants are capable of using a tool to retrieve an out-of-reach toy. A desired toy was placed out of reach at different positions near a white cardboard rake-like tool (15 × 20 cm), designed to be visually plain (see Fig. 1). During the whole experiment, infants sat in the lap of one of their parents in front of a table (80 × 120 cm). An experimenter sat facing the infants behind the table. A digital video camera recorded the whole session.

Procedure

Infants were first allowed to familiarize themselves with the toy and tool by manipulating them for approximately 30 s to 1 min. In the tool-use test itself, an attractive toy was placed in front of infants successively in five conditions (see Fig. 1): toy attached to the rake part of the tool (C1: no spatial gap, attached), toy inside and against the rake part of the tool (C2: no spatial gap, unattached), toy inside the tool but not against it (C3: small spatial gap), toy to the side of the tool (C4: large spatial gap), and toy in the middle of the table with the tool directly held out to the infant by the experimenter (C5: effectively a very large spatial gap). The conditions were presented in order of increasing spatial gap from C1 to C5. All infants received one trial at C1, where they all immediately succeeded. They were then directly presented with two trials at C2. If both trials were successful, they received two trials at C3 (and so on until C5). If infants failed in one or both trials of a condition, they were given one or two additional trials of that condition. If infants failed to retrieve the toy on two of three trials, parents were asked to give two consecutive demonstrations of the failed condition. If infants failed in a condition after a demonstration, they were directly presented with the C5 condition. Thus, the C3 and C4 conditions were presented only if infants succeeded in the previous condition either spontaneously or after a demonstration; only the C1, C2, and C5 conditions were presented to all of the infants.

Data analysis

Data were analyzed (a) in term of success/failure for each condition (C1–C5) and (b) on the basis of a behavioral category for each infant. For this, a score of 0 was attributed when infants expressed no interest in the toy, the tool, or (more generally) the task; a score of 1 was attributed when infants were mostly interested in the out-of-reach toy, pointing toward it and possibly trying to retrieve it without

Fig. 1. Mean percentage of success in each condition as a function of age (with error bars showing 1 standard error above and below the mean).
using the tool; a score of 2 was attributed when infants were mainly interested in manipulating the tool itself, possibly alternating its attention between the toy and the tool but not in connecting the two; a score of 3 was attributed when infants systematically and repetitively brought the tool to bear on the toy but seemingly not with the purpose of retrieving the toy; and a score of 4 was attributed when infants succeeded in retrieving the toy with the tool. We also coded as 4 the rare cases when infants clearly attempted to retrieve the toy with the tool but failed because they inadvertently moved the toy out of reach (means of 2, 3, 3, 0, and 1% of trials at 14, 16, 18, 20, and 22 months of age, respectively). An important point should be noted about the C2 and C3 conditions, where the tool and toy were spatially close. In these conditions, the toy was positioned so that it lay between the tool head and the infants. This had the consequence that simply pulling the tool through a small distance would inevitably bring the toy into reach. Thus, in these conditions, successes scored as 4 could have been achieved by chance because infants could pull the tool and obtain the toy by pure spatial contingency (O’Regan, Rat-Fischer, & Fagard, 2011). High scores in the C2 and C3 conditions with little or no spatial gap, therefore, should not be considered as true indicators of infants’ comprehension of the tool. For this reason, we analyzed these conditions separately in some analyses.

Scoring reliability

Infants’ behaviors were coded from the videotapes, and 13 infants (22%) were coded independently by a second observer to assess interobserver reliability. Reliability between the two observers was 90%.

Results

Does spontaneous success vary with age and condition?

Fig. 1 presents the mean percentage of spontaneous success for each condition as a function of age. Infants succeeded spontaneously in the C1 condition on the first trial, leading to a mean of 100% at each age; thus, this condition was not further analyzed. For the other conditions, a repeated measures analysis of variance (ANOVA) on the percentage of spontaneous successes (n = 2–5 per infant for each condition) as a function of age (14, 16, 18, 20, or 22 months) and condition (C2, C3, C4, or C5) showed a main effect for age, F(4,49) = 11.87, p < .001, \( \eta^2 = .16 \), and a main effect for condition, F(3,147) = 33.48, p < .001, \( \eta^2 = .26 \). The age by condition interaction was not significant. A post hoc least significant difference (LSD) test for age effect showed that the 14- and 16-month-olds (mean success = 20.31 and 23.13%, respectively) were different from the 18- and 20-month-olds (mean success = 40.15 and 45.18%, respectively) and from the 22-month-olds (mean success = 69.86%). The 18- and 20-month-olds were also different from the 22-month-olds. A post hoc LSD test showed that all conditions differed significantly from each other except C4 and C5 (p = .20). All 18- and 20-month-olds who succeeded spontaneously at C4 and C5 had seen a demonstration leading to success in a simpler condition. In contrast, 4 22-month-olds succeeded spontaneously in conditions with a large spatial gap without any previous demonstration in simpler conditions.

