The understanding of a simple reach and grasp action of a hand as goal-directed by 6 and 9 months old infants

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Abstract

There is evidence that at an age of 6 months old, infants are able to at least interpret a simple goal-directed action as intentional. But there are still questions on how infants come to a goal-directed interpretation of human actions. Therefore, we conducted two experiments, investigating the role of cues from the situation and from the actor's behavior allowing infants to understand the goal-directedness of an action. More specifically, using the violation of expectations method, we examined how 6 and 9 months old infants interpret a simple action of a hand, which does not provide infants with any situational and behavioral cues. Therefore, we first familiarized infants with a reach and grasp movement of a hand towards a toy. This was followed by two test events: one in which the path of the hand was changed (to reach for the same object) and one in which the target object changed (either grasping a new object in Experiment 1 or stopping at the new object in Experiment 2). We found that infants of 9 months old looked both longer to the new goal test event (Experiment 1) and no goal test event (Experiment 2) compared to the same goal test event (used in both experiments). This indicates they found both the reach and grasp of a new goal and the achievement of no goal at all more unexpected compared to achieving the same goal. Six months old infants however, only found it more unexpected when the hand did not achieve a goal anymore, but only when provided with additional situational cues (our control condition). This suggests a developmental shift in the role of cues from the actor and the situation for the interpretation of goal-directed actions of humans by infants.

Keywords: infancy, goal-directed actions, violation of expectations paradigm, goal attribution

Introduction

How do children develop an understanding of the world surrounding them? It is known from research that around 6 months, children have build up expectations about the behavior of other humans and understand that there is a goal underlying most of their actions (e.g. Woodward, 1998). However, we are still exploring which mechanisms account for the development of action understanding. Most researchers agree that this develops as a combination of an innate reasoning system and experience with goal-directed behavior through observation and infants' own actions.

Defining goal-directed behavior

Before one can investigate how infants interpret, perceive and understand goal-directed behavior, one must define goal-directed behavior in order to fully understand the implications of infants' understanding of goal-directedness. Goal-directed behavior can simply be described as an action performed by an actor in a particular situation towards a specific end state. Goal-directed behavior of humans can also be seen as part of intentionality, in which the actor's desires and intentions lead to (bodily) movement to achieve a particular goal (for example a specific object). Because their behavior is partly driven by their intentions, people are capable of deciding to perform a specific act in a particular manner. Thus, an action can be considered goal-directed or intentional if it can be viewed as a means to a particular end.

Furthermore, humans are capable of automatically view most actions not as purely physical movements but as actions directed at and structured by goals. This perception of others' action in terms of intentional relations (and thus drawing meanings from other's behavior) is fundamental to human social life and functioning. Moreover, it can be seen as foundational for cognitive, linguistic and social development (Barresi & Moore, 1996; Gerson & Woodward, 2012). Actions are movements that are directed towards certain goals and that are performed to initiate desired changes in the environment (e.g., Elsner, 2007; Prinz, 1997). These actions consist of two observable elements: a movement part and a particular outcome of that movement. This outcome must have been intended by the actor, and therefore, both the action movement and action outcome are observable cues for the underlying goals of the action. However, there are still questions on how infants perceive, understand and interpret the actions of other persons.

The origins of understanding goal-directed actions

As mentioned before, goal-directed actions of humans can be seen as intentional, or representing in one’s mind what the goal is and what action is needed to achieve that goal. Therefore, the understanding of goal-directed actions can be seen as a pre-cursor of later “theory of mind” abilities (e.g. Ascherleben, Hofer & Jovanovic, 2008; Gergely & Csibra, 2003). Theory of mind can be seen as the understanding that other people also have mental states such as believes, desires, emotions and intentions and goals and that these may differ from own mental states (Gergely, Nadasdy, Csibra & Biro, 1995; Meltzoff, 1995). It is agreed infants show already precursors of this theory of mind, but there is still no clear answer to how and when infants come to an understanding of other one’s mind. Because more simple mental states like goals and intentions may be easier to understand, these may be particularly appropriate to investigate the early roots of theory of mind (Meltzoff, 1995).

Piaