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Infants' perception of goal-directed actions: A multi-lab replication reveals that infants anticipate paths and not goals

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ABSTRACT

Influential developmental theories claim that infants rely on goals when visually anticipating actions. A widely noticed study suggested that 11-month-olds anticipate that a hand continues to grasp the same object even when it swapped position with another object (Cannon, E., & Woodward, A. L. (2012). Infants generate goal-based action predictions. *Developmental Science*, *15*, 292–298.). Yet, other studies found such flexible goal-directed anticipations only from later ages on. Given the theoretical relevance of this phenomenon and given these contradicting findings, the current work investigated in two different studies and labs, whether infants indeed flexibly anticipate an action goal. Study 1 (N = 144) investigated by means of five experiments, under which circumstances (e.g., animated agent, human agent) 12-month-olds show flexible goal anticipation abilities. Study 2 (N = 104) presented 11-, 32-month-olds and adults both a human grasping action as well as a non-human action. In none of the experiments did infants flexibly anticipate the action based on the goal, but rather on the movement path, irrespective of the type of agent. Although one experiment contained a direct replication of Cannon and Woodward (2012), we were not able to replicate their findings. Overall our work challenges the view that infants are able to flexibly anticipate action goals from early on, but rather rely on movement patterns when processing other's actions.

1. Introduction

During the first year of life, infants start to visually anticipate other people's actions (Adam et al., 2016; Ambrosini et al., 2013; Cannon & Woodward, 2012; Daum, Gampe, Wronski, & Attig, 2016; Falck-Ytter, Gredebäck, & von Hofsten, 2006). For example, 12-month-olds anticipate the goal of a simple manual reach-and-transport action (Falck-Ytter et al., 2006). However, infants show difficulties in anticipating actions when situations become more complex (Gredebäck, Stasiewicz, Falck-Ytter, Rosander, & von Hofsten, 2009). In addition, it has been suggested that action anticipation depends on whether a human or a non-human agent is performing the action (Cannon & Woodward, 2012; Daum, Attig, Gunawan, Prinz, & Gredebäck, 2012; Kanakogi & Itakura, 2011) and that movement characteristics of actions such as distances, durations and velocities have a strong impact on the anticipation of the goal of observed actions (Daum, Gampe et al., 2016). In this paper we present a series of studies conducted in several laboratories

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that investigated whether infants and adults are able to visually anticipate an action goal when two goals are available and whether they differentiate between human and non-human (i.e. animated) agents.

Being able to understand that other people have goals is essential for processing social information. Understanding the goal-directedness of human actions has been related to the ability of perspective taking (Krogh-Jespersen, Liberman, & Woodward, 2015) and of coordinating one's own actions with others (Sebanz, Bekkering, & Knoblich, 2006). Influential developmental theories have therefore stressed the role of goal encoding and anticipation for early social-cognitive development (e.g., Woodward, 2009). In the study by Falck-Ytter et al. (2006), infants anticipated the action of a hand that placed objects into a container (for a related setup see also Brandone, Horwitz, Aslin, & Wellman, 2014). However, movement path and goal were confounded in this paradigm, and for this reason, no conclusion is possible whether infants' anticipations were based on the information provided by the movement or the information about the action goal. The encoding of an action as goal directed goes beyond the representation of pure physical movements. Accordingly, a study by Cannon and Woodward (2012) presented a manual reaching action with not only one but two possible action goals to infants at the age of 11 months. After being familiarized with the hand always grasping the same of the two objects, the objects' position changed place for the following test trial. During the test trials, the infants observed an uncompleted manual movement where the hand stopped before indicating a clear movement direction. The infants showed anticipations towards the familiarized object in the now new location. This indicates that infants did not just anticipate the mere movement pattern but that they encoded the action as being directed towards a specific goal. This goal attribution served as the basis for the subsequent goal anticipation.

As striking as these results are, different results were obtained by Daum et al. (2012). They used a similar methodological approach with a slightly modified paradigm. In their study, participants were familiarized with an animated fish that moved behind an occluder to one of two goal objects. In the test phase, with the location of the two goal objects being swapped, only 3-year-olds and adults anticipated the correct goal. Two-year-olds anticipated both the path and the goal, indicating that they seem to be in a transition phase. In contrast, 9- and 12-month-olds expected the fish continue to move on the movement path as in the familiarization phase. These contradictory findings represent a puzzle, particularly for developmental theories that capitalize on the role of goal understanding in early development.

Notably, a number of studies that used a similar paradigm as Cannon and Woodward (2012) do not give a clear picture either. These studies are different from Cannon and Woodward as the human agent sat at a table and was fully visible to the participants (Krogh-Jespersen & Woodward, 2014, 2018; Krogh-Jespersen et al., 2015; Krogh-Jespersen, Kaldy, Valadez, Carter, & Woodward, 2018; Paulus, 2011). Participants observed an agent grasping one of two objects for once, followed by two consecutive test trials in which the agent performed an uncompleted reaching action. Again, the objects' position was swapped for test trials. Krogh-Jespersen and Woodward (2014) demonstrated with this paradigm that goal-directed fixations of 15-month-olds needed more time to be initialized, indicating additional cognitive effort when taking an action goal into account instead of when the mere movement pattern was anticipated. Interestingly, goal-anticipations were not demonstrated consistently in this paradigm for older children. Two-year-olds anticipated neither the goal nor the previous location systematically (Krogh-Jespersen et al., 2018) and 21-month-olds only made goal-directed anticipations in the first, but demonstrated chance performance in the second test trial (Krogh-Jespersen et al., 2015). Overall, there is a heterogeneous pattern of results on whether or not young children show flexible goal anticipations for a human actor.

Given this evidence it is on the one hand unclear from which age on infants anticipate other's actions as goal-directed and on the other hand, whether they differentiate between non-human and human agents.

Developmental theories claim that one's own experiences are fundamental for understanding others actions. This is also known as the *human first-view* (Luo & Baillargeon, 2005; Meltzoff, 1995; Woodward, 2005). Because a human hand performed the action in the study by Cannon and Woodward (2012), this could have facilitated infants' goal encoding. Some suggest that infants use their own motor abilities when anticipating other's actions (e.g., Kilner, Friston, & Frith, 2007; Paulus, 2012). For example Krogh-Jespersen and Woodward (2018) demonstrated that already 8-month-olds anticipate an action goal, but only after they practiced reaching for an object themselves. Others suggest that infants are simply more familiar with human hands than with a non-human agent (Ruffman, Taumoepeau, & Perkins, 2012). This account would imply that infants are more experienced with hands grasping objects than with moving fish, as they have probably not often seen an animated fish before. Indeed, previous studies demonstrated earlier anticipations within infants when actions were more familiar (Cannon & Woodward, 2012; Filippi & Woodward, 2016; Gredebäck & Kochukhova, 2010; Gredebäck & Melinder, 2010; Kanakogi & Itakura, 2011). Cannon and Woodward (2012) showed that infants did not anticipate an action as goal-directed when performed by a mechanical claw (see also Adam et al., 2016; Kanakogi & Itakura, 2011).

In contrast, the so called *all agents-view* (Luo & Baillargeon, 2005) proposes that infants attribute goals to any individual that can be identified as an agent (Leslie, 1995). It has been argued that humans attribute goals to non-human agents as long as they show specific characteristics, like self-propelledness (Luo & Baillargeon, 2005), equifinal variations (Kamewari, Kato, Kanda, Ishiguro, & Hiraki, 2005), or an action outcome produced by the agent (Adam, Reitenbach, & Elsner, 2017). However, most empirical evidence concerning the *all agents-view* comes from looking-time studies (e.g. Gergely, Nádasdy, Csibra, & Bíró, 1995; Luo & Baillargeon, 2005). Thus, it is still an open question whether infants are able to generate online anticipations when perceiving non-human instead of human actions.

However, as it is neither empirically nor theoretically clear when and to what extent infants are able to anticipate an action based on the action goal and not on the movement pattern, we report two studies, assessed in two different labs, that address this question in further detail. Study 1 contains five experiments, which disentangle the precise methodological issues between Cannon and Woodward (2012) and Daum et al. (2012). The goal of the first study was to investigate which aspects are fundamental for infants' goal encoding abilities within 12 months of age. Two major questions guided this research: First, whether infants show goal-directed anticipations for non-human as well as for human actions equally, as proposed by the *all agents-view*, or whether infants are better in anticipating the goal of a human action than the goal of a non-human action, as suggested by the *human first-view*. Second, whether the seemingly contradictory findings of Cannon and Woodward (2012) and Daum et al. (2012) are a result of further methodological differences. In the study by Daum et al. (2012), the agent shortly disappeared behind an opaque occluder. This paradigm was used to trigger participant's eye-movements to the position where they expect the agent to reappear (adapted from Kochukhova & Gredebäck, 2007). However, infants have to maintain the association between the agent and the object when the agent is not visible, which might require additional cognitive capacities, such as memory or attention (Hespos, Gredebäck, von Hofsten, & Spelke, 2009; Jonsson & von Hofsten, 2003). This additional requirement of cognitive resources could be another reason why infants in the Daum et al. study (2012) showed goal-directed anticipations only from later on.

Further, the two studies used different designs in providing the stimuli. Cannon and Woodward (2012) presented infants four blocks, which each contained three familiarization trials, one swap trial (in which the objects' position changed place) and one test trial. Daum et al. (2012) presented participants eight familiarization trials, one swap trial and two test trials. The more frequent presentation of learning trials in the Daum et al. study (2012) could have increased the attentional focus to the location of the object. As was demonstrated by Paulus et al. (2011), already 9-month-olds based their anticipations of an agent's choice for a path on the agent's previous choices. Further, it is also possible that infants encoded both goal and path of the action simultaneously, thus it is unclear which aspect dominates infants visual anticipations.

The following five experiments of Study 1 present a step by step approximation of the paradigm from Daum et al. (2012) to the paradigm of Cannon and Woodward (2012). The last experiment represents a replication as close as possible to the study by Cannon and Woodward (2012). Initially, we hypothesized that the type of agent and the presence of an occluder influence infants' goal anticipations. Following the *human first-view*, we expected more goal anticipations in the experiments that contain a human agent. In contrast, the *all agents-view* predicts no differences in the goal anticipations between all five experiments, because human and non-human agents are processed equally from early on. We would further assume that infants show more goal-directed anticipations in the experiments without an occluder.

The second study, conducted in a different lab, directly compared the two paradigms in a within-subjects design. That is, Study 2 assessed whether children and adults show systematic differences in their anticipations when observing human and non-human goal-directed actions. A second goal of Study 2 was to answer the question whether the two paradigms assess the same underlying ability regarding their goal anticipations, as proposed by the *all agents-view*. Since non-human agents are widely used in studies on social perception within children (e.g., Hamlin, Wynn, & Bloom, 2007; Kuhlmeier, Wynn, & Bloom, 2003), it is crucial to find out whether they actually perceive animated stimuli in the same way as human stimuli. We tested 11-month-olds as our youngest age group, since this age group showed goal-directed anticipations in the study by Cannon and Woodward (2012). We also included 32-month-olds, because developmental changes of children's goal anticipations for an animated agent between the age of 24 and 36 months were observed by Daum et al. (2012). Developmental changes were also observed by Krogh-Jespersen et al. (2015, 2018), although they found a decrease of goal-directed anticipations for a human agent in toddlers. Given this puzzle, the inclusion of 32-month-olds in Study 2 seems informative. We additionally wanted to clarify whether and how adults differ in their perceptions of the stimulus material presented in the two paradigms. Accordingly, stimulus material was presented in a within design with a human- and a non-human animated agent. One is based on Cannon and Woodward (2012) and contained a human hand grasping one of two objects; the other is based on Paulus, Schuwerk, Sodian, and Ganglmayer (2017) and contained an animated agent walking along a path towards one of two targets (similar to Daum et al., 2012, where an opaque occluder was used). The *human first-view* proposes goal encoding for 11- and 32-month-olds to be more likely in the hand- than in the path-paradigm (Cannon & Woodward, 2012; Daum et al., 2012). In contrast, the *all agents-view* proposes goal anticipations in both paradigms. Either of the theories predicts adults to visually anticipate an action goal for both human- and non-human agents (Daum et al., 2012; Pfundmair, Zwarg, Paulus, & Rimpel, 2017).

