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Author: Verschoor, Stephan Alexander
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Chapter 4: Outcome potential influences twelve-month-olds’ interpretation of a novel action as goal-directed

Szilvia Biro, Stephan Verschoor, Esther Coalter and Alan M. Leslie
Chapter 4

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Abstract

Learning about a novel, goal-directed action is a complex process. It requires evaluating the causal potential of the action and linking the action to its outcome for later use in new situations to predict the action or to anticipate its outcome. We investigated the hypothesis that linking a novel action to a salient change in the environment is critical for infants to assign a goal to the novel action. We report a study in which we show that 12-month-old infants, who were provided with prior experience with a novel action accompanied with a salient visible outcome in one context, can interpret the same action as goal-directed even in the absence of the outcome in another context. Our control condition shows that prior experience with the action, but without the salient effect, does not lead to goal-directed interpretation of the novel action. We also found that, for the case of 9-month-olds infants, prior experience with the outcome producing potential of the novel action does not facilitate a goal-directed interpretation of the action. However, this failure was possibly due to difficulties with generalizing the learnt association to another context rather than with linking the action to its outcome.
Introduction

As adults, we habitually see actions of social agents as bent toward particular ends. However, learning about a novel, goal-directed action is not a straightforward process, it involves multiple steps. When one observes a novel action for the first time, one has to be able to identify the outcome of the observed action and figure out which aspects of the action are essential for achieving the outcome, that is, one has to evaluate the causal potential of the action. A second necessary step is to store the link between the observed novel action and its outcome for future use. Finally, one has to be able to retrieve the stored link and to use it in an entirely new context. For example, observation of the novel action in a new situation can lead to the anticipation of the outcome without having witnessed the attainment of the associated outcome. This last step of appreciating that the novel action has the potential to produce a particular outcome, enables us to engage in fast on-line processes of intertwined goal anticipation and action prediction\(^7\).

A number of mechanisms have been suggested for the above steps in the process of learning about a novel goal-directed action. Teleological reasoning (Gergely & Csibra, 2003) and simulation procedures (e.g. Meltzoff, 2002; Tomasello, 1999) have been suggested to solve the inferential problem of action and goal selection, and a bi-directional action-effect association mechanism (Hommel et al., 2001) has been proposed to take care of the linking and retrieval of stored means-end relations. While there is debate about the relations between these mechanisms and the role they play in the emergence and

\(^7\) Note that by the term “outcome” we mean the actual (causal) effect of the action, while we use the term “goal” to refer to the mental representation of this outcome. An action is thus considered goal-directed if it can be seen as performed to achieve a particular outcome, in other words, if it is a means to an end.
development of goal-directed action interpretation in infancy (e.g., Woodward, 2009; Biro & Leslie, 2007; Biro et al., 2011; Shimizu & Johnson, 2004; Johnson, 2000), most of these mechanisms seem to share an assumption about an important precondition in infancy for interpreting novel actions as goal-directed. For infants to be able to successfully identify the outcome, and to link it to the action, the outcome of the novel action needs to involve a salient and easily detectable change in the environment (e.g. Király et al., 2003; Elsner, 2007; Biro & Leslie, 2007; Meltzoff, 1988; Verschoor et al., 2010).

The assumption of the necessity of a salient outcome is inherent in teleological reasoning (Gergely & Csibra, 2003), which states that an action is judged as a well-formed goal-directed action if it can be justified as an efficient action towards the outcome. Thus, when one observes a novel action, the goal of the action can be inferred by considering what change of state would be efficiently brought about by this action in the given situation. However, young infants have only limited background resources – such as knowledge about physical constraints - to make such inferences when the outcome is not immediate, not directly visible, or only one of many co-occurring outcomes (e.g., Csibra et al., 2003). The presence of a salient effect can therefore considerably ease the evaluation of the causal potential of an observed novel action. The role of salient changes is also central in the theoretical account proposed to explain the development of action planning and perception (Elsner & Hommel, 2001) on the basis of William James' ideomotor principle. This theory states that actions are inherently represented and linked to each other by their distal effects. Furthermore, theories that credit infants with domain specific modular systems that are sensitive to behavioral cues have also emphasized the role of salient outcomes caused by the means in infants' attribution of goal-directedness (e.g. Leslie, 1994; Gergely et al., 1995). In particular, Biro and Leslie recently proposed a cue-based bootstrapping model (2007) which claims that infants’ innate sensitivity to behavioral cues (such as salient outcomes, self-propelledness, variations of the action) is coupled with a learning mechanism that can link behavioral cues to other surface features such as the appearance or type of actions. When such a link has been established, infants can anticipate
goal-directed actions from actors identified by surface features without collecting direct evidence for behavioral cues.

