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Outcome producing potential influences twelve-month-olds' interpretation of a novel action as goal-directed

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ABSTRACT

Learning about a novel, goal-directed action is a complex process. It requires identifying the outcome 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.

1. 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(Csibra & Gergely, 2007). 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. 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

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the potential to produce a particular outcome, enables us to engage in fast on-line processes of intertwined goal anticipation and action prediction[1].

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, Musseler, Aschersleben, & Prinz, 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 development of goal-directed action interpretation in infancy (e.g., Woodward, 2009; Biro & Leslie, 2007; Biro, Verschoor, & Coenen, 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, Jovanovic, Prinz, Aschersleben, & Gergely, 2003; Elsner, 2007; Biro & Leslie, 2007; Meltzoff, 1988; Verschoor, Weidema, Biro, & Hommel, 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, Biro, Koós, & Gergely, 2003). The presence of a salient effect can therefore considerably ease the evaluation 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 (2007) recently proposed a cue-based bootstrapping model 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 & Aschersleben, 2003; Gerson & Woodward, 2012; Hauf, Elsner, & Aschersleben, 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 Section 4 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, Hauf,

[1] 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.

& Aschersleben, 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 (2007) study, 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[2]. 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 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 similar to Woodward's (1999) "back of the hand touch" study. 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.

Finally, we would like to point out that two training studies (Sommerville, Woodward & Needham, 2005; Gerson & Woodward, 2014) have recently shown that 3.5-month-old infants who cannot reach and grasp objects themselves, are able to interpret the grasping action as goal-directed if they gained prior experience with picking up objects by wearing a mitten with Velcro attached to the palm. Although our study shares similarities with these studies, it asks different questions. First, we focus on learning about, and generalizing, the goal-directedness of an entirely novel, unfamiliar action, an action with which infants had no previous experience of any kind. Second, we aim to tease apart the crucial aspect of prior action experience by including two training conditions, one with and one without an observable salient effect. We will return to the comparison of our study and these two training studies in Section 4.

2. Method

2.1. 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, 8), and disagreement between coders (0, 2), respectively. The infants were recruited through mailings or advertisements. This study was approved by the ethics committee of the psychology department of Leiden University.

[2] 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.

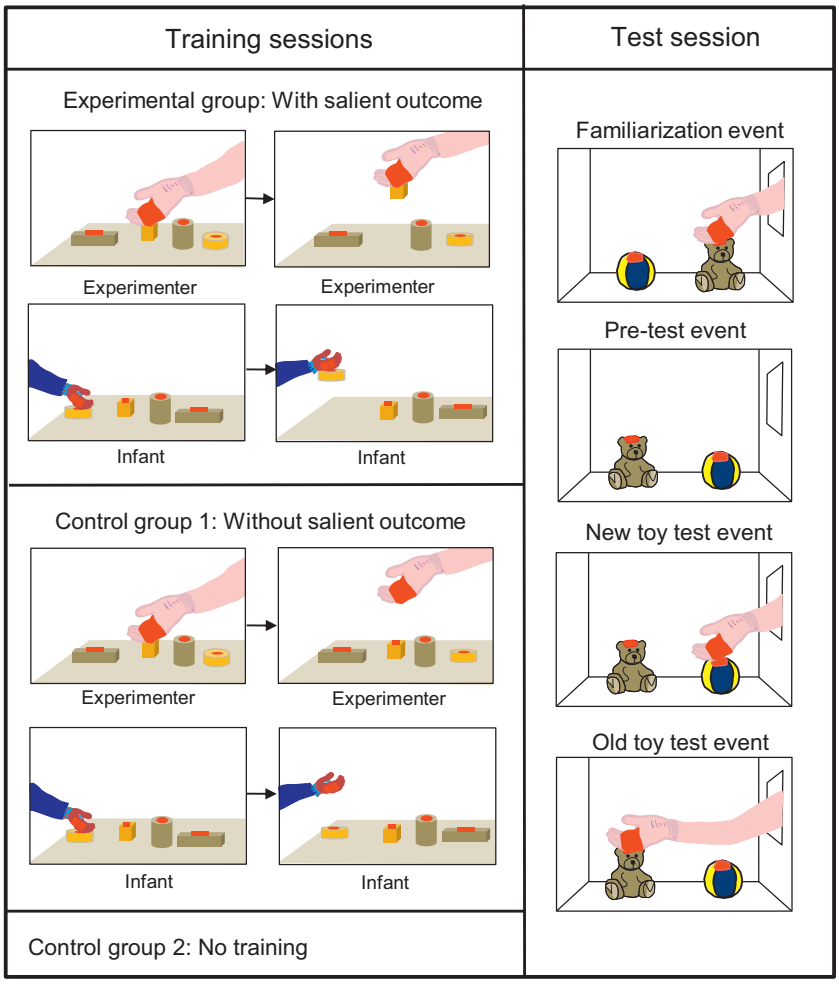

Fig. 1. Illustration of the training sessions and the subsequent testing session.