The current effort from two labs is a valuable approach with the aim to conceptually and partly even directly replicate a finding that is central in a heated debate in developmental psychology on the early origins of social cognition. It is essential to know in greater detail to which extent the findings by Cannon and Woodward (2012) are replicable before drawing strong theoretical conclusions. Thus, one central point of this endeavor was to examine whether or not we could (conceptually or directly) replicate Cannon and Woodward (2012) and contribute thus to the theoretical debate by examining the robustness of a key finding.

2. Study 1

Study 1 investigates whether 12-month-olds are able to make goal-directed anticipations. Given the contradicting findings of Cannon and Woodward (2012) and Daum et al. (2012), the aim was to test which aspects are relevant for infants' ability to anticipate an action goal. Therefore, the stimuli of Daum et al. (2012) were assimilated step-by-step over five experiments to the stimulus material used by Cannon and Woodward (2012). In Experiment 1 the animated stimuli of Daum et al. (2012) were used but displayed in the same presentation order as in Cannon and Woodward's study (2012). In Experiment 2, the occluder was removed and the action direction was changed from vertical to horizontal, whereas the fish still remained as the agent. In Experiment 3, the fish was replaced by a human hand as the agent. Additional adaptions regarding timing were made in Experiment 4. Finally, Experiment 5 used newly filmed videos, which were designed to be as comparable to the stimuli of Cannon and Woodward (2012) because the original stimulus material was not available. According to the *human first-view*, one would hypothesize to find anticipations towards the previously observed movement path or random gaze behavior in conditions using a non-human agent (Experiment 1 and Experiment 2). In contrast, one would expect anticipations towards the previously observed goal in the conditions in which a human hand served as the agent (Experiment 3, 4 and 5). According to the *all agents-view* infants should demonstrate in all five experiments goal directed anticipations. We further expected that experiments without an occluder would facilitate infants processing of the action, thus we expected to find an increase of goal-directed anticipations in the conditions that did not make use of an occlusion paradigm.

2.1. Experiment 1

In the first experiment, the influence of the design of stimuli presentation on infants' encoding of the action was tested. Infants were shown the stimulus material as used by Daum et al. (2012), an animated fish that moved towards one of two goal objects and was briefly occluded. We combined the stimulus material with the procedure used by Cannon and Woodward (2012) where the stimuli were presented in four blocks; each block contained three familiarization trials, one swap trial, and one test trial. Further some criteria for inclusion (three of four blocks with usable data) and analysis of gaze shifts (gaze shift from the start-AOI to one of the goal-AOIs with 200 ms fixation) were the same as in the study by Cannon and Woodward (2012).

2.1.1. Method

The preprocessed eye-gaze data of both studies is available at https://osf.io/bucrv/?view_only=fa9e929fe4524755b38383fd223378f5. To protect participants' data privacy, demographic information is not shared in this data set.

2.1.1.1. Participants. The sample included 24 healthy 12-month-olds (12 girls, mean age = 12 months and 4 days; 11;21–12;15). Ten additional infants had to be excluded due to inattention and restlessness (n = 1), crying (n = 4), technical problems (n = 1) and failure to provide enough eye-tracking data (n = 4; see *Measures* section for details).

2.1.1.2. Stimuli. Participants were presented videos of a red-blue fish, that moved by itself (self-propelledness) on a blue background. At the beginning of the videos, the fish was situated at the bottom in the middle of the screen. The targets were a yellow duck and a colored ball placed on the left and right corner at the top of the screen (see Fig. 1). In the middle of the screen was a round occluder in the color of wooden grain.

Infants saw four blocks and each block consisted of three familiarization trials, one swap trial and one test trial. Before each block an attention getter was presented to direct infants' attention to the screen. In the familiarization trial (total duration was 15.12 s) the fish first jumped up and down (accompanied by a sound) for 3 s and then moved towards the occluder (2.44 s). The agent disappeared behind the occluder for 0.92 s and reappeared to aim for one target. At the goal object (after 2.08 s) the fish poked the target for three times (3 s) and the target reacted with small movements, which was combined with a sound. During the swap trial, the two targets changed place (4.96 s) and were shown for another second after the changeover to the infant. In the test trials, the fish again jumped up and down (3 s) before approaching the occluder (2.44 s). The agent stayed behind the occluder for the rest of the trial (another 10.12 s). The total duration of the whole presentation (all four blocks) was 5 min and 24 s. Target object as well as the position of the target object was counterbalanced between participants.

2.1.1.3. Setting and procedure. For testing, infants were seated in a car safety seat (Maxi Cosi Cabrio) with a distance of 60 cm between the eye tracker and the child and stimuli were presented on a 17"-monitor (25° × 21°). Gaze was measured through a Tobii 1750 eyetracker (precision: 1°, accuracy: 0.5° and sampling rate: 50 Hz) and a nine-point infant calibration was used. The stimuli-presentation was conducted via the software ClearView (version 2.7.1., Tobii).

2.1.1.4. Measures. To analyze infants' eye-movements, three areas of interest were defined based on Daum et al. (2012, see Fig. 1). The lower area was the starting area of the agent, the other two included the two goal objects. For all measures, we analyzed the first fixation participants performed from the start area to one of the goal-AOIs (first look analysis). Infants had to fixate the goal-AOI for 200 ms, within a radius of 50 pixels (based on Cannon & Woodward, 2012). Gaze shifts were categorized as *anticipatory*, when the

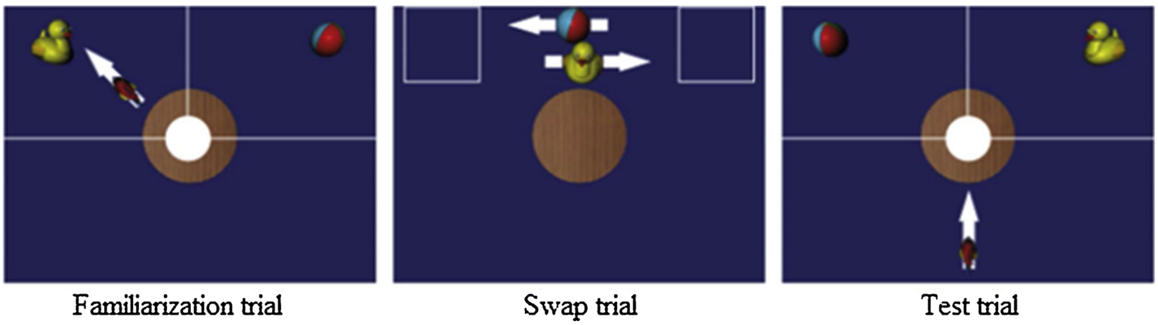

Fig. 1. Stimulus material of the familiarization trial, swap- and test trial of Experiment 1. The white arrows represent the movement path of the agent and the targets. The white lines mark the AOIs.

first fixation was directed in one of the goal-AOIs before the agent reappeared from the occluder during familiarization trials (occlusion-time plus 200 ms). In the test trials, this time interval was extended for another 1000 ms (see Cannon & Woodward, 2012), because the agent did not reappear from behind the occluder (occlusion-time plus 200 ms plus 1000 ms). Gaze shifts were categorized as *reactive*, when fixations to one of the goal-AOIs occurred after the agent reappeared in the familiarization trials. For the test trials, a fixation to one of the goal AOIs after the 2120 ms was categorized as reactive.

First, we calculated the *anticipation rate*, which is the relation of all anticipations to all gaze shifts (anticipatory as well as reactive). This measure indicates how much participants generally perform anticipations; it is not including information to which specific location infants anticipated. To further analyze the type of anticipations, the *accuracy rate* was calculated. For this, the number of anticipations towards the specific target AOI was divided by the total number of gaze shifts (anticipatory and reactive). For this analysis, the number of anticipations was averaged over all familiarization trials and test trials. For familiarization trials the *goal-related accuracy rate* (ratio of goal anticipations and all gaze shifts) and the *non-goal-related accuracy rate* (ratio of anticipations to the other object and all gaze shifts) were defined. To analyze infants' learning performance in the familiarization phase, two scores were compared (Daum et al., 2012): The accuracy score of the averaged anticipations of the first familiarization trials of all four blocks and the accuracy score of the averaged anticipations of the last familiarization trials of all four blocks. For test trials the *identity-related accuracy rate* (ratio of anticipations to the goal object in the new location and all gaze shifts) and the *location-related accuracy rate* (ratio of anticipations to the other object in the old location and all gaze shifts) were generated. Again, the anticipations were averaged over all four test trials for each score. In sum, for both the familiarization as well as the test phase, each accuracy score consists of four trials. To be included in analysis, infants had to watch the screen at least 200 ms from the start of the movie until the agent disappeared behind the occluder; and 200 ms after disappearance until the end of the movie. Infants were included for final analysis if they had at least three of four test trials that fulfilled these criteria (Cannon & Woodward, 2012). Further they had to look at the swap trial for at least 2000 ms to be included.

In all experiments of Study 1, we controlled for the possible influence of the type of target and position of target on the number of anticipations for the first four familiarization trials and test trials. As no significant influence could be found in none of the five experiments, the following analysis was averaged over these factors. Further, the anticipation rate of the first four and last four familiarization trials, as well as test trials, were averaged across the four blocks.

2.1.2. Results

2.1.2.1. Anticipation rate. The anticipation rate for the whole experiment was 0.79 (SD = 0.15) and 0.74 (SD = 0.20) for the familiarization phase only. We compared the anticipation rate of the last familiarization trials with anticipation rate of the test trials with a Wilcoxon signed-rank test and found a significant difference. Participants anticipated more in the test trials ($M = 0.91$, $SD = 0.17$) than in the last familiarization trials ($M = 0.72$, $SD = 0.30$), with $z = -2.92$, $p = .003$, $r = .42$.

2.1.2.2. Familiarization phase. A Wilcoxon signed-rank test was calculated to compare the goal-related accuracy rate with the non-goal-related accuracy rate in the last familiarization trials. Indeed, children anticipated more to the goal ($M = 0.58$, $SD = 0.34$) than to the non-goal ($M = 0.14$, $SD = 0.25$), with $z = -3.25$, $p = .001$, $r = -.47$. This indicates that the children learned to correctly anticipate the reappearance of the agent from behind the occluder during the familiarization phase. A comparison of the first familiarization trials averaged across the four blocks ($M = 0.51$, $SD = 0.34$) and the last familiarization trials did not show a significant increase of goal-directed anticipations over time, $z = -1.41$, $p = .16$, $r = -.20$.

2.1.2.3. Test phase. The Wilcoxon signed-rank test demonstrated a higher location-related accuracy rate ($M = 0.60$, $SD = 0.32$) than an identity-related accuracy rate ($M = 0.31$, $SD = 0.31$), $z = -2.14$, $p = .03$, $r = -.31$. Further, a comparison of the goal-related accuracy rate of the last familiarization trials with the identity-related accuracy rate in the test trials showed a significant difference, $z = -2.56$, $p = .01$, $r = -.37$. In contrast, there was no significant difference between the goal-related accuracy rate of the last familiarization trials and the location-related accuracy rate of the test phase, $z = -0.34$, $p = .73$, $r = -.05$.

For the following analysis, only anticipations (and not reactions) were used. A Chi-Square-Test was calculated over the number of identity- and location-related anticipations in test trials. Infants anticipated the reappearance of the agent based on location ($n = 51$) than on identity of the goal object ($n = 28$), $\chi^2(1) = 6.70$, $p = .01$.