Does the effect of a demonstration vary as a function of age and condition?

Success versus failure

All infants who received a demonstration had failed at the previous trial. We compared the percentage of infants who succeeded after a demonstration. Because the number of infants was not necessarily the same between age groups for each condition, we could not use a standard chi-square analysis. Thus, the data were analyzed using the procedure of Marascuilo, corresponding to a chi-square analysis adapted to multiple comparisons when sample size is not equal between groups. For the C2 and C4 conditions, there were no significant age differences. The only significant differences were between the youngest and oldest age groups at the C3 condition. \( \chi^2(df = 1, N_{14} = 5, N_{22} = 1) = 0.80, p < .05 \) (20% success after a demonstration at 14 months, 100% success after a
demonstration at 22 months), and the C5 condition, $\chi^2(df = 1, N_{14} = 11, N_{22} = 4) = 0.75, p < .05, (0$ vs. $75\%$ success at 14 and 22 months, respectively).

**Level of performance (0–4)**

To further analyze the effect of a demonstration, we used the score defined in the data analysis section to compare the behaviors toward the toy and tool before and after a demonstration. Given the fact that there were few demonstrations for some infants, we decided to pool little or no spatial gap conditions (C2 and C3) as well as large spatial gap conditions (C4 and C5). Thus, for infants who received a demonstration at the two conditions (e.g., C2 and C3), the value considered is the mean over the two conditions, whereas for infants who received a demonstration at only one of the two conditions (e.g., C2 or C3), the value considered is this value.

**C2 and C3 conditions**

The difference in scores before and after a demonstration was tested using a paired $t$ test for each age group. The effect of a demonstration was significant for 18-month-olds ($m_{\text{before}} = 0.83, m_{\text{after}} = 3.00), t(5) = −3.08, p < .05, d = 1.26$, and 20-month-olds ($m_{\text{before}} = 1.71, m_{\text{after}} = 2.86), t(6) = −2.83, p < .05, d = 1.07$. The $t$ test showed no significant effect of demonstration for 14-month-olds ($m_{\text{before}} = 1.56, m_{\text{after}} = 2.33), t(8) = 2.19, p = .06, d = 0.73$, and 16-month-olds ($m_{\text{before}} = 1.10, m_{\text{after}} = 2.30), t(9) = −2.17, p = .06, d = 0.69$. The 22-month-old group could not be tested because only 2 infants needed a demonstration over all trials in the C2 and C3 conditions. Both infants switched from a score of 1 (before demonstration) to a score of 4 (after demonstration).

**C4 and C5**

Fig. 2 shows the scores before and after a demonstration at C4 and C5. Paired $t$ tests showed evidence for a significant effect of the demonstration at 18 months, $t(6) = −2.32, p = .05, d = 0.88$, and at 22 months, $t(7) = −2.47, p < .05, d = 0.87$. There was no significant score difference between before and after a demonstration for the three other age groups: 14 months ($p = .19$), 16 months ($p = .72$), and 20 months ($p = .16$).

**Discussion**

The aim of this study was to investigate the developmental steps leading to tool-use acquisition in infants across specific age groups during the second year of life. Five conditions involving different spatial relationships between the toy and the tool were successively presented, with a demonstration being provided by the experimenter in case of failure.

Fig. 2. Mean scores before and after demonstration as a function of age (with bars showing 1 error above the mean) in conditions with a large spatial gap (C4 and C5).

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The results show that in all conditions, when the toy was not attached to the tool, performance increased significantly with age, with 14- and 16-month-olds differing from older infants and 18- and 20-month-olds also differing from 22-month-olds. For all age groups, the difficulty of using a tool increased with the spatial distance between the toy and the tool. Thus, the task was very easy when a physical connection between the toy and the tool was present (C1), more difficult with the toy against the tool (C2), even more difficult with the toy inside but not against the tool (C3), and most difficult when there was a spatial gap between the toy and the tool (C4 and C5). These results are in accordance with previous results stressing the importance of the spatial gap between the toy and the tool (Bates et al., 1980; Brown, 1990; van Leeuwen et al., 1994).