While the influence of observed salient action effects on infants' own exploratory or imitative behavior is well-documented (e.g. Elsner, 2007; Elsner and Aschersleben, 2003; Hauf et al., 2004, Rovee-Collier, 1987; Verschoor et al., 2010), there is much less evidence of their impact on infants' understanding of and prediction for others’ observed novel actions (see discussion below). The aim of the current paper is to investigate the role of a salient outcome in the process of interpreting a novel action as goal-directed. Thus, we asked whether infants can appreciate the link between a novel action and its salient outcome and whether they can make use of the learnt link in a new context by interpreting the observed novel action as directed to a particular goal even in the absence of the salient outcome. In other words, we tested whether infants can assign a goal to an unfamiliar action that in a different context they had previously associated with a salient visible effect.

There is evidence that infants can already interpret a familiar hand action such as grasping as goal-directed as early as six months of age. In a study using a visual habituation method, infants watched a hand repeatedly grasping one of two toys on a stage (Woodward, 1998). After habituation, the positions of the toys were swapped and the hand grasped either the new toy in the old location or the old toy in the new location. Infants looked longer at the new toy test event indicating that they expected the hand to grasp the same toy. However, when 6 and 9-month-old infants were habituated in a similar setting with an unfamiliar novel action in which the back of a hand simply touched one of the target toys, the infants looked equally long in the two test events, which suggests that they did not specifically expect the hand would touch the same toy again (Woodward, 1999).
It has been suggested, however, (Király et al., 2003, Biro & Leslie, 2007) that infants’ predictions in the grasping hand condition might not have been based on the grasping action per se, but rather on the strong association of the potential salient outcome that a grasping action can produce (such as the picking up of an object), a means-end relation with which infants are very familiar (Leslie, 1982, 1984). The crucial role of a salient action effect in interpreting a novel action as directed towards a particular goal-state has been demonstrated by replicating the “back of the hand touch” experiment in which the back of the hand did not only touch, but also pushed the target toy to a new location in both the habituation and test phases (Király et al., 2003; Jovanovic et al., 2007). In these experiments, infants from 6 months seemed to interpret the action as goal-directed: they expected the hand to touch and push the same object. A similar looking pattern was found when other types of unfamiliar actions with salient outcomes were used in the same experimental paradigm (Hofer et al., 2005; Biro & Leslie, 2007), for example when a wooden rod touched and - with the help of a Velcro piece - picked up the target toy.

Woodward and colleagues (Heineman-Pieper & Woodward, 2003; Cannon & Woodward, 2010) have criticized these studies, however, by arguing that moving a new object can explain longer looking time to the new toy test event rather than a violation of expectation regarding the goal of the action. However, in the Biro and Leslie study (2007), the force of this alternative explanation is considerably weaker. In that study, 9- and 12-month-old infants looked longer in the new toy than in the old toy test events, even when there was movement only during the familiarization but not in the test events, in which the toy was touched only. This finding also indicates that 9- and 12-month-old infants were able to generate an expectation about the novel action during the test phase without seeing the salient outcome. Thus, they were making use of the learnt association between the action ("touching the toy") and the

Furthermore, 6-month-olds did not look longer to the new toy than in the old toy test event when the action-effect was present during both familiarization and test phases, as they should have if they had reacted only to the movement. This age group only interpreted the unfamiliar action in terms of a goal when other action characteristics, such as variations of the approach movement, were also present.
salient outcome ("being picked up") in a new spatial arrangement. Note, however, that the retrieval of this association was taking place in the same general context involving the same objects. It therefore does not prove that infants are indeed able to make use of the learnt link between the novel action and the salient outcome in an entirely new situation. To show that infants are able to fully generalize the particular outcome producing potential of a novel action which they learnt by previously associating the action with a salient outcome, the learning phase has to take place separately from the testing phase and they have to be in different situations.