2.1.2.4. Additional analysis. Finally, when interpreting these findings, and comparing them to the original study, one has to consider that the data was differently analyzed than the original study of Cannon and Woodward (2012). The inclusion criteria used are stricter than in the original study by Cannon and Woodward (2012). For example, infants had to look for a specific time at the swap trial or fixate the start area for a certain time before the agent moved behind the occluder, etc. Also, gaze shifts that occurred after a certain time were no longer defined as anticipatory, but as reactive. The resulting scores were calculated different to the original study, which used a proportion score and did not include non-anticipations. Although our use of stricter criteria should result in a more reliable assessment of true goal anticipation, one could argue that the different results are caused by these stricter criteria. To exclude this possibility, we additionally analyzed our data as closely as possible to the approach by Cannon and Woodward (2012; details can be seen in the supplementary material). This additional analysis did not change the pattern of results; the mean proportion score of 0.34 ($SD = 0.30$) was significantly different from chance with $t(23) = -2.64$, $p = .015$, Cohen's $d = 0.54$, indicating a significant looking bias towards the location and not the goal.

2.1.3. Discussion

Experiment 1 aimed to examine whether the different findings reported in Cannon and Woodward (2012) and Daum et al. (2012) are the result of differences in the procedure of the stimulus presentation. The findings show that 12-month-olds learned to correctly anticipate the reappearance of the agent by the end of the familiarization phase. However, in the test trials, infants anticipated the action based on the location of the goal object and not on its identity. Therefore, it doesn't seem that the more frequent presentation of the action in Daum et al.'s study (2012) highlighted the path of the action and caused children's location-related anticipations. Ultimately, the divergent findings are not caused by the different presentation order and amount of learning and test trials. The next experiment will test whether the occluder has a significant effect on infants' anticipations.

2.2. Experiment 2

In Experiment 2, the animated stimuli were used without an occluder; the agent was visible the whole time. Additionally, the direction of the movement was changed from a vertical to a horizontally movement (as in Cannon & Woodward, 2012). Given the claim that horizontal movements are easier to anticipate for infants (Gredebäck, von Hofsten, & Boudreau, 2002), we intended to facilitate anticipations and to test whether a change of the movement direction increases infants' identity-related anticipations. Also to draw infants' attention to the screen at the beginning of the action, an ostensive cue was integrated (a voice stated "Look").

2.2.1. Method

2.2.1.1. Participants. Again, the sample included 24 healthy 12-month-olds (12 girls, mean age = 12 months and 4 days, 11;20–12;10). Nine additional infants had to be excluded due to inattention and restlessness (n = 2), crying (n = 1) or failure to provide enough eye-tracking data (n = 6).

2.2.1.2. Stimuli and procedure. The experimental setup was exactly the same as in Experiment 1, only that the targets (duck 3.9° × 4.1°, penguin 3.5° × 4.0°) were now situated in the two corners at the right side of the monitor (see Fig. 2). Further the starting point of the agent (1.9° × 4.0°) was close to the left monitor side. No occluder was visible and the background was light blue. Stimuli where similar to Experiment 1 with the exception that in the first two seconds of each movie a voice stated "Look", to catch infants' attention. In the familiarization trial the agent jumped up and down (1.96 s, combined with a whistle sound) and started to move towards the target objects. After 4.72 s the agent took a turn to one of the targets, which he reached after another 2.60 s and poked it (see Experiment 1). The whole familiarization trial lasted for 14.92 s. In the swap trial the two objects changed position within 5.96 s and the whole trial lasted for another 5 s. Test trials were similar to Experiment 1, except that the agent, when approaching the target, stopped after 4.72 s just after the middle of the scene and remained there for the rest of the trial (another 4.96 s). The whole presentation time for the movies was 5 min and 2 s. Again goal object and position of goal object were counterbalanced between participants.

2.2.1.3. Measures. For Experiment 2 the calculation of the measures followed Experiment 1. Areas of interest can be seen in Fig. 2. Gaze shifts were defined as *anticipatory*, if anticipations took place from the beginning of the movement towards the objects until the agent made a turn to one of the targets (for test trials: time of standstill of the agent plus 1000 ms). This results in an anticipatory period of 5720 ms for test trials in total. All gaze shifts that occurred after the turn of the agent were coded as *reactive* (in test trial after the additional 1000 ms).

2.2.2. Results

2.2.2.1. Anticipation rate. For this experiment the anticipation rate was 0.81 (SD = 0.14) for the whole experiment, and 0.76 (SD = 0.19) for the familiarization phase. As in Experiment 1, we found an increase in anticipations in the test trials (M = 0.94, SD = 0.13) compared to the last familiarization trials of all four blocks (M = 0.74, SD = 0.30), with $z = -2.62$, $p = .01$, $r = -.38$.

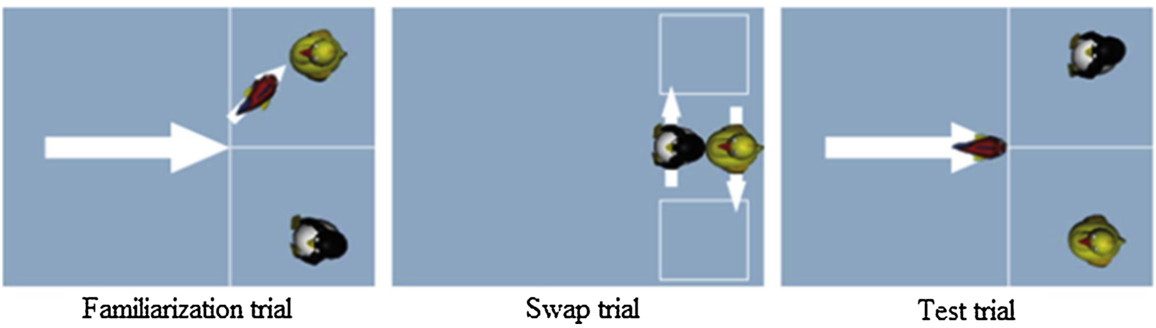

Fig. 2. Stimulus material of the familiarization trial, swap- and test trial of Experiment 2. The white arrows represent the movement path of the agent and the targets. The white lines mark the AOIs.

2.2.2.2. Familiarization phase. Infants showed in the last familiarization trials more anticipations to the goal ($M = 0.60$, $SD = 0.35$) than to the non-goal ($M = 0.14$, $SD = 0.21$), $z = -3.43$, $p = .001$, $r = -.50$. The goal-related accuracy rate in the first familiarization trials ($M = 0.52$, $SD = 0.33$) was not significantly different from the goal-related accuracy rate in the last familiarization trials ($M = 0.60$, $SD = 0.35$), $z = -0.85$, $p = .40$, $r = -.12$. The infants quickly learned to correctly anticipate the target.

2.2.2.3. Test phase. The analysis showed no significant difference between the identity-related accuracy rate ($M = 0.41$, $SD = 0.35$) and the location-related accuracy rate ($M = 0.54$, $SD = 0.33$), $z = -1.12$, $p = .26$, $r = -.16$. Further, a comparison between the goal-related accuracy rate in the last familiarization trials ($M = 0.60$, $SD = 0.35$) with the identity-related accuracy rate ($M = 0.41$, $SD = 0.35$), $z = -1.58$, $p = .12$, $r = -.23$, and the location-related accuracy rate ($M = 0.54$, $SD = 0.33$), $z = -0.91$, $p = .36$, $r = -.13$, was not significant. Infants anticipated in the test phase towards the goal as well as to the original location of the object.

Following Experiment 1, only anticipations were analyzed. The Chi-Square test over the four test trials between identity- ($n = 37$) and location-related gaze-shifts ($n = 47$) was not significant, $\chi^2(1) = 1.19$, $p = .28$.

The additional analysis, with the same measure and inclusion criteria as Cannon and Woodward (2012, see Experiment 1 for details) revealed chance performance of the infants' looking behavior, with $t(23) = -0.72$, $p = .482$, Cohen's $d = 0.15$, $M = 0.45$, $SD = 0.33$.

2.2.3. Discussion

Experiment 2 investigated whether the absence of an occluder and the change in movement direction (from vertical to horizontal) had a facilitating effect on infants' goal encoding abilities. Results of the test trials demonstrated that anticipations of the 12-month-olds were at chance level. They neither showed a significant looking bias towards the goal object, nor to the old location. As they demonstrated goal-directed anticipations at the end of the familiarization phase, problems in learning the association between the agent and the target are not the case. It seems likely that the absence of the occluder facilitated infants' goal anticipations (Hespos et al., 2009; Jonsson & von Hofsten, 2003). It seems easier for infants to encode the goal of an action, when the agent is visible for the whole time. The additional change from a vertical to a horizontal position and the use of a verbal cue at the beginning of the action could have facilitated the task as well. For the next experiment we wanted to see whether the type of agent influences infants' anticipations.

2.3. Experiment 3

To test whether infants are more likely to flexibly attribute goal-directed behavior to a human agent, the animated fish was replaced by a human hand that moved to and grasped one of two goal objects. Timing and procedure of the action, as well as size of the targets differed from Cannon and Woodward (2012), as they remained the same as in Experiment 1 and 2.

2.3.1. Method

2.3.1.1. Participants. The final sample included 32 healthy 12-month-olds (16 girls, mean age = 12 months and 1 day, 11;15–12;15). The sample size is larger for this and the following experiments of Study 2, due to more conditions than in the previous experiments (see section Stimuli and Procedure). Eleven additional infants were tested but excluded due to inattention and restlessness ($n = 4$), crying ($n = 2$), or not enough eye-gaze data ($n = 5$).

2.3.1.2. Stimuli and procedure. Stimuli in Experiment 3 are the same as in Experiment 2, except for the following differences: Instead of an animated fish, a human hand (4.6° × 7.6°) was filmed. The two targets (duck 4.8° × 4.9°, penguin 4.5° × 4.8°) still have been animated with CINEMA 4D (Maxon, Version R10). The human hand was inserted in the video via a blue screen method (see Fig. 3). For the familiarization trials the human hand started to move its fingers and a whistle sound occurred (1.92 s). Then the hand moved from the left side in the direction of the targets. After 4000 ms the hand crossed the middle and made a turn to one of the targets. The

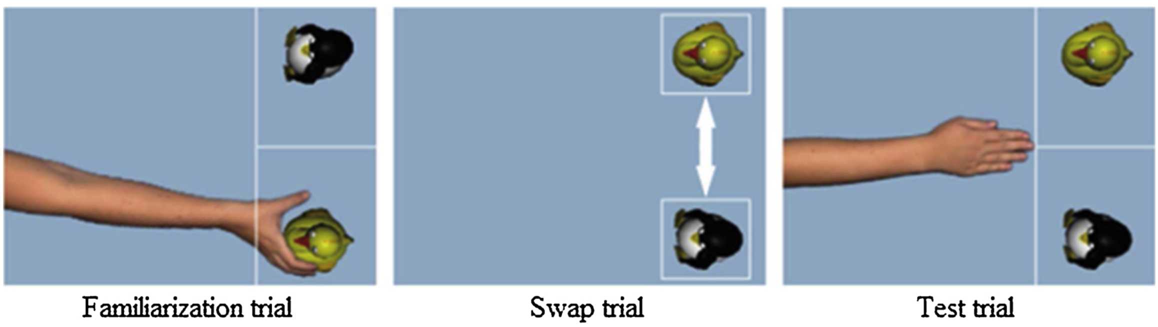

Fig. 3. Stimulus material of the familiarization trial, swap- and test trial of Experiment 3. The white arrows represent the movement path of the targets. The white lines mark the AOIs.

hand reached the target after 2 s, grasped it (1.12 s) and moved it further to the right (action effect plus sound lasted for 0.92 s). The whole familiarization trial took 14 s. The test trials started exactly like the familiarization trials. After the hand started to move towards the middle, it stopped after 4 s for another 5 s. Duration of the test trial was 14.12 s in total. The whole presentation lasted 4 min and 48 s.