2.2. Apparatus

2.2.1. 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 cm^3 to 32 cm^3) 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 it (see e.g., also Needham, Barrett, & Peterman, 2002) (see Fig. 1). The training session (which took 3 min 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).

2.2.2. 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 × 85 cm wide × 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.)

2.3. Procedure and stimuli

2.3.1. 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. She then made sure that the infant was watching and focusing on her action by saying: "Look at my hand!". She raised her hand and then lowered it with the palm up to touch the wooden block with the back of her hand. Thanks to the Velcro band she was wearing, her hand stuck to the block. Then she lifted up the block. 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.

2.3.2. Training session for the control group 1

The procedure was equivalent to that of the experimental group including the experimenter's encouragements and verbal or facial feedback, 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.

2.3.3. Test session for both the experimental and control groups

2.3.3.1. 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 lowered her hand and touched the top of one of the two toys with the back of her hand in the same manner as during the training session and stayed still for 15 s. (Note the hand did NOT pick up the toys.) (see Fig. 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.

2.3.3.2. 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 s. 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 touched 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 touched the new toy (new toy test event). In both types of test trials, after the hand touched 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 Fig. 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 s and then looked away continuously for 2 s. If infants looked away before 2 s 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.

2.4. Coding the test session and the training session

The looking times for the test events were coded online and by a second offline coder. The offline observer was also unaware of the type of test trial and the experiment type. Inter-observer agreement was computed for each infant's looking times in the two test trials by subtracting the difference between the online and offline observers' looking time measures and dividing by the online observer's measure. If the agreement was less than 95%, then a third coder was asked to measure the looking times. In two cases the third coder did not agree with any of the other observers (the infant's looking was considered ambiguous). The looking times of these two infants were therefore excluded from the analysis (see also Section 2.1). The offline coder also measured the looking times of infants during the familiarization phase.

In the training session, an offline observer scored the infants' behavior from the videotaped records. Infants' observational experience was scored by calculating 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 mittened 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 was also measured. Parental assistance 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. A second offline observer coded 30% of the training sessions. The inter-observer agreement was adequate, the average score of the intra-class coefficient (single measure, absolute agreement) for all measures in the training session was .73 (range = .68–.86).

3. Results

3.1. 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-month-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-month-old experimental groups, $F(1, 46) = .89$, $p = .35$, $\eta_p^2 = .02$ (see Fig. 2).

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. The two age groups were analyzed separately. 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-month-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 × test type × experiment type interaction, $F(2, 66) = 3.74$, $p = .029$, $\eta_p^2 = .10$, was also revealed[3]. To explore this interaction, separate ANOVAs were first 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 and control group 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 Fig. 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). Further exploration of the interaction by separately testing the groups who saw the old or new toy test types revealed an experimental type effect during the 1st test event in infants who saw the old toy test event, $F(2, 34) = 4.80$, $p = .014$, $\eta_p^2 = .22$. Pairwise comparisons showed that the experimental group looked significantly less long than either the control 1 ($p = .046$) or control 2 group ($p = .005$). There was no difference between the experimental and control groups in the looking times of infants who saw the new toy test event. No differences were found during the 2nd test event between any of the groups.

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, $F(1, 22) = 7.23$, $p = .013$, $\eta_p^2 = .24$, indicating longer looking times in the first than in the second trial. No effect of test type was found (see Fig. 3).

We also compared the 9 and 12 months experimental 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, $F(1, 44) = 4.09$, $p = .049$, $\eta_p^2 = .08$. This interaction indicates the looking pattern that has already been reported separately for the two age groups: infants looked longer at the new goal test event in the first test trial only in the 12-month-old experimental group.

3.2. Training session

Independent t-tests were carried out to test if there was a difference between the 12 months experimental and control 1 groups, and between the 9- and 12-month-old experimental groups in their training scores. We found no difference in infants' attention to the demonstration, $p = .06$ and $p = .36$, respectively, or in any of the own action experience scores, $ps > .06$ and $ps > .31$. Parental assistance scores did not differ either between any of the groups, $ps > .30$ and $ps > .26$, 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, $t(44) = -2.89$, $p = .006$, indicating that the 9 months olds were paying significantly less attention to their own hand while their parents moved it than the experimental 12-month-old group did. No difference was found for this score between the two 12 months group (experimental and control 1), $p = .20$. See Table 1 for a summary of the training scores.

Next, we checked whether there was any difference 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 the training measures in any of the groups (9 months: $ps > .17$; 12 months experimental: $ps > .38$; 12 months control 1: $ps > .13$). 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.