In the current study, 9- and 12-month-old infants therefore first participated in a training session in which they gained experience with a novel action and its salient outcome. Infants observed the experimenter touching wooden blocks on a table with the back of her hand and picking them up with the help of a Velcro band that she was wearing on her hand. The infants were themselves also given the opportunity to perform this novel action and to produce the interesting outcome. (Note that the aim of the study was not to disentangle the role of observational versus own action experience with the novel action. Our design in the training aimed to allow the infants to gain ample experience about the salient outcome of the action from either of the two sources.) Following the training phase, the infants were moved to another experimental area and participated in a looking time study identical to Woodward’s “back of the hand touch” study (1999). This familiarized them with the back of the hand touching one of two toys without picking it up. After the two toys’ positions had been switched, they were shown two test events in which the back of the hand touched either the same or a new toy.

If the salient effect (pick up) during the training phase enables infants to interpret the novel action (touch with the back of the hand) as being goal-directed, and if they were then able to rely on this interpretation in a new situation even without witnessing the salient effect, then they should be able to generate a goal-directed expectation about this novel action in the test events. Therefore, we expected
infants to look longer in the new toy test event than in the old toy test event. Two control conditions were also included to make sure that it is indeed the presence of the action effect that causes the difference in the subsequent interpretation of the novel action in the new situation. One of the control conditions differed from the experimental condition only in that no salient effect was produced during the training phase. That is, the touch of the back of the hand did not result in the picking up of the wooden blocks. In the other control condition, no training phase was included. Infants participated only in the looking time study. We expected that infants would not be able to generate a particular expectation about the target of the action in the two control conditions and that they would thus look equally long in the two test events.

**Method**

**Participants**

Twenty-four 9-month-olds (11 males and 13 females, mean age = 39.1 weeks, \( SD = 1.36 \) weeks, range from 37.1 weeks to 41.6 weeks) participated in the experimental condition. Seventy-two 12-month-olds (40 males and 32 females, mean age = 52.8 weeks, \( SD = 2.3 \) weeks, range from 47.7 weeks to 56.4 weeks) were assigned into three groups: experimental (24), control 1 (24) and control 2 (24). An additional 9 nine-month-olds and 15 twelve-month-olds were excluded due to fussiness (5, 5), experimenter error during the training or test session (4, 10, respectively). The infants were recruited through mailings or advertisements.

**Apparatus**

**Training session**

The infant sat at a table in his/her parent’s lap in the infant lab. The experimenter sat at the other side of the table facing the infant. Four plain wooden blocks (a cube, two cylinders, and a brick varying in
size from 8 cm³ to 32 cm³) were used, each had a piece of red Velcro attached to its top. The experimenter had a red Velcro band (about 4 cm wide) on her right hand. The infant was wearing a mitten with red Velcro pieces sewed on the back of it⁹. See Figure 1. The pre-training session (which took 3 minutes on average) was video-taped for later scoring. The training sessions for control group 1 and the experimental group were identical except that for control group 1 the Velcro pieces on the wooden blocks did not stick to the band or mitten (because the same "soft" side of Velcro was used on both the blocks and the band/mitten).

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⁹ The idea of using a mitten with Velcro came from the study of Needham et al., 2002 that investigated if sticky mittens can enhance object exploration skills in pre-reaching infants.
<table>
<thead>
<tr>
<th>Training</th>
<th>Test</th>
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<tbody>
<tr>
<td>With salient</td>
<td>Familiarization</td>
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<tr>
<td>Without salient</td>
<td>Pre-test</td>
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<td></td>
<td>New toy test</td>
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<td>Old toy test</td>
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*Figure 1.* Illustration of training sessions and the subsequent testing session.
Test session

Infants sat on their parent's lap in a darkened and curtained booth that was situated in another part of the infant laboratory room. Infants were facing a stage from a distance of approximately 70 cm. The stage was 60 cm high x 85 cm wide x 40 cm deep and was made from white cardboard. A curtain could be raised to block the stage from view between trials. An opening on the right side of the stage, which was covered by white curtain, allowed the experimenter to enter her arm into the stage area. Two concealed lamps illuminated the stage. A computer signal could turn the lamps on and off to inform the experimenter to start and stop the trials, respectively. A video camera focusing on the baby’s face was mounted above the stage peeping through the opening of a dark curtain. A hidden observer, blind to the test condition and experiment type, timed the infants' looks in the test trials by using a specially built computer program at the displays from head-and-shoulders en face video image. Another camera mounted above and behind the head of the infant also recorded the stage area (a split screen recording was made of all infants, with the stage image on the top and, the baby’s face on the bottom part of the display).