Type of goal object and position of the object were counterbalanced between participants. Further, the orientation of the hand, that is, thumb pointing towards the goal object, as well as left and right hand were counterbalanced within participants. This led to four different combinations for the blocks, namely 1) familiarization: right hand, test trial: right hand, 2) familiarization: right hand, test trial: left hand, 3) familiarization: left hand, test trial: left hand, 4) familiarization: left hand, test trial: right hand. The order of combination was also counterbalanced.

For analysis the same scores were calculated as in Experiment 1 and 2. Gaze shifts for test trials were defined as *anticipatory* if they occurred within a time period of 5000 ms (from the beginning of the reaching action onwards). Also inclusion criteria remained the same. AOIs were identical to Experiment 2. To control for an influence of hand orientation on the scores, Kruskal–Wallis tests were performed for Experiment 3, 4 and 5 and turned out not significant. Therefore, the following analysis was averaged over this factor.

2.3.2. Results

2.3.2.1. Anticipation rate. For the whole experiment, the anticipation rate was 0.91 ($SD = 0.10$) and for the familiarization phase 0.89 ($SD = 0.12$). Although participants performed more anticipations in the test trials ($M = 0.95$, $SD = 0.11$) than in the last familiarization trials of all four blocks ($M = 0.88$, $SD = 0.19$), the Wilcoxon-signed rank test was not significant for this experiment, with $z = -1.86$, $p = .06$, $r = -.23$.

2.3.2.2. Familiarization phase. The Wilcoxon signed-rank test showed that the goal-related accuracy rate in the last familiarization trials ($M = 0.60$, $SD = 0.34$) was significantly higher than the non-goal related accuracy rate of the last familiarization trials ($M = 0.28$, $SD = 0.31$), $z = -2.58$, $p = .01$, $r = -.32$. There was no significant difference between the goal-related accuracy rate of the first familiarization trials ($M = 0.53$, $SD = 0.27$) and the goal-related accuracy rate of the last familiarization trials ($M = 0.60$, $SD = 0.34$), $z = -1.21$, $p = .23$, $r = -.15$.

2.3.2.3. Test phase. There was no significant difference between infants' identity-related ($M = 0.40$, $SD = 0.31$) and location-related ($M = 0.55$, $SD = 0.28$) accuracy rate, $z = -1.41$, $p = .16$, $r = -.18$. Infants anticipated more to the goal in the familiarization phase ($M = 0.60$, $SD = 0.34$) than to the same goal in the test trials ($M = 0.40$, $SD = 0.31$), $z = -2.26$, $p = .02$, $r = -.28$. In contrast they did not differ in their anticipations to the goal in the last familiarization phase ($M = 0.60$, $SD = 0.34$) and their anticipations to the old location in the test phase ($M = 0.55$, $SD = 0.28$), $z = -0.74$, $p = .46$, $r = -.09$.

A further Chi-Square-Test with the number of anticipations in all four test trials between goal- and identity-related anticipations turned out to be not significant, $\chi^2(1) = 3.64$, $p = .057$, although a tendency towards more location-related ($n = 65$) than identity-related anticipations ($n = 45$) could be observed.

Again, also the additional analysis according to Cannon and Woodward (2012) resulted in chance performance of the infants, with $t(31) = -1.53$, $p = .137$, Cohen's $d = 0.27$, $M = 0.43$, $SD = 0.27$.

2.3.3. Discussion

Experiment 3 examined whether the type of agent has an influence on infants' goal anticipations. Therefore, a human hand reaching for one of two objects was presented to 12-month-olds. Results showed that infants did not increase their goal-related anticipations in this experiment. In contrary, they showed the tendency to anticipate the grasping action based on the movement path and not the goal object.

Theoretically this finding speaks against the claim that experience with an action improves infants' anticipations (Cannon & Woodward, 2012; Gredebäck & Melinder, 2010; Kanakogi & Itakura, 2011; Kochukhova & Gredebäck, 2010). Still, it is not clear which factors caused the differences between our experiments with Daum et al's findings (2012) and Cannon and Woodward's (2012). Some differences (timing of the action, start of the presentation, effect of the action, type of goal objects) have remained in the last three experiments. For example, in Experiment 1, 2 and 3, the animated objects visibly swap places in the swap trial and are not presented already in their new position like in Cannon and Woodward's (2012) stimuli. It is not clear in what way this could have affected their anticipations. Hence changes in the stimuli material have been made on these factors for the next experiment.

2.4. Experiment 4

Because in Experiment 2 and 3, the anticipations were ambivalent, this could be an indication for an increase of identity-related gaze shifts caused by the nature of the agent. To further assess this potential shift of processing caused by the stimulus material, the stimuli have been changed further in Experiment 4 to increase similarity to the stimuli of Cannon and Woodward (2012). Therefore, the timing of the action and the action effect were adapted. Additionally, movements of the hand at the beginning of the trials were removed and the swapping procedure of the target objects was no longer presented. Participants only observed a still frame of the already swapped objects. The rest of the factors, such as blocked design, no occluder, direction of movement, and type of agent stayed the same as in Experiment 3. Differences to Cannon and Woodward (2012) remained regarding the target objects (a duck and a penguin here, a green frog and a red ball in Cannon & Woodward, 2012). Also following Experiment 3, the agent was inserted via a blue screen method and targets were still animated. Further, type and size of targets were different than in the original study.

2.4.1. Method

2.4.1.1. Participants. The sample included 32 healthy 12-month-olds (16 girls, mean age = 11 months and 26 days, 11;12-12;11). Thirteen additional infants were tested but excluded due to inattentiveness and restlessness (n = 1), crying (n = 1), not enough eye-tracking data (n = 10) or technical problems (n = 1).

2.4.1.2. Stimuli and procedure. Movies were similar to Experiment 3 and adapted to the videos of Cannon and Woodward (2012). Each movie started with a black still frame for 0.36 s. After 0.04 s the agent moved into the picture. After another 1.56 s the hand made a turn into the direction of a target. The agent reached the target after 1.04 s. He grasped the object and did not move thereafter (no action effect, only sound; 0.4 s). After 0.52 s the black screen was presented for 0.48 s. One familiarization trial lasted 4.36 s. For the swap trial a still frame with the objects in changed position was presented for 3.56 s. For test trials the agent again moved into the picture after 0.04 s. Then the hand moved in the direction of the targets and stopped after 1.52 s right after the middle of the screen. Movies of test trials lasted each 2.88 s. Presentation time of the whole stimuli material over all four blocks was 1 min and 33 s.

Goal object, position of goal object, orientation of hand, and the order of presentation was again counterbalanced across the infants. The analysis remained the same as in the previous experiments. However, since the test trial is very short in this experiment, the criteria to treat gaze shifts after the standstill of the hand plus another 1000 ms as reactive is no longer applicable. Therefore, all gaze shifts were treated as anticipatory. Inclusion criteria were identical to the other three experiments, except that infants had to watch each movie at least for 100 ms from the start until the turn and again from the turn until the end of the movie. Also they had to look at the swap trial at least for 700 ms.

2.4.2. Results

2.4.2.1. Anticipation rate. The anticipation rate for the whole experiment was 0.74 (SD = 0.18) and 0.65 (SD = 0.24) for all of the 12 familiarization trials. Again, the anticipation rate of the test trials was higher (M = 1.00, SD = 0.00) than in the last familiarization trials of all four blocks (M = 0.61, SD = 0.30), $z = -4.32$, $p < .001$, $r = -.54$.

2.4.2.2. Familiarization phase. Goal-related accuracy rate of the last familiarization trials (M = 0.49, SD = 0.29) was significantly higher than the non-goal-related accuracy rate of the last familiarization trials (M = 0.12, SD = 0.19), $z = -3.98$, $p < .001$, $r = -.50$. Further the goal-related accuracy rate of the first familiarization trials (M = 0.47, SD = 0.37) was not significantly different from the goal-related accuracy rate of the last familiarization trials (M = 0.49, SD = 0.29), $z = -0.53$, $p = .60$, $r = -.07$.

2.4.2.3. Test phase. Results revealed that the identity-related accuracy rate (M = 0.30, SD = 0.29) was significantly lower than the location-related accuracy rate (M = 0.70, SD = 0.29) in the test phase, $z = -3.23$, $p = .001$, $r = -.40$. There was also a significant difference between the goal-related accuracy rate in the last familiarization trials (M = 0.49, SD = 0.29) and the identity-related accuracy rate in the test phase (M = 0.30, SD = 0.29), $z = -2.14$, $p = .03$, $r = -.27$. Infants showed more anticipations towards the goal in the familiarization phase than in the test phase. Moreover, another Wilcoxon signed-rank test showed that the location-related accuracy rate in the test phase (M = 0.70, SD = 0.29) was significantly higher than the goal-related accuracy rate in the last familiarization trials (M = 0.49, SD = 0.29), $z = -3.04$, $p = .002$, $r = -.38$.

Again, when only the number of anticipations was included, a Chi-Square test demonstrated that infants anticipated the action more in relation to the location (n = 83) than to the identity of the goal (n = 36), $\chi^2(1) = 18.56$, $p < .001$.

The same pattern was observed in the additional analysis according to Cannon and Woodward (2012), in which infants demonstrated a preference for the previous location, with $t(31) = -4.05$, $p < .001$, Cohen's d = 0.72, M = 0.29, SD = 0.29.

2.4.3. Discussion

In the fourth experiment we wanted to discover, whether the changes of the stimuli in comparison to Experiment 3 would now enable a replication of Cannon and Woodward's results (2012). Findings indicate that 12-month-olds show more anticipations directed towards the location and not the goal object. Even after using stimuli that are highly similar to Cannon and Woodward (2012), we could not replicate their findings. However, our stimuli still contained subtle differences regarding the targets and construction of the stimuli, such as that a human hand was overlaid on the animated background with a blue screen method. Hence, we performed a last experiment that contains a replication as close as possible to the Cannon and Woodward (2012) study.

2.5. Experiment 5

To replicate the results of Cannon and Woodward (2012), the stimuli were newly filmed. Direction, timing, and procedure of the action were as close as possible to the original study. The two targets, now also a red ball and a green frog, were at the same position of the screen and had the same size. There should be no to only few differences in the method used between this experiment and Cannon and Woodward (2012).

2.5.1. Method

2.5.1.1. Participants. Thirty-two healthy 12-month-olds were included for the final sample (16 girls, mean-age = 11 months; 27 days, 11;16-12;13). Additionally, 22 infants were tested but excluded due to inattentiveness and restlessness (n = 7), crying (n = 1) or not enough eye-gaze data (n = 14).

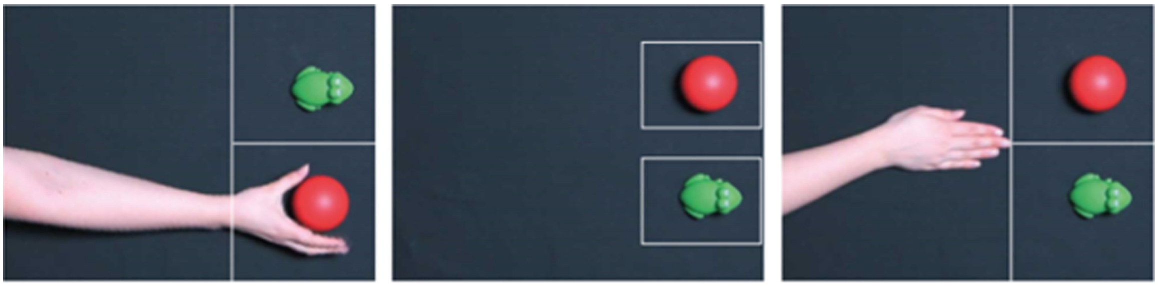

Fig. 4. Stimulus material of the familiarization-, swap- and test trial of Experiment 5. The white lines mark the AOIs in Experiment 5. For comparison to the original stimuli, see Cannon and Woodward (2012).