[3] 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. Furthermore, there was no difference in the looking times during the familiarization trials between infants who were allocated to the group that saw the New toy or the Old toy test event in any of the experiment type groups ($ps > .11$).

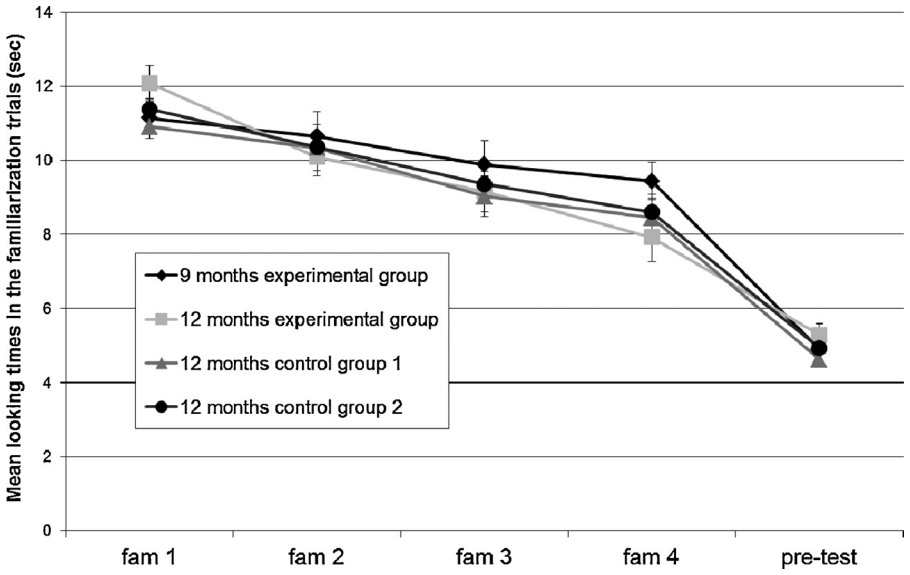

Fig. 2. Mean looking times with standard errors during the familiarization trials for the 9- and the three 12-month-old groups.

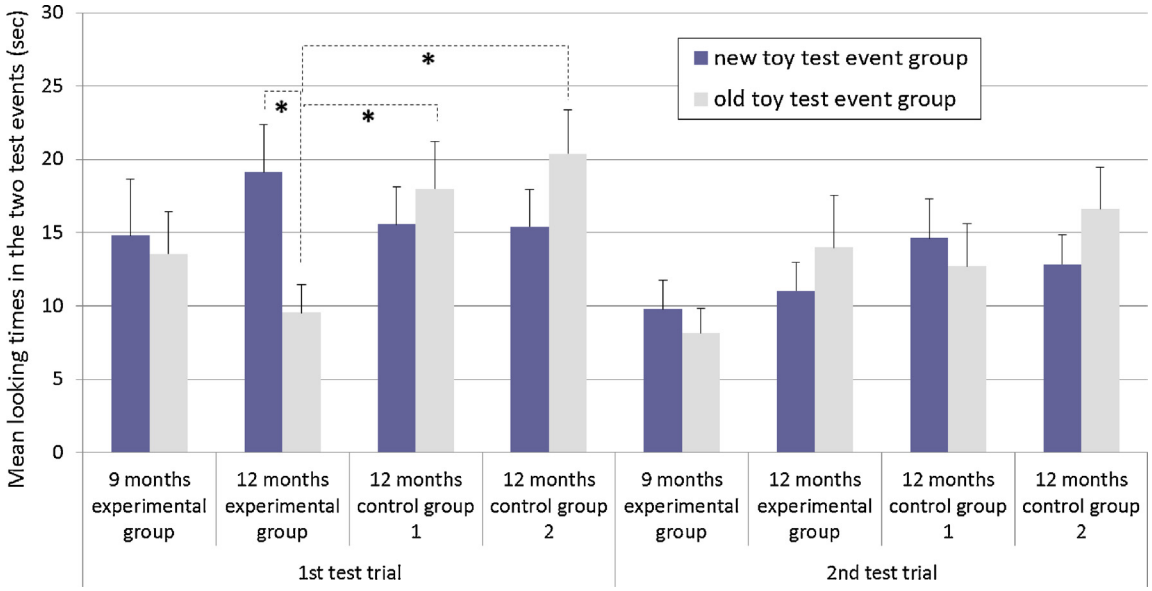

Fig. 3. Mean looking times with standard errors in the two test trials by test event type for the 9- and the three 12-month-old groups (* $p < .05$).

Table 1
Summary of the mean training scores with standard errors in brackets for the 9 and 12 months experimental groups and the 12 months control 1 group.