Procedure and Stimuli

Training session for the experimental group

After the parent with the infant sat down at the table, the experimenter placed the first wooden block in front of her on the table and drew the infant’s attention to it. Then the experimenter dropped the back of her hand on the wooden block and, thanks to the Velcro band she was wearing, her hand stuck to the block. Then she lifted up the block. She made sure that the infant was watching and focusing on her action by saying: "Look at my hand!". After this, she separated the wooden block from the band and repeated the same action. As the next step, the experimenter or the parent secured the mitten on the
infant’s hand (on the preferred hand if there was such) and the experimenter placed the wooden block in front of the infant. The infant then was encouraged by the experimenter and the parent to imitate the same action with his/her mittened hand (“Do you want to do this too?” or “It's your turn now!”). Parents were instructed to help infants – if necessary - perform the action by gently pressing the back of the mittened hand of the infant against the wooden block. The infant or the experimenter removed the block from the mitten and the infant was offered to pick up the same block once more. The experimenter then hid that block under the table and placed the next block in front of her on the table. The same sequence was repeated with all four blocks. After the training session, the infant and the parent were immediately asked to move to the curtained booth for the test session. The experimenter was the same person for both sessions.

*Training session for the control group 1:*

The procedure was equivalent to that of the experimental group, with the exception that the experimenter could not pick up the wooden blocks by the band with the back of her hand and thus she simply touched them (since the Velcro pieces did not stick together) and then lifted her hand. Similarly, infants could only touch the wooden blocks with their mittened hand but could not pick them up.

*Test session for both the experimental and control groups:*

*Familiarization phase:*

Infants saw four identical familiarization trials. At the start of each trial, the experimenter lowered the curtain to reveal the stage. On the stage floor, there were two toys of around the same size: a yellow plastic Winnie-the-Pooh bear and a ball with green and white patterns. A piece of red Velcro was attached
to the top of both toys. After the online observer turned the lights on above the stage using a computer signal, the experimenter reached in through the opening on the right side of the stage holding her palm up. She was wearing the same Velcro band as in the training session. She dropped her hand on top of one of the two toys and stayed still for 15 seconds. (Note the hand did NOT pick up the toys.) See Figure 1. When the end of the 15-second interval was indicated to the experimenter by the light switching off, the experimenter raised the curtain. The position of the toys and location of the action were counterbalanced in the familiarization trials.

**Test trials**

After the fourth familiarization trial the positions of the two toys were switched behind the curtain. Then the curtain was lowered and the changed positions without the presence of the hand were shown to the infants for 5 sec. Following this short pre-test trial, one of two types of test events was presented to the infants. Half of the infants saw two identical tests trials in which the back of the hand dropped on the same toy as in the familiarization (old toy test event). The other half of the infants saw two tests trials in which the back of the hand dropped on the new toy (new toy test event). In both types of test trials, after the hand dropped on the toy it stayed still as long as the infants watched the scene. (Note that the hand did NOT pick up the toys during the test phase either.) See Figure 1. The online observer started to measure the looking times when the hand touched the toy and if baby was looking at the stage. The test trial ended when infants had looked continuously for a minimum of 2 sec and then looked away continuously for 2 sec. If infants looked away before 2 sec had elapsed, then the trial was ignored and started again. The experimenter raised the curtain when the end of a valid or ignored trial was indicated to her by the light switching off. Parents were asked to close their eyes during the test trials and instructed to refrain from talking to the infant during the whole session except for giving comfort when necessary.
Reliability coding and scoring of the training session:

To assess reliability in the test session and measure behavior in the familiarization phase, an offline observer measured each infant’s looking times from the videotaped record. The offline observer was also unaware of the type of the test trials and the experiment type. Inter-observer agreement was computed for each infant’s looking times in the two test trials and the agreement was accepted if it was above or equal to 95%. (This was the case for 70% of the cases.) For the rest of the cases a second offline observer was asked to measure the looking times again independently. If this did not lead to agreement with one of the other observers, then the looking times of that infant were excluded from the analyses (this happened in two cases).

In the training session, two offline observers independently scored the infants’ behavior from the videotaped records. Infants’ observational experience was scored by the absolute duration of their attention to the action demonstration by the experimenter. Since the action demonstration in the experimental groups lasted somewhat longer than in control group 1 due to the fact that the experimenter had to separate the block from the Velcro band, we also calculated the duration of attention relative to the length of the demonstration (duration ratio). Infants’ own action experience was scored by the number of times infants properly performed the action. Since turning the hand outward is an awkward and difficult movement for infants, any attempt that resembled such a movement was counted (this was only an issue in the control condition because there was no pick-up). The number of any other actions related to touching the blocks, such as grabbing them with the other hand, banging or shoving them, shaking the mitted hand with the block stuck on, or separating the block with the other hand from the mitten, was also scored. The sum of these two scores was also calculated to obtain an indication of the general level of activity of the infants. Furthermore, the duration of infants’ own acting and the latency to start to act were also measured. Parental help was scored by the number of times they helped perform the action and by
the duration of parent-assisted action. In addition, we also scored whether infants looked at their hand while their parents moved it and then we calculated the ratio of attended parent-assisted actions by dividing the number of attended parent-assisted actions by the total number of parent-assisted actions. Inter-observer agreement was computed for each score and the agreement was between 0.71 and 0.88.