2.5.1.2. Stimuli, procedure and analysis. Stimuli were identical to Experiment 4 except that the goal objects were now a green frog (3.4° × 4.4°) and a red ball (4.3° × 4.1°; see Fig. 4). For the action, the human hand (4.9° × 9.4°) reached from the left to the right side of the screen. No animations were used anymore. Material was edited and cut with Final Cut Pro (Version 7.0.3). To ensure that the action was timed accurately, one movie of Cannon and Woodward (2012) was used as a basis for cutting the stimuli. As already Experiment 4 followed the timing of Cannon and Woodward (2012), there were no other changes made (see Experiment 4 for details).

Goal-object, position of goal-object, hand orientation and order of hand orientation was counterbalanced throughout participants, leading to 16 different combinations. Analysis of the data and inclusion criteria were carried out as in Experiment 4.

2.5.2. Results

2.5.2.1. Anticipation rate. For the whole experiment, the anticipation rate amounts to 0.74 (SD = 0.14). For the familiarization trials the anticipation rate is 0.65 (SD = 0.18). A Wilcoxon signed-rank test revealed a significant difference between the anticipation rate of the test trials (M = 1.00, SD = 0.00) and the last familiarization trials (M = 0.56, SD = 0.31), with $z = -4.40$, $p < .001$, $r = -.56$.

2.5.2.2. Familiarization phase. Goal-related accuracy rate in the last familiarization trials (M = 0.39, SD = 0.31) was significantly higher than the non-goal-related accuracy rate of the last familiarization trials (M = 0.18, SD = 0.27), $z = -2.03$, $p = .04$, $r = -.25$. There was no significant difference between the goal-related accuracy rate in the first familiarization trials (M = 0.50, SD = 0.30) and the goal-related accuracy rate in the last familiarization trials (M = 0.39, SD = 0.31), $z = -1.51$, $p = .13$, $r = -.19$.

2.5.2.3. Test phase. A Wilcoxon signed-rank test demonstrated no significant difference between the identity-related (M = 0.40, SD = 0.35) and location-related (M = 0.60, SD = 0.35) accuracy rate in the test phase, $z = -1.53$, $p = .13$, $r = -.19$. Also the goal-related accuracy rate in the last familiarization trials (M = 0.39, SD = 0.31) did not differ from the identity-related accuracy rate in the test phase (M = 0.60, SD = 0.35), $z = -2.62$, $p = .009$, $r = -.23$. Nevertheless, the goal-related anticipation rate in the last familiarization trials (M = 0.39, SD = 0.31) was significantly lower than the location-related accuracy rate in the test trials (M = 0.60, SD = 0.35), $z = -2.62$, $p = .009$, $r = -.23$.

A Chi-Square test over the number of anticipations of the test trials showed a significant difference, $\chi^2(1) = 4.40$, $p = 0.036$. Infants anticipated more often to the location (n = 66) than to the identity of the goal (n = 44).

The analysis according to Cannon and Woodward (2012) with the same measure and inclusion criteria demonstrated chance level of infants' looking behavior, with $t(30) = -0.92$, $p = .363$, Cohen's d = 0.17, M = 0.44, SD = 0.39.

2.5.3. Discussion

While the previous experiments 1–4 represent conceptual replications of the study by Cannon and Woodward (2012), Experiment 5 represents a direct replication. Because the original stimuli were not available, the stimuli were newly filmed for Experiment 5 and video edited to make them as similar to the original stimuli as possible. Nevertheless, the current findings show that 12-month-olds demonstrated more anticipations to the location than to the goal.

The results of this direct replication are in line with the findings of Experiment 1–4 and of Daum et al. (2012). The differing findings between the two paradigms can neither be explained by the presence of an occluder nor by the type of agent. Detailed implications of these findings are discussed in the General Discussion.

2.6. Discussion Study 1

The aim of Study 1 was to examine which factors (type of agent, occlusion, order of trials, timing and procedure of the action, movement direction) effect infants' goal encoding and caused the contradictory findings of two previous studies focusing on the same research question (Cannon & Woodward, 2012; Daum et al., 2012). Based on previous findings (Cannon & Woodward, 2012; Hespos et al., 2009; Kanakogi & Itakura, 2011), the hypothesis of Study 1 was that the different results could primarily be attributed to two factors, namely type of agent (human vs. non-human) and differences in the requirement of cognitive resources caused by the use of an occlusion paradigm. For this purpose, these differences were consecutively aligned in Study 1. In 5 experiments, an agent was presented to 12-month-old infants who moved to one of two goals. Before the test phase, positions of the target objects were swapped. Results over all 5 experiments showed that 12-month-olds learned the association of the agent and the target during familiarization phase already after three trials, thus demonstrating fast learning within infants (Krogh-Jespersen & Woodward, 2014). For test trials, infants showed in four of the five experiments more location- than identity-related anticipations. In one experiment, infants anticipated equally often towards the identity and the location of the target. Over all five experiments, infants demonstrated 311 location-related and 189 identity-related anticipations.

The hypothesis that the different results of the two studies (Cannon & Woodward, 2012; Daum et al., 2012) could be attributed to the type of agent and the occluder was not confirmed. Further, our results are neither in line with the human first- nor with the all agents-view, since we did not find goal anticipations in any of the experiments. This finding is not in line with previous studies, which highlight the role of experience (human first-view) for understanding an action as goal-directed in the first year of life (Cannon & Woodward, 2012; Gredebäck & Melinder, 2010; Kanakogi & Itakura, 2011; Krogh-Jespersen & Woodward, 2018). They are in line with findings demonstrating that infants anticipate others' actions based on their previous path (Paulus et al., 2011). However, results are not in line with looking time studies that demonstrated understanding of goal-directed actions of non-human agents already within infants, as stated by the all agents-view (e.g. Kamewari et al., 2005; Luo, 2011; Luo & Baillargeon, 2005; Schlottmann & Ray, 2010). Nonetheless, it remains an open question, why infants expected the agent to move to the familiarized location and not to the previous goal.

The assumption, that the occluder could have an influence on infants' anticipations, was not confirmed either in Study 1. Infants showed location-related anticipations, independent of the presence of an occluder. On the one hand, studies have suggested that the use of an occluder requires extra skills for infants (Hespos et al., 2009; Jonsson & von Hofsten, 2003). On the other hand, previous findings showed that infants in their first year of life are able to anticipate the reappearance of a temporarily occluded object (Gredebäck & von Hofsten, 2004; Gredebäck et al., 2002; Rosander & von Hofsten, 2004). Our results are in line with the latter set of findings.

In sum, the current findings suggest that at the age of 12 months, the ability to flexibly anticipate the actions of others based on goal identity has not yet developed, irrespective of whether the agent was human or not, and therefore, infants have also shown anticipations based on the location. In Study 2 this issue is further addressed in another lab and with different stimuli. The inclusion of older age groups (32-month-olds and adults) in Study 2 will also reveal how stable this effect is over the course of development.

3. Study 2

The second study analyzed whether children and adults show goal encoding for two different paradigms, one using a human hand as an agent (e.g., Cannon & Woodward, 2012) and one a non-human animated animal (e.g., Daum et al., 2012; Paulus et al., 2011). We intended to find out whether infants use similar processing strategies for both paradigms. Thus, both tasks were presented to 11-month-olds, 32-month-olds and adults in a within-subject design. In both paradigms, the agent walked to one of two objects for several times. For test trials the objects' position was swapped and participants observed an uncompleted action. The hand-paradigm is based on the study by Cannon and Woodward (2012), while the stimuli differed in a few manners. Most notably, the number of trials and the presentation order of learning and test trials were different. Further details are described below in the method section. Moreover, to facilitate infants' encoding of the scenario, we also decided to familiarize participants with the actor and the targets. Goal-directed anticipations from 11 months onward in the hand-paradigm would replicate the findings of Cannon and Woodward (2012). In the path-paradigm, we expected 11-month-olds and 32-month-olds to anticipate the old path, thus the novel goal, as the action is performed by a non-human agent (Daum et al., 2012). We hypothesized to find anticipations towards the familiarized goal within the adult sample in both paradigms (Daum et al., 2012; Pfundmair et al., 2017). A correlational analysis of the anticipatory looking behavior between the two paradigms should further clarify whether the different processing mechanisms assessed by the two paradigms are related to each other. We expected to find at least in the adult sample a positive correlation, because they showed goal anticipations for human and non-human agents in previous studies (Daum et al., 2012; Pfundmair et al., 2017). In case we would find a correlation between the two paradigms within children, as predicted by the *all agents-view*, we wanted to make sure that this relation is not mediated by individual factors of the child (Licata et al., 2014). Hence, we included a measure for temperament (Infant Behavior Questionnaire revised very short form; Putnam, Helbig, Gartstein, Rothbart, & Leerkes, 2014; Early Childhood Behavior Questionnaire very short form; Putnam & Rothbart, 2006) as well as a cognitive measure for pattern recognition. Therefore, items were adapted from the Bayley-Scales (Bayley, 2006; German version by Reuner & Rosenkranz, 2014; see supplemental material) for the 32-month-olds. As there are, to our knowledge, no comparable items for 11-month-olds, a task for working memory (Pelphrey et al., 2004; Reznick, Morrow, Goldman, & Snyder, 2004) was used as an indicator for pattern recognition. In this task infants had to remember in several trials at which of two windows the experimenter appeared beforehand.

3.1. Method

3.1.1. Participants

The final sample included 34 11-month-olds (mean age = 11.44 months; *SE* = 0.15; 15 girls), 35 32-month-olds (mean age = 32.11 months; *SE* = 0.09; 23 girls) and 35 adults (mean age = 23.03 years; *SE* = 1.04; 30 women). Additionally, 8 children

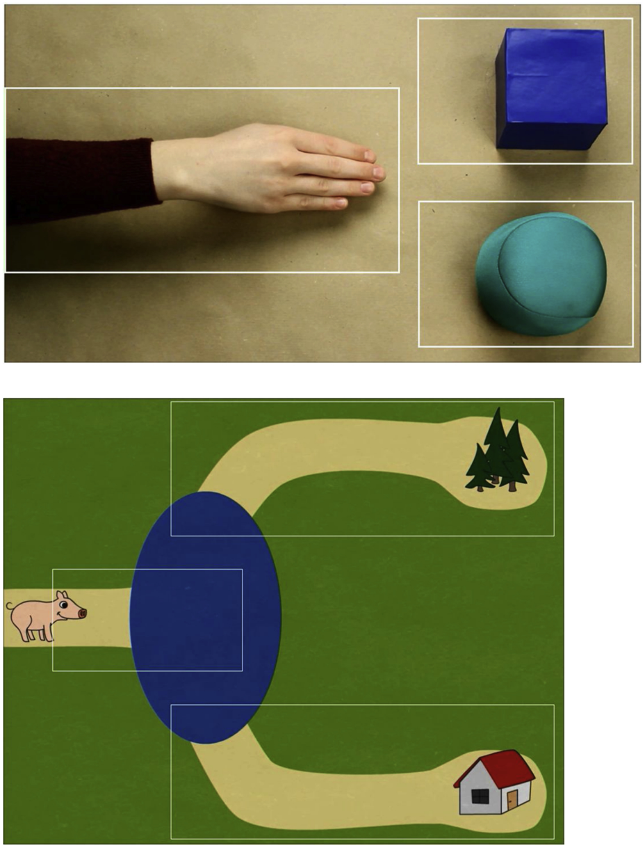

Fig. 5. Stimulus material of the test trial of the hand- and path-paradigm in Study 2. White boxes indicate the AOIs.

were tested but excluded, as they did not want to watch the second movie (n = 4), were inattentive (n = 2), or because of measurement failure (n = 2). Three additional adults had to be excluded due to technical problems. Participants came from a larger city in Germany. The infant population was recruited from local birth records and adult participants were recruited from a student population. Participants or their caregivers gave informed written consent. The study was approved by the local ethics board.