The following is a more detailed analysis of infants’ ability to succeed in the task without a demonstration according to age group. At 14 and 16 months, in the comparatively easy conditions with little or no spatial gap, the success rate was less than approximately 50%, which is in line with a longitudinal study on a similar task (O’Regan et al., 2011). O’Regan et al. (2011) suggested that the early successes in these conditions are due more to the fact that the toy can move with the tool by contiguence, as the toy lies in the trajectory between the tool head and the infants, than to a true understanding of the tool’s functionality. In this 14- to 16-month age period, infants never succeeded in conditions with a spatial gap, which also fits with previous results (Brown, 1990; O’Regan et al., 2011; van Leeuwen et al., 1994). At 18 months, infants begin to succeed in conditions with a large spatial gap, when the toy is not between the tool head and the infants, which is coherent with O’Regan and colleagues’ results suggesting that 18 months of age is a landmark for this kind of tool-use task. However, O’Regan and colleagues’ results bore on only 4 infants followed longitudinally and needed to be confirmed. At 22 months, infants still did not systematically succeed in the two conditions with a large spatial gap, which is in accordance with the literature (Keen, 2011).

With regard to the necessity for a demonstration of the use of the tool, infants benefit from watching an adult demonstration starting at around 18 months of age. This is fairly coherent with the findings of Chen and Siegler (2000), who, in a task requiring a group of 18- to 26-month-olds to choose between alternative tools, including one similar to our tool, found that adult demonstrations can be very effective. In the current study, this effect was particularly visible when we analyzed the change in behavior between the trial directly before the demonstration and the trial after the demonstration. For C2 and C3 (little or no spatial gap), it was only starting from 18 months of age that infants changed their behavior between the trial directly before the demonstration and the trial after the demonstration. For C4 and C5 (spatial gap), only the 18- and 22-month-olds showed an improvement after the demonstration. This improvement manifested itself by the fact that infants in these two age groups mostly went from focusing their initial attention either on the toy (scored 1) or on the tool (scored 2) to focusing their attention on the combination of both the tool and the toy (scored 3 or 4). At 20 months, however, no significant effect of a demonstration was found. The global and individual results indicate that all 7 participants who needed a demonstration in these conditions had an initial score of 1, focusing their attention mostly on the toy. After a demonstration, only 2 infants changed their behavior to combine the two components. We have no explanation for this drop in performance at 20 months and assume that it is due to a quirk in the 20-month group of infants.

It is worth noting that at C4 and C5, the 14-month-olds tended to have a higher score than the 16-month-olds. A fine-grain analysis of the frequency of the different behaviors observed at each age shows that 14-month-olds globally manipulate the tool (scored 2) more than the other age groups. In contrast, the 14-month-olds seemed to express less interest toward the out-of-reach toy (scored 1) than the 16-month-olds. Thus, even if all of the 14-month-olds noticed the toy and showed interest in it, it seems that their attention was more easily attracted toward the tool and its exploration.

Why did tool-use learning from the demonstration appear only after 18 months in this study? After all, infants are known to learn means–end tasks from observation from the beginning of their second year of life (Esseily et al., 2010; Provasi, Dubon, & Bloch, 2001; see Elsner, 2007, for a review). The absence of effect of the demonstration before 18 months may be partly explained by the particular conceptual difficulty of the tool-use task compared with other simpler tasks and because of the several successive steps it involves. But the absence of an early effect of demonstration may also be due to the way we provided the demonstration, which was relatively restricted in content and variety. If this is true, then adding more information to the demonstration such as pedagogical cues (e.g., Csibra &
Csibra, G., & Gergely, G. (2006) Social learning and social cognition. The case for pedagogy. In Y. Munakata (Ed.), Carpenter, M., Call, J., & Tomasello, M. (2002). Understanding “prior intentions” enables 2-year-olds to imitatively learn a tool-use task. It would be interesting to further investigate the link between the increase in tool-use performance observed here at around 18 months and the change, at around the same age, in the capacity to learn a complex skill by observation.

References