**Test session**

Infants' looking times during the familiarization trials were analyzed first. Univariate ANOVA showed no significant difference between the experimental and control groups for the 12-month-olds, \( F(2,68) = 2.44, p = .10, \eta_p^2 = .07 \), or between the 9 and 12 months old experimental groups, \( F(1,46) = .57, p = .45, \eta_p^2 = .01 \), in the average looking times of the four familiarization trials. Infants in all groups showed a decline in their looking times across the familiarization trials, the difference between the 1st and 4th familiarization trials were significant in all groups, 9 months: \( t(23) = 5.45, p < .001 \); 12 months experimental: \( t(23) = 5.17, p < .001 \); 12 months control 1: \( t(23) = 4.25, p < .001 \); 12 months control 2: \( t(23) = 4.24, p < .001 \). The looking times in the pre-test trial in which the infants could see the changed position of the toys on the stage did not differ between the experimental and control groups for the 12-month-olds, \( F(2,68) = 2.51, p = .09, \eta_p^2 = .07 \), or between the 9 and 12 months old experimental groups, \( F(1,46) = .89, p = .35, \eta_p^2 = .02 \), see Figure 2.
Figure 2. Mean looking times during the familiarization trials for the 9- and the three 12-month-old groups. (The lengths of the first four trials were 13 sec, the pre-test trial was 5 sec long.)
The looking times of the two test trials were analyzed separately for the two age groups. Preliminary analysis of looking times for the two test trials did not reveal any effect of gender, location of the action (near side vs. far side), type of toy touched (bear vs. ball) or the position of the toys (bear left vs. bear right) in any of the groups. Therefore, these factors were omitted from further analyses. Using test type (2, new toy and old toy) and experiment type (3, experimental, control 1 and 2) as between-subject factors and trial (2, first and second) as a within-subject factor, a repeated measures ANOVA was carried out for the 12 months old infants. The analysis found a main effect of trial, $F(1,66) = 4.99, p = .029, \eta_p^2 = .07$, indicating that infants overall looked longer in the 1st than in the 2nd test event. A significant effect of trial x test type x experiment type interaction, $F(2,66) = 3.74, p = .029, \eta_p^2 = .10$, was also revealed. To explore this interaction, separate ANOVAs were carried out in each experiment type group. The ANOVAs showed no main or interaction effects of trial or test type factor in control group 1, control group or 2. On the other hand, in the experimental group a trial and test type interaction was found, $F(1,22) = 6.13, p = .021, \eta_p^2 = .21$. T-tests showed that infants looked longer in the new toy test event than in the old toy test event in the first test trial, $t(22) = 2.54, p = .019$, two-tailed, but not in the second test trial, $t(22) = -.74, p = .46$, see Figure 3. These results were confirmed with non-parametric tests (first test trial in the experimental group: Mann-Whitney $U = 33.5, z = -2.22, p = .024$, two-tailed). In addition, further analyses revealed that during the 1st test event infants who saw the old toy test event in the experimental group looked significantly less long, $F(2,34) = 4.80, p = .014, \eta_p^2 = .22$, than infants who saw the same test event in the control 1 ($p = .046$) or control 2 group ($p = .005$). There was no difference between the three groups in the looking times of infants who saw the new toy test event or during the 2nd test event in any of the test types.

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These effects remained the same when the difference between the looking times for the 1st and 4th familiarization trials was included as a covariate in the analysis. Thus, the amount of decline had no effect on the looking time pattern in the test events.
In the 9 months old group a repeated measures ANOVA for looking times in the test events with trial (2) as within-subject factor and test type (2) as between-subject factor revealed only a trial effect, $F(1,22) = 7.23, p = .013, \eta^2_p = .24$, indicating longer looking times in the first than in the second trial. No effect of test type was found, see Figure 3. We also compared the two age groups in their looking times in the test events by using a repeated measures ANOVA with trial as within-subject factor and test type and age group as between-subject factors. We found a three-way interaction between trial, age group and test type, $F(1,44) = 4.09, p = .049, \eta^2_p = .08$. This interaction indicates that - in addition to the looking pattern that has already been reported separately for the two age groups - there was a significant difference between 1st and 2nd test trials in the 9 months old group that saw the old goal test event, $t(11) = 2.85, p = .016$, while there was no such difference in the 12 months old group, $t(11) = -1.30, p > .21$. 
Training session

Since the demonstration during the training session was somewhat longer in the experimental group than in the control due to the fact that the experimenter had to separate the block from the Velcro band in the experimental group, the absolute time the 12 months old infants attended the demonstration was longer in the experimental group than in the control 1 group condition, $t(46) = 3.72, p = .001$. However, there was no difference between the two groups in the time infants spent attending the demonstration relative to the total time of the demonstration (duration ratio), $t(46) = -2.25, p = .06$. The two age groups in the experimental condition (9 and 12 months) did not differ from each other in absolute attention duration, $t(46) = -.66, p = .50$, or relative attention duration, $t(46) = .91, p = .36$. We found no further differences between any of the groups in the scores for infants’ own action experience or parental assistance ($p_{s} > .20$) except for one of the scores. The $t$-test revealed a difference between the two age...
groups in the ratio of attended parent-assisted action, $t(46) = -2.89, p = .006$, indicating that the 9 months olds were paying significantly less attention to their own hand while their parents moved it than the experimental 12 months old group did. See Table 1 for a summary of the training scores.

Next, we checked whether there was any difference in age, looking times during the familiarization trials or in the training scores between infants who were allocated to the group that saw the New toy or the Old toy test event. No difference was found in any of these measures in any of the groups ($p_s > .15$). Finally, to examine whether the behavior of the infants during the training session had any effect on their looking patterns in the subsequent test session, all the analyses of variance of looking times for the test events were also carried out with all training scores entered as covariates (ANCOVAs). The pattern of results remained unchanged in all analyses.
Table 1. Summary of training scores.

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<th>Attention to demonstration</th>
<th>Infants own action</th>
<th>Parental assistance</th>
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<tr>
<td></td>
<td>Absolute duration of</td>
<td>Number of Proper</td>
<td>Duration of</td>
<td>Mean</td>
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<td></td>
<td>attention</td>
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<td></td>
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<td>Number of Other</td>
<td>Sum of</td>
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<tr>
<td></td>
<td>ratio</td>
<td>action</td>
<td>action</td>
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<tr>
<td></td>
<td>Mean s.e.</td>
<td>Mean s.e.</td>
<td>Mean s.e.</td>
<td>Mean s.e.</td>
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<td>47.73 3.42 .97 .01</td>
<td>1.71 .43</td>
<td>4.67 .94</td>
<td>6.38 1.10</td>
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<td>30.24 5.52 2.14 0.51</td>
<td>19.10 2.57 4.92 .44</td>
<td>23.59 3.47 2.83 0.66</td>
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<tr>
<td><strong>12 months experimental</strong></td>
<td>51.11 3.71 .96 .02</td>
<td>1.33 .32</td>
<td>4.79 .77</td>
<td>6.13 .86</td>
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<td>23.59 3.47 2.83 0.66</td>
<td>15.58 1.69 4.83 .56</td>
<td>25.50 9.37 4.79 .45</td>
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<td>1.04 .28</td>
<td>5.08 .57</td>
<td>6.13 .60</td>
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<td>37.02 6.08 3.14 2.36</td>
<td>25.50 9.37 4.79 .45</td>
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Chapter 4

Discussion

We tested the ability of 9 and 12 months old infants to interpret a novel action as goal-directed when they previously could associate this novel action with a salient effect in another situation. We found that 12 months old infants who took part in the experimental training session in which they were provided experience with a novel action accompanied by a salient effect, looked longer in the new toy test event than in the old toy test event in the subsequent testing session. This result thus suggests that the infants were able to generate a particular expectation about the goal of this novel act in a new situation even in the absence of the salient action effect. Note that the difference in looking time was only present in the first test trial and not in the second, which is however not surprising or unprecedented as during repeated presentations infants’ expectation may change by reinterpreting the situation on the basis of previous test trials. The 12 months olds in the two control conditions in which the novel action did not produce a salient effect, did not show evidence of being able to interpret the novel action as goal-directed in the testing session, as they looked equally long in the two test events. In addition, infants in both control groups looked longer at the old toy test event in the first test trial than infants in the experimental group which further supports the interpretation that only the experimental group expected this event to take place. In the 9 months old group there was no difference in looking times between the two test events, which indicates that the training session with salient effect did not facilitate a goal-directed interpretation of the novel action for these infants. Taken together we demonstrated that, by 12 months of age, infants can generalize the outcome producing potential of a novel action to interpret the novel action as goal-directed.

The performance of the 12 months olds in the two control conditions clearly indicates that it was the presence of the salient action effect in the experimental condition that was critical for changing the
subsequent interpretation of the novel action. The lack of influence of the training session in control condition 1 excludes the possibility that the facilitating effect of the training in the experimental condition was achieved simply by receiving more prior (observational) experience with the unfamiliar action or by seeing this action being performed by a person who was interacting with the infants and who drew their attention to the action. The lack of difference between the looking times for the test events in control condition 2 shows that the original "back of the hand touch" action without effect is not interpreted as goal-directed not only by 6- and 9- as had previously been demonstrated (Woodward, 1999), but also by 12-month-olds. Furthermore, this latter result also excludes the possibility that the difference between the experimental and control 1 conditions reflects disruptive effects of the control training rather than a facilitating effect of the experimental training.

Our study suggests that a) a salient outcome is critical in interpreting a novel action as goal-directed and that b) 12 months old infants can make use of a learnt link between the action and its outcome in a new context by interpreting the novel action in terms of a goal even in the absence of the salient outcome. These findings can be viewed as a demonstration of cue-based bootstrapping by which infants’ initial sensitivity to behavioral cues is united with a learning process about different types of actions (Biro & Leslie, 2007).

Why did the 9 months olds not benefit from the training? One simple answer could be that younger infants would have needed more experience with an unfamiliar action and its effect in order to link them together. Another possibility is that the infants could link the novel action to the outcome, but had difficulties with retrieving the learnt association. Studies on imitation and memory of own action-effect contingencies show that contextual changes such as changes in the room surroundings or cues can greatly influence the quality of imitation or the memory of actions (Rovee-Collier, 1996; Moore & Meltzoff, 2004). Since our training and test sessions took place in different surroundings, contextual
generalization was certainly necessary. It has been suggested that the ability to generalize across contexts develops somewhere around 9 months of age. However, the exact age at which infants can transfer certain information seems to depend on the degree of change and on the task involved, which makes different studies difficult to compare. In the domain of action understanding, Sommerville and her colleagues (2009) recent study is the most relevant one for our purposes. They found that 10 months olds could only use prior information about the particular goal of an action to generate an expectation about a means action if the information was given in the same room. Imitation studies also show that, by 12 months, infants are not affected by context change in their recall of observed actions (e.g., Klein & Meltzoff, 1999).

Besides contextual differences, the difficulty with the retrieval and generalization of the associated link may also have been caused by the manner in which the infants encoded the observed action during the training session. As we have argued, an important step in learning a new goal-directed action is to be able to determine which aspects of the action are causally necessary to achieve the outcome. For example, if the infants assumed that the person as a whole, her other movements, her smile, or the particular objects that were used were (also) relevant to produce the salient effect in the training session, then the absence of these features in the test session could have prevented the infants from making use of the association. Thus, the retrieval/generalization problems may not (only) stem from the way memory for events are organized, but also from the difficulties with applying teleological reasoning due to the limited prior experience and knowledge about actions and actors at this age.

It is also important to differentiate our study from other training studies with similar features. Elsner and Ashcerleben (2003), for example, investigated the influence of salient action effects produced by a novel object by providing observational training to 9-18 months old infants. They found that only from the age of 12 months did infants benefit from a salient action effect. What they tested, however, was
not whether the effect influenced infants' goal-directed interpretation of an observed novel action but whether it changed their own exploratory behavior. Nevertheless, their developmental pattern fits with our finding.

Hofer and her colleagues (2005), on the other hand, tested 9 months old infants' goal-directed interpretation of a novel tool by providing a short prior demonstration in which the tool was handled by both a model and the infants themselves. Here, however, the subsequent test session did provide salient action-effects. Their training study therefore did not aim to test whether infants can interpret a novel action as goal-directed in the absence of the outcome.

In two training studies, one that provided observational experience with the particular goal of an actor (Sommerville & Crane, 2009) and one that provided own action experience with a novel means-end action (Sommerville et al., 2008), it was found that 10 months old infants had benefited from these trainings when they were subsequently tested on their understanding of observed means-end relationships. However, the entire means-end sequence was presented in the habituation phase of the testing, thus the infants were not required to solely rely on the association between the action and the outcome that they had built up during the training.

Sommerville, Woodward and Needham's (2005) study is the most similar to the current training study. In their study 3.5 months old infants, who cannot reach and grasp objects themselves, participated in a training in which they were wearing a mitten with Velcro attached to the palm and with which they could pick up two toys. This experience allowed them to interpret a grasping hand of another person (without the salient effect of pick-up) as goal-directed. How can we reconcile the large age difference between that study and ours? One possibility might be that in Sommerville, Woodward and Needham's study the objects that the infants picked up during the training were identical to those that were used in the subsequent habituation paradigm. Hence, there was less demand on the ability to generalize the
outcome producing potential of the mittened grasping hand from training to test. Alternatively, while grasping and then transferring an object is a natural hand action with which even young infants have ample prior observational experience, picking up objects by touching them with the back of the hand is unnatural, violates infants' existing physical knowledge (about support and mechanics) and may thus be harder to learn.

A further possibility to explain the difference between these studies leads us to the question of the role of the type of experience that infants can benefit from to interpret an observed novel action as goal-directed. Note, however, that the current study was not designed to test whether the interpretation of an observed action is primarily influenced by infants' own experience with the action or by observational experience. Instead, we emphasized the importance of appreciating the power of an action to produce outcomes in infant's goal-directed action interpretation. We therefore varied the presence or absence of a salient effect via both types of experience.

A recent study that has contrasted the impact of infants' own action experience and observational experience on the interpretation of means-end actions, found self-experience to be primary (Sommerville et al., 2008). However, in both this study and in those that show a strong correlation between infants' own ability to produce certain means-end actions and their understanding of others' similar actions in terms of goals (Sommerville and Woodward, 2005a, 2005b), a salient action outcome was always produced by the infants' own action. Our study is the first to show that, without this salient outcome, own action experience with the novel action does not enhance the ability to interpret the novel action as goal-directed. The salient outcome thus seems to be the crucial mediating factor.

Another reason for the age difference between our study and Sommerville, Woodward and Needham's (2005) might therefore be that the amount of own action experience with the novel action and its effect was insufficient for the 9 months olds in our study. The coding of our training session shows
that infants indeed scored low on the number of proper own action scale. This might have been due to difficulties with imitating the awkward back of the hand touch action or due to a dislike of wearing the mitten. On the other hand, the 12-month-olds scored just as low on this scale, which suggests that either even a small amount of self experience was sufficient for them or that they could make better use of the observational experience by this age. We found, however, that, compared to 12-month-olds, 9-month-olds looked less at their own moving hand while their parents helped them to produce the novel action with its effect. It is therefore possible that 9-month-olds indeed gained somewhat less experience with the effect of the novel action from the training session due to their relative lack of attention during parental help. Future research, however, is required to clarify the exact role of observational vs. motor experience in learning about novel goal-directed actions.

Finally, it is important to point out that in the current study it is hard to distinguish whether infants learnt a new means action or the function of a novel tool, or both. In other words, during the training infants may not (only) have associated the salient effect with the “back of the hand touch” action, but (also) with the Velcro band itself. That is, the infants may have learnt that the Velcro band is for picking things up. In the testing phase, the hand was presented with the Velcro band on and the infants could thus rely on the inferred function of the Velcro band in their interpretation of the action. Future research can for example disentangle these possibilities by using a Velcro band with two different types of hand actions during the test and training phases.

The function of a tool is usually learnt together with a certain action by which the tool can be used to produce an outcome. While for certain tools the proper (i.e. most efficient) use requires very

\[11\] This could also have added to the possible generalization difficulty of the 9 months olds, because the mitten they had self experience with and the Velcro band they observed did not look exactly the same.
specific actions (e.g. a pair of scissors), for other tools the range of actions that allows proper functioning is much wider (e.g. a towel). An interesting question is therefore what types of cues help infants to figure out the level of specificity of the action by which a tool can best be operated.

In summary, we have shown that experiencing a salient effect of a novel hand action (or use of a novel tool) can alter 12 months old infants’ interpretation of the action (or the tool). By appreciating the potential of the action (or tool) to produce an outcome, infants can attribute a goal when they observe the novel action (or novel tool) in a new situation. Our finding shows the essential role a salient outcome plays in the developing ability of infants’ goal-directed understanding of novel actions.