3.1.2. Stimuli and procedure

Participants were presented with two different paradigms. Both paradigms were shown on a 23-inch monitor, which was attached to a Tobii TX300 corneal reflection eye tracker with a sampling rate of 120 Hz (Tobii Technology, Sweden). Children were either seated on their parent's lap or in a car-safety seat (Chicco) about 60 cm away from the screen. For 11- and 32-month-olds, a 5-point calibration was performed. Adults were calibrated with a 9-point procedure. Data collection and analyzation was carried out with Tobii Studio (Tobii Technology, Sweden). All movies had the size of 1920 × 1080 pixels.

In the subsequent section, the stimuli for the hand-paradigm are described first, the animated path-paradigm second.

3.1.2.1. Hand-paradigm. The procedure started with a movie, which introduced the agent. The female actor was sitting on a table and waving at the participant (6 s). To familiarize participants with the targets, two pictures were shown (each 2 s). Each showed one of the two targets, a green ball and a blue cube, accompanied by a sound. Next, the learning trials started. Similar to Cannon and Woodward (2012), the movies of the learning trials presented the two targets at the right side of the screen. The ball was situated in the upper position, the cube in the lower position (see Fig. 5). The table was light brown. After 0.10 s, the hand reached into the picture (supplemented by a subtle, short sound) from the left side of the screen towards the targets, until just past midline (2.65 s). It then made a curvilinear path towards the ball and grasped it (after another 0.85 s) for 0.40 s combined with a squeak-sound. The whole learning trial lasted for circa 4 s, and was shown for 5 times in a row. Next, participants were presented with the swap trial, which consisted of a picture of the objects in swapped position accompanied by a rattle sound (4 s). Finally, in the test trials the hand reached in from the left (with the same sound as in the familiarization trials) and stopped just past midline (2.80 s). A still-image of the hand in this position was presented for another 6.10 s. A test trial lasted for 8.90 s and was presented for three times in a row. Between each test trial a black screen with an attention-getting sound was presented, to redirect infants' attention to the screen.

3.1.2.2. Path-paradigm. First, participants were familiarized with the setup using an introductory movie. It showed a horizontal path that led from the right to the left side of the screen. A rabbit was sitting at the right side of the path and a transparent occluder was located in the middle of the path. After 0.2 s the rabbit started to jump up and down, supplemented by a sound. At the same time the occluder turned opaque and the rabbit started to move towards the end of the path through the occluder (6.88 s), turned around and went back towards the starting point. The whole movie lasted for 12.54 s. Afterwards five learning trials were presented. The learning trials contained a path that was leading to two different goals (similar to Paulus et al., 2017); a house that was situated on the upper path and a wood, situated on the lower path (see Fig. 5). The occluder was overlaid at the crossroad where the path divided into two options leading to the different goals. The agent was a pig that was located at the left side of the path. At the beginning of the movie the transparent occluder turned opaque (0.44 s). Afterwards the pig started to jump for two times (accompanied by a sound) and moved towards the occluder, until it disappeared for 2.37 s. The pig then reappeared on the upper path and moved towards the house. When it reached the house a bell sound was played. The whole movie took 10.52 s. Following the learning trials, a swap trial was shown (total duration 10.03 s). First a frame of the objects in the old position was presented; after 3 s both targets disappeared with a sound and reappeared in changed position after another 2 s with the same sound. Targets in changed position were presented for 5 more seconds. The pig was situated at the beginning of the path during the whole trial. The following test trials started completely identically to the learning trials, except that the targets were now in changed position and the pig did not reappear from the occluder for 6 s. The duration of one test trial was 11.52 s and test trials were presented three times in a row. Between the three test trials the same black screen with the attention-getting sound was inserted, as was done in the hand-paradigm.

Both paradigms were shown to each participant. Order of paradigms was counterbalanced. Between the two eye-tracking movies 11-month-olds and 32-month-olds did a task for a control measure on the table. A detailed description of control measures can be found in the files of the supplemental material.

3.1.3. Measures

The Tobii standard fixation filter with a velocity threshold of 35 pixels/window and a distance threshold of 35 pixels was used to define fixations. For the hand-paradigm three AOIs were defined: One AOI covered the area of the hand (“starting area”, 31.94%), the other two AOIs covered the targets (each 13.67%). Participants gaze behavior was measured for the whole test trial. AOIs for the path-paradigm were implemented as followed: The “start-AOI” covered the starting point of the action, namely the first part of the path, which led to the occluder (5.46%, see Fig. 5). The other two AOIs were situated on the area where the paths reappeared from the occluder (each 14.53%). The “start-AOI” was active for 1.79 s before the agent disappeared behind the occluder. Once the agent disappeared, fixations to the other AOIs were measured. For analysis of participant’s gaze behavior, three different measures were used for both paradigms, following previous research (Paulus et al., 2011; Schuwerk & Paulus, 2015). First we assessed whether participants generally anticipated to one of the two targets, irrespective to which one. The second measure assesses participants’ expectations based on their first fixations to either of the targets. The third measure assessed looking time durations to both targets. This measure was included to control for corrective eye movements.

3.1.3.1. Frequency Score. This score assesses whether all three age groups showed an equal amount of general anticipations (irrespective to which of the two targets they fixated) in all three test trials for each paradigm. In the hand-paradigm, a fixation was counted with 1, when participants first fixated the hand and fixated one of the targets after (no matter which of the targets). For the path-paradigm, a fixation was counted with 1, when participants first looked at the path leading to the occluder before the agent disappeared and fixated on one of the target-AOIs after the agent disappeared. A fixation somewhere else or no fixation was coded with 0 (Schuwerk, Sodian, & Paulus, 2016).

3.1.3.2. First Fixation Score. This score was calculated similar to the Frequency Score, with the only difference that now the type of first fixation, namely to which specific target was fixated, was considered. To be counted as a first fixation for the hand-paradigm, participants had to fixate the hand first and fixate on one of the targets after. In the path-paradigm, first fixations were only included when participants first looked at the path leading to the occluder before the agent disappeared and fixated on one of the other AOIs after the agent disappeared. A fixation from the beginning of the path to the correct path was coded with 1, a fixation to the incorrect, that is, the familiarized path, was coded with −1 and a fixation somewhere else on the screen or no fixation was coded with 0 (Schuwerk & Paulus, 2015). The score was averaged over the three test trials for analysis. If participants have two or more missing values for test trials in each paradigm they were excluded for that score. One 32-month-old in the hand-paradigm did not show gaze data for at least two test trials and one 11-month-old in the path-paradigm.

3.1.3.3. Differential Looking Score (DLS). A score was calculated that represents the relative amount of time on one AOI in relation to the other. This score was additionally included to control for corrective eye-movements, as participants could fixate first on one AOI but direct most of the following fixations to the other AOI (Schuwerk & Paulus, 2015; Senju, Southgate, White, & Frith, 2009). Therefore the total looking time to the incorrect goal-AOI was subtracted from the total looking time to the correct goal-AOI and divided by the sum of total looking time to both goal-AOIs in that time. This results in scores between −1 and 1; a value towards −1 would indicate a preference for the novel goal, a value towards 1 a preference for the old goal.

Table 1
Results of the generalized estimating equations model with the predictors age group, trial and an interaction of age group and trial on the frequency of anticipations in the hand-paradigm.

Predictor	B	SE	Wald	*df*	*p* value	Exp(B)	95% Confidence interval for Exp(B)	
							Lower	Upper
Age group	0.12	0.69	0.03	1	0.864	1.13	0.30	4.40
Trial	0.99	0.85	1.35	1	0.25	2.68	0.51	14.11
Age group*Trial	−0.52	0.34	2.30	1	0.13	0.60	0.31	1.16

3.2. Results

3.2.1. Frequency of anticipations

For the hand-paradigm, participants anticipated in 280 out of 312 trials (9.74%). For the path-paradigm, participants anticipated in 270 out of 312 trials (6.54%). A generalized estimating equations model (GEE; Zeger & Liang, 1986) was calculated for each paradigm separately (unstructured working correlation matrix, logit link function, binomial distribution) to see whether age group or test trial (first, second or third trial) or the interaction of age group and test trial had an effect on participants' frequency of anticipatory first fixations. Results can be found in Tables 1 and 2. For both paradigms, neither of the predictors had a significant influence on the frequency of anticipations. This means that all age groups showed an equal amount of anticipations in all three test trials for both the hand- and path-paradigm.

3.2.2. First Fixation Score

A repeated measures ANOVA with the First Fixation Score was performed with the within-subject factor paradigm (hand- vs. path-paradigm) and the between-subject factor age group (11-months, 32-months, and adults). No main effect of paradigm was found, $F(1, 99) = 0.64$, $p = .427$; $\eta_p^2 = 0.01$, but a significant main effect of age group, $F(2, 99) = 6.55$, $p = .002$, $\eta_p^2 = 0.12$. The interaction of paradigm and age group was also significant, $F(2, 99) = 9.65$, $p < .001$, $\eta_p^2 = 0.16$. Consequently, a one-way ANOVA with the between subject factor age group was performed for each paradigm separately. Analysis for the hand-paradigm did not reveal significant differences between the age groups, $F(2, 100) = 1.93$, $p = .151$, $\eta_p^2 = 0.04$, whereas the ANOVA for the path-paradigm turned out significant, $F(2, 100) = 13.35$ $p < .001$, $\eta_p^2 = 0.21$. Bonferroni' post-hoc tests showed a significant difference between 11-month-olds ($M = -0.34$, $SE = 0.10$) and adults ($M = 0.24$, $SE = 0.10$) with $p < .001$, Cohen's $d = 0.95$, and 32-month-olds ($M = -0.45$, $SE = 0.10$) and adults, $p < .001$, Cohen's $d = 1.15$. The difference between the two infant groups was not significant, $p = 1.00$, Cohen's $d = 0.19$.

3.2.3. DLS

Results for the DLS showed a similar pattern. The repeated measures ANOVA with the between subject factor age group and the within subject factor paradigm demonstrated no significant effect of paradigm, $F(1, 100) = 0.16$, $p = .215$, $\eta_p^2 = 0.02$, and age group, $F(2, 100) = 1.30$, $p = .277$, $\eta_p^2 = 0.18$. The interaction effect of paradigm and age group turned out significant, with $F(2, 100) = 10.61$, $p < .001$, $\eta_p^2 = 0.18$. One-way ANOVAs were performed for each paradigm separately. The ANOVA for the DLS for the hand-paradigm was significant, $F(2, 100) = 3.35$, $p = .04$, $\eta_p^2 = 0.06$. Bonferroni' post-hoc tests showed no significant difference between 11-month-olds ($M = -0.05$, $SE = 0.07$) and 32-month-olds ($M = -0.23$, $SE = 0.07$), with $p = .23$, Cohen's $d = -0.44$, and between adults ($M = -0.30$, $SE = 0.07$) and 32-month-olds, $p = 1.00$, Cohen's $d = -0.17$. However, comparison between adults and 11-month-olds turned out significant, $p = .04$, Cohen's $d = -0.59$. Similarly, analysis for the path-paradigm showed a significant effect with $F(2, 101) = 6.60$, $p = .002$, $\eta_p^2 = 0.12$. Bonferroni' post-hoc tests demonstrated a significant difference between 11-month-olds ($M = -0.27$, $SE = 0.08$) and adults ($M = 0.12$, $SE = 0.08$), $p = 0.003$, Cohen's $d = 0.80$, and between 32-month-olds ($M = -0.20$, $SE = 0.08$) and adults, $p = .020$, Cohen's $d = 0.68$. Again the difference between the 11-month-olds and 32-month-olds was not significant, $p = 1.0$, Cohen's $d = 0.15$.

Table 2
Results of the generalized estimating equations model with the predictors age group, trial and an interaction of age group and trial on the frequency of anticipations in the path-paradigm.