	Observation	Infants own action				Parental assistance		
	Attention duration ratio	Number of proper action	Number of other action	Sum of action	Duration of action	Parent action duration	Number of parent-assisted action	Attended parent-assisted action ratio
9 months exp.	.97 (.01)	1.71 (.43)	4.67 (.94)	6.38 (1.10)	30.24 (5.52)	19.10 (2.57)	4.92 (.44)	.74 (.05)
12 months exp.	.96 (.02)	1.33 (.32)	4.79 (.77)	6.13 (.86)	23.59 (3.47)	15.58 (1.69)	4.83 (.56)	.91 (.03)
12 months control 1	.98 (.01)	1.04 (.28)	5.08 (.57)	6.13 (.60)	37.02 (6.08)	25.50 (9.37)	4.79 (.45)	.81 (.07)

4. Discussion

We tested the ability of 9- and 12-month-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-month-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 however, that we need to interpret this finding with caution, since the difference between the two types of test events was only present during the first test trial and not during the second. Nevertheless, such looking patterns are not surprising or unprecedented (e.g., Biro & Leslie, 2007 or Leslie & Chen, 2007) since during repeated presentations infants' expectation may change by reinterpreting the situation on the basis of the previous test trial. The 12-month-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 both test trials. In addition, infants in the experimental group, compared to both control groups, looked less long at the old toy test event in the first test trial, 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-month-olds in the two control conditions 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. However, we note again that this change was only present in the 1st trial. 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-month-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). We therefore argue that the reason for the lack of goal-directed interpretation of the "back of the hand touch" (Woodward, 1999) is that infants have no existing associations (unlike in the case of the grasping action) about the potential of this action to produce a salient outcome.

Why did the 9 months olds not benefit from the training in our study? 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) 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).

Next, we return to the comparison of our study and the two other training studies that we described in the introduction (Sommerville et al., 2005; Gerson & Woodward, 2014). All three studies show converging evidence that prior action experience can allow infants to interpret actions as goal-directed that they could not interpret as such without this prior experience. However, we extend this finding in two directions. We show that a relatively short prior training can also be beneficial in case of an entirely novel action and therefore not only for a familiar action such as grasping. Note that even though 3.5-month-olds cannot grasp and pick up objects themselves, they already have ample prior observational experience with grasping actions and that the training session can thus build on these prior experiences. Furthermore, we show that the crucial factor in the prior training is not the experience with the action per se, but with its salient action-outcome. Nevertheless, in our study we only find evidence for the influence of the training for 12-month-olds. How can we reconcile the large age difference between these studies and ours? One possibility might be that in the studies of Sommerville et al.'s (2005) and Gerson and Woodward (2014) the objects that the infants picked up during the training were identical to those

that were used in the subsequent testing session. Hence, there was less demand on the ability to generalize the outcome producing potential of the mittened grasping hand from training to test. This is strongly supported by Gerson and Woodward's finding that when different objects were used in the training and the test session then active experience with the Velcro-mitten did not facilitate goal-directed interpretation of the grasping hand. Alternatively, while grasping and then transferring an object is a natural hand action, 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.

It is also important to differentiate our study from other training studies with similar features. Elsner and Aschersleben (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 infants' own exploratory behavior. Nevertheless, their developmental pattern fits with our finding.

In three other training studies that provided observational experience with the particular goal of an actor (Sommerville & Crane, 2009), own action experience with a novel means-end action (Sommerville, Hildebrand, & Crane, 2008), and a short demonstration of tool use (Hofer et al., 2005), it was found that infants around 9–10 months benefited from the training when they were subsequently tested on their understanding of observed means-end relationships. However, the subsequent test sessions in all these studies presented the entire means-end sequences and the infants were thus not required to rely solely on the association between the action and the outcome that they had established during the training. These studies therefore did not aim to test whether infants can interpret a novel action as goal-directed in the absence of the outcome.

A further difference between our and other training studies leads us to the question whether the interpretation of an observed action is primarily influenced by infants' own experience with the action or by observational experience. Note, however, that the current study was not designed to distinguish between these two types of experiences. Instead, we emphasized the importance of appreciating the potential of an action for producing outcomes in infant's goal-directed action interpretation. We therefore varied the presence or absence of a salient effect via both types of experience.

Recent studies that have 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; Gerson & Woodward, 2014). However, in both these studies 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 & Woodward, 2005a,b), 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.

Hence, another reason why the 9-month-olds did not benefit from the training might be that the amount of own action experience with the novel action and its effect was insufficient. 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.

In summary, we have shown that experiencing a salient effect of a novel hand action can alter 12-month-old infants' interpretation of the action. By appreciating the potential of the action to produce an outcome, infants can attribute a goal when they observe the novel action 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.

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