Predictor	B	SE	Wald	*df*	*p* value	Exp(B)	95% Confidence interval for Exp(B)	
							Lower	Upper
Age group	0.37	0.58	0.41	1	0.521	1.45	0.47	4.47
Trial	0.61	0.53	1.34	1	0.247	1.84	0.66	5.19
Age group*Trial	−0.23	0.25	0.86	1	0.353	0.79	0.49	1.29

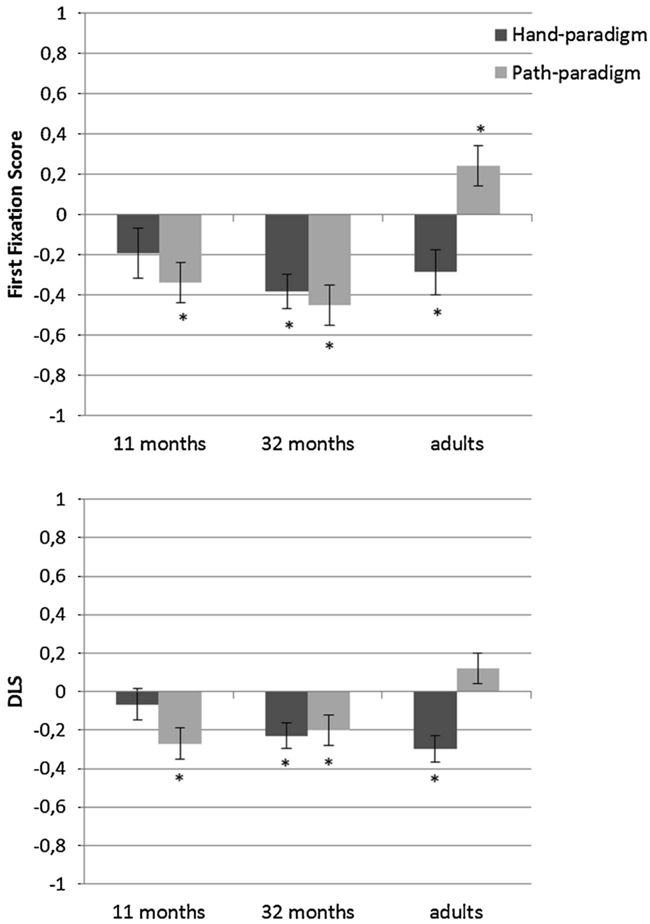

Fig. 6. Descriptives of the First Fixation Score and DLS for each paradigm per age group. Error bars mark standard errors of the means. Asterisks indicate a significant difference from chance.

3.2.4. Comparisons across paradigms per age group

Repeated measures ANOVAs were performed for each age group separately with the within-subject factor paradigm. Analysis of the First Fixation Score for the 11-month-olds revealed no difference in performance for the two paradigms, $F(1, 32) = 3.41$, $p = .07$, $\eta_p^2 = 0.10$, just as for the 32-month-olds, $F(1, 33) = 0.45$, $p = .51$, $\eta_p^2 = 0.01$. In contrast, adults performed in both paradigms differently, with $F(1, 34) = 16.64$, $p < .001$, $\eta_p^2 = 0.33$ (see also Fig. 6 for descriptives). Adults showed a looking bias towards the novel object in the old location in the hand-paradigm, but a looking bias towards the goal in the path-paradigm. The same pattern was demonstrated for the DLS: No difference was found for the 11-month-olds, $F(1, 33) = 3.37$, $p = .08$, $\eta_p^2 = 0.09$, and 32-month-olds, $F(1, 33) = 0.04$, $p = .84$, $\eta_p^2 = 0.001$. However adults showed a significant difference between the two paradigms, with $F(1, 34) = 3.01$, $p < .001$, $\eta_p^2 = 0.43$, with the same pattern as for the First Fixation Score.

3.2.5. Type of anticipated action

Further to check whether participants showed a significantly different looking bias from chance towards one or the other AOI, one sample *t*-tests against chance level were calculated for each paradigm and each age group separately (indicated by the asterisks in Fig. 6). 11-month-olds showed chance performance in the hand-paradigm for the First Fixation Score, $t(33) = -0.88$, $p = .39$, Cohen's $d = -0.15$, and the DLS, $t(33) = -0.73$, $p = .47$, Cohen's $d = -0.13$. For the path-paradigm they showed a significant looking bias towards the previous path, for the First Fixation Score, $t(32) = -3.36$, $p = .002$, Cohen's $d = -0.58$, and the DLS, $t(33) = -3.30$, $p = .002$, Cohen's $d = -0.57$. 32-month-olds performed in every paradigm above chance. They anticipated that the hand would grasp the novel object in the old location, indicated by the First Fixation Score, $t(33) = -4.46$, $p < .001$, Cohen's $d = -0.77$, and DLS, $t(33) = -3.44$, $p = .002$, Cohen's $d = -0.59$; as well as that the agent would reappear on the old path aiming for the novel goal, for First Fixation Score, $t(34) = -4.63$, $p < .001$, Cohen's $d = 0.78$, and DLS, $t(34) = -2.59$, $p = .014$, Cohen's $d = 0.44$. Similarly adults anticipated significantly above chance that the hand would grasp the novel object in the old location, with $t(34) = -2.57$, $p = .02$, Cohen's $d = -0.44$ for the First Fixation Score, and $t(34) = -4.33$, $p < .001$, Cohen's $d = -0.73$ for the DLS. In contrast for the path-paradigm, adults anticipated the agent's reappearance on the correct path, with $t(34) = 2.24$, $p = .032$, Cohen's $d = 0.38$ for the First Fixation Score. Results of the DLS turned out not significant, $t(34) = 1.41$, $p = .167$, Cohen's $d = 0.24$.

Table 3
Results of correlation analysis between the two paradigms per age group.

	First Fixation correlation	DLS correlation
11-month-olds	$r_s(33) = 0.219$	$r_s(34) = -0.174$
32-month-olds	$r_s(34) = -0.039$	$r_s(34) = 0.266$
Adults	$r_s(35) = 0.328$	$r_s(35) = 0.361^{*}$

Note: DLS = Differential Looking Score.
* $p < 0.05$.

To be able to compare our results better with Cannon and Woodward (2012) we further analyzed only the first test trial of the hand-paradigm. As Cannon and Woodward (2012) presented infants four blocks in the design of three learning trials and one test trial per block, and given that we presented participants five learning- and three consecutive test trials, an analyzation of only the first test trial is closer to a replication of the original study (with the difference being that we have five instead of three learning trials). One-sample *t*-test revealed chance performance for the 11-month-olds for the DLS ($M = 0.05$, $SE = 0.11$), $t(32) = 0.49$, $p = .63$, Cohen's $d = 0.09$, and a First Fixation Score of $M = -0.12$, $SE = 0.17$. The 32-month-olds showed a significant looking bias towards the old location for the DLS ($M = -0.26$, $SE = 0.08$), $t(33) = -3.18$, $p = .003$, Cohen's $d = -0.55$, with also a negative First Fixation Score ($M = -0.53$, $SE = 0.15$). Similarly the *t*-test was also significant for the adults with $t(34) = -4.05$, $p < .001$, Cohen's $d = -0.69$, for the DLS ($M = -0.36$, $SE = 0.09$), and a First Fixation Score of $M = -0.37$, $SE = 0.15$, indicating a looking bias towards the location. In sum, even when we only analyzed the first test trial, we did not find goal directed anticipations over all age groups for the hand-paradigm.

3.2.6. Correlation analysis

For each age group the Spearmen's Roh correlation between scores of the hand- and path-paradigm were calculated (see Table 3). All correlations of the control measures can be found in the supplemental material. Analysis of the 11-month-olds and 32-month-olds revealed no significant correlations between the two paradigms. Interestingly, for adults the First Fixation Score did not correlate with each other, whereas the DLS turned out significant.

3.2.7. Additional analysis

Also Study 2 was additionally analyzed as similar as possible to the study by Cannon and Woodward (2012). Details of analysis and results can be seen in the supplementary material. Results suggest that neither for the hand- nor for the path-paradigm, infants anticipated the action goal-directed. Even when looking at the three test trials separately for the hand-paradigm (see Fig. 7), participants' performance was never above chance level.

3.3. Discussion

The second study investigated two questions: (1) Do children and adults anticipate an action of a non-human agent and human agent based on the previously observed goal instead of the previously observed movement path? (2) Do children and adults show similar processing strategies regarding goal encoding for two different paradigms? To this end 11-month-olds, 32-month-olds and adults were presented with two different paradigms. One presented a human hand reaching for one of two objects and the other presented an animated animal walking to one of two goals. Both followed a similar paradigm as described in Study 1 with a previous

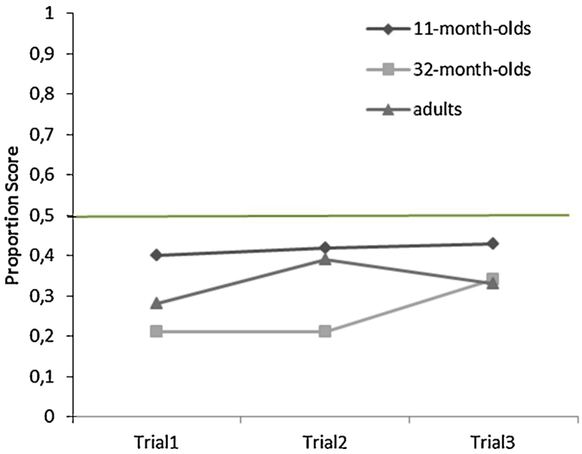

Fig. 7. Descriptives for the hand-paradigm of Study 2 for each trial and age group when data was analyzed as similar as possible to Cannon and Woodward (2012).

familiarization phase and a subsequent test phase in which the position of the goal objects were swapped. Results revealed that when the location of targets had changed, 11-month-olds and 32-month-olds did not perform goal-directed anticipations for both types of actions. This is surprising, since we expected goal anticipations for human actions from early on (Cannon & Woodward, 2012; Meltzoff, 1995; Woodward, 2005). Instead we observed for 11-month-olds chance performance when presenting the action performed by the hand. Considering the path-paradigm with the animated agent, 11-month-olds looked longer towards the familiarized path leading to the novel goal. Hence results are similar to Study 1 and Daum et al. (2012). Together with the experiments of Study 1, our results are not in line with those by Cannon and Woodward (2012) and do not support theoretical claims (e.g., Woodward, 2009) that the ability to flexibly anticipate other's action goals emerges in infancy. Rather, they support approaches that assume that early action understanding is a multi-faceted construct that involve different kinds of processes and mechanisms (Uithol & Paulus, 2014).

32-month-olds showed a looking bias in both paradigms towards the old path. On the one hand, this is noteworthy, as not even older children visually anticipated the goal of a human action. Yet, even previous research reported a mixed pattern of goal anticipations for human actions in toddlers (Krogh-Jespersen et al., 2015, 2018). The performance in the path-paradigm is in accordance to previous findings (Daum et al., 2012) and our hypothesis. Our results imply that 11-month-olds and 32-month-olds are not able to anticipate goals of non-human actions. This does not support the theoretical claim that infants understand goal-directed actions of non-human actions from early on (Luo & Baillargeon, 2005). The correlational analysis confirmed that children do not use the same processing strategies when observing a human or animated animal, as we didn't find any significant correlations between the paradigms.

In sum, our results cannot confirm the widely made assumption that children perceive human actions based on their goals (Ambrosini et al., 2013; Cannon & Woodward, 2012; Falck-Ytter et al., 2006; Woodward, 1998). Quite the contrary, the findings suggest that infants process actions based on visuo-spatial information and represent actions as movement patterns. Thus, our findings support low-level accounts of social understanding, indicating that infants make use of simple information when they process actions, such as statistical regularities (Daum, Wronski, Harms, & Gredebäck, 2016; Ruffman, 2014; Uithol & Paulus, 2014). Further we did not find any correlations within children between the two paradigms, which speaks against the claim that children process human und non-human actions similarly from early on (Leslie, 1995; Luo & Baillargeon, 2005).

Adults reacted according to our expectations in the path-paradigm: They fixated the novel path leading to the familiarized goal first. Surprisingly adults showed contradicting anticipations in the hand-paradigm; they expected the hand to grasp the novel object. Thus, they encoded the movement trajectory instead of the action goal. This is interesting, since the goal of the actor should be clear at least for adults. However, so far there is only one study that tested the paradigm of Cannon and Woodward (2012) in adults. Pfundmair et al. (2017) found that adults anticipated the goal of a grasping hand as well as of a grasping claw, which is in contrast to our findings. Given this contradiction and lack of prior studies within adults, further investigation is needed. Maybe this paradigm is not equally suitable for adults as it might be for children (i.e. measuring the same underlying ability).

Interestingly, in our study we found a positive correlation between adults' looking times in the two paradigms, which indicates that they demonstrated related processing strategies for the two types of stimuli. Ramsey and de C. Hamilton (2010) showed in a fMRI-study that adults process goal-directed actions of a triangle similar to goal-directed grasping actions of a human hand. They concluded that the fronto-parietal network, which is often referred to as the human mirror neuron system, actually encodes goals rather than biological motion (Ramsey & de C. Hamilton, 2010). Similar assumptions have been made by Schubotz and Von Cramon (2004), who found activity in motor areas for abstract, non-human stimuli. One assumption would be that the role of experience influences participants' performance in the two tasks (Ruffman et al., 2012). Adults probably gained more experience with animations and cartoons throughout their life, whereas infants are still not well familiarized with them.

4. Meta-analysis

In the previously described studies, we conducted six similar experiments that measured whether infants between 11- and 12-months of age anticipate the goal of an action instead of the movement path. Infants performed in none of the six experiments visual anticipations towards the goal, questioning the theoretical claim that infants selectively encode and anticipate other's action goals (Cannon & Woodward, 2012; Woodward, 1998). Instead we observed the tendency of infants to anticipate the movement path. In order to produce a more reliable estimate of the observed looking bias towards the location, a meta-analysis was conducted. We wanted to find out whether this effect is significant over all of our six experiments.

4.1. Method

4.1.1. Effect sizes

Effect sizes for the meta-analysis were expressed as correlation coefficients, *r*. This metric was chosen, as correlation coefficients are easier to interpret and compared with other metrics (Field, 2001; Rosenthal, 1991). The experiments of Study 1 were treated as single studies for the meta-analysis. As we wanted to see whether the effect of infants making location- instead of goal-directed anticipations is significant over all experiments, we used for each experiment of Study 1 the effect size of the comparison between location and goal-directed anticipations in test trials. This resulted in five effect sizes for each experiment of Study 1 (see Table 2 for effect- and sample sizes). For Study 2 we used the mean effect size of both paradigms of the First Fixation Score, following Rosenthal's (1991) suggestion for cases when there are more effect sizes within a study. As the effect sizes of Study 1 are based on infants' first fixations, we did not include the Differential Looking Score of Study 2 in this analysis. In Study 2, the direction of infants' looking bias was measured via one-sample *t*-tests, which is why we used the effect-sizes thereof (see Table 2).

Table 4
Effect sizes used for meta-analysis and number of participants per experiment.

Experiment	Effect-size r	Number of participants
Study 1		
Experiment 1	−0.31	24
Experiment 2	−0.16	24
Experiment 3	−0.18	32
Experiment 4	−0.4	32
Experiment 5	−0.19	32
Study 2	−0.18	34

4.1.2. Method of meta-analysis

We assume that our sample sizes come from the same population and expect our sample effect sizes to be homogenous, since all our experiments are similar and collected from similar populations. According to this we decided on a fixed-effects model instead of a random-effects model, as suggested for these circumstances by Field and Gillett (2010). For calculating the fixed-effects model, the approach by Hedges et al. (Hedges & Olkin, 1985; Hedges & Vevea, 1998) was used. The analysis was calculated via written syntax for SPSS (see Field & Gillett, 2010).

4.2. Results

The mean effect size based on the model was −0.24 with a 95% confidence interval (CI_{95}) of' −0.38 (lower) to −0.09 (upper) and a highly significant z score (z = 3.07, p = .002). According to Cohen's criterion (1988) this is a small to medium effect. A chi-square test of homogeneity of effect sizes was not significant, $\chi^2(5) = 1.51$, p = .912. This supports our previous assumption of a low between-study variance indicating that our participants are sampled from the same population.

To illustrate infants' looking bias towards the location instead of the goal over all experiments, the number of anticipations towards the location versus the goal was summed up over all six experiments. From a total of 681 anticipations, infants directed 423 anticipations towards the location whereas 258 anticipations were performed towards the goal (Table 4).

4.3. Discussion

The meta-analysis aggregated data from 178 participants over all six experiments and demonstrated that samples of 11- to 12-month old infants show anticipations directed towards the path of an action and not to its goal, with a small to moderate magnitude. This result underlines the previous findings of Study 1 and 2, and highlights the conclusion of our findings: Through all our 6 experiments we were not able to find a goal-directed looking bias within 11- to 12-month-olds. Rather, we observed anticipations of infants towards the location indicating that infants encode the movement path instead of the goal of an action. This is further discussed in the next section.

5. General discussion

The present work addresses the question of whether and under which circumstances children and adults flexibly anticipate actions as goal-directed. It has been claimed that infants show visual goal anticipations earlier for human than for non-human actions (Meltzoff, 1995; Paulus, 2012; Ruffman et al., 2012; Woodward, 2005), whereas others proposed that infants are able to anticipate goals for non-humans equally well as for humans (Leslie, 1995; Luo & Baillargeon, 2005). Cannon and Woodward (2012) demonstrated that 11-month-old infants are able to encode an action of a human hand, but not of a mechanical claw as goal-directed. In contrast, Daum et al. (2012) could only find goal-directed anticipations within children from 3 years of age and adults, when using an animated agent instead of a human hand. With the current set of studies, we aimed to contribute to the current debate on infants' goal anticipations by exploring whether infants indeed anticipate actions flexibly based on goals rather than based on movement paths and patterns. Two different labs collaborated over the attempt to replicate both conceptually and directly the findings reported by Cannon and Woodward (2012). We hypothesized that infants understand human actions earlier than actions of a non-human animated agent. Therefore, we expected to replicate the findings of Cannon and Woodward (2012) in our experiments that used a human hand as agent but not necessarily in the experiments that used non-human animated animals as agents.

However, despite our systematic variation of any other factors that could have had an influence on infants' action perception (such as type of agent, presence of an occluder or number of learning- and test trials), we failed to replicate the findings of Cannon and Woodward (2012) across all our experiments and labs. Infants between 11 and 12 months of age did not anticipate an action in relation to its goal, but rather to its movement path. This was observed, irrespective of whether the agent was a human or an animated animal. We even included an experiment that was as close as possible based on the stimuli of Cannon and Woodward (2012) and were not able to replicate their finding. A meta-analysis aggregated over all of our data emphasizes our result and illustrates a consistent effect for a looking bias towards the location and not the goal within 11- and 12-month-olds.

The finding, that infants and young children base their anticipations on the movement path relates to previous eye-tracking studies (e.g., Paulus et al., 2011; Schuwerk & Paulus, 2015) and further stresses the role of frequency information for infants' action processing. Our results underlie the claim that already infants are able to detect contingencies and regularities in their environment, as supposed to be an important learning mechanism (Kirkham, Slemmer, & Johnson, 2002; Ruffman et al., 2012; Smith & Yu, 2008).

Does this mean that infants do never show flexible goal-directed anticipations? It should be noted that the paradigm by Cannon and Woodward (2012) presented participants with a scene of two objects placed on a white background and a hand that appears from the left side to grasp one of them. This scene is filmed from a birds'-eye view and does not include the whole situation, namely an agent sitting on a table in front of two targets. Theoretically, it has been proposed by predictive coding accounts that active perception is informed by environmental features (e.g., Clark, 2013). Also studies with infants could demonstrate the informative influence of context information on infants' action anticipations (Fawcett & Gredebäck, 2015; Stapel, Hunnius, & Bekkering, 2012). Usual situations in our environment provide us with lots of information that is already there before an action takes place, and thus open room for top-down influence before an action is performed (Clark, 2013). Thus, it is possible that the situation in the Cannon and Woodward-paradigm (2012), as well as in our experiments, might be too abstract and out of context. The fact that we also couldn't find goal-directed anticipations for adults adds additional concern towards this paradigm. However, adding more ecological cues might help infants. Other studies reported goal anticipations within infants when they were presented with a movie depicting the entire human agent grasping for an object (Kim & Song, 2015; Krogh-Jespersen & Woodward, 2014, 2018; Krogh-Jespersen et al., 2015). Furthermore, there are studies demonstrating goal anticipations in infants and toddlers when they had the possibility to learn about the agent's goal (Paulus, 2011; Paulus et al., 2017). For example, in Paulus et al.'s study (2017), children observed an agent walking to a goal for several times whereas the goal's position changed from time to time. This highlighted the goal object on the expense of the movement path (see also Ganglmayer, Schuwerk, Sodian, & Paulus, 2019). In sum these findings suggest that infants might need additional information in order to visually anticipate the goal and not the movement path.

Another possibility relates to cultural factors. While the study of Daum et al. (2012) and the current studies were implemented in Europe, the study of Cannon and Woodward (2012) was conducted in the U.S. A comparison of various studies on children's TV consumption suggests that infants watch more TV in the U.S. than in Europe (Feierabend & Mohr, 2004; Zimmerman, Christakis, & Meltzoff, 2007). In an additional pilot study, we asked 22 parents of 12-month-olds about the average time their infants watch TV. Results showed that only 23% of the 12-month-olds watch TV and for an average time of 4 min. In comparison, Zimmerman et al. (2007) reported that infants in the US spend on average an hour per day in front of a TV screen. Given the fact that prior experience with technology and real objects increases learning through TV (Hauf, Aschersleben, & Prinz, 2007; Troseth, Saylor, & Archer, 2006), it is possible that different experiences with TV and screens could be a reason for our diverging findings. Yet, on the other hand, since we did not find goal-related anticipations in 32-month-olds or even adults (Study 2) who arguably have ample experiences with TV, this factor is rather unlikely to be the central cause underlying our non-replication.

Our work highlights the importance for replication studies in developmental psychology, as recently researchers warned of false positive findings and publication biases. Recent attempts to replicate findings of implicit Theory of Mind tasks turned out difficult as well (e.g., Burnside, Ruel, Azar, & Poulin-Dubois, 2018; Kammermeier & Paulus, 2018; Kulke, Reiß, Krist, & Rakoczy, 2017; Powell, Hobbs, Bardis, Carey, & Saxe, 2017). Some specifically tried and failed to replicate an implicit Theory of Mind task based on anticipatory looking measures, questioning the robustness of these tasks (Kulke, von Duhn, Schneider, & Rakoczy, 2018; Schuwerk, Priewasser, Sodian, & Perner, 2018). One strength of the present manuscript concerns the integration of work conducted at two different labs. Such a collaborative effort is not only in line with suggestions for future best practices (e.g., Frank et al., 2017), but also increases the conclusiveness of our results.

In sum, our findings over various types of stimuli and across two labs suggest that infants around 11 and 12 months of age do not flexibly anticipate an action based on its goal, but primarily use the information about the movement path, when presented with two possible targets that change location for test trials (following Cannon & Woodward, 2012). This indicates that infants base their anticipations on frequency information (similar to Henrichs, Elsner, Elsner, Wilkinson, & Gredebäck, 2014). When they observe an action performed in a certain way, they use this information to predict that action in the future (Ruffman, 2014). However, infants in their first years of life seem to process this information in relation to movement paths (Paulus et al., 2011). Our findings also imply that we need to reflect on what we exactly mean when we say that infants understand goals, as a goal, in its general meaning, refers to a desire (Ruffman et al., 2012; Uithol & Paulus, 2014). In conclusion, according to our six experiments, infants do not flexibly anticipate action goals around 12 months. Rather, their anticipation of others' actions might rely on more simple heuristics, such as movement trajectories.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.infbeh.2019.101340.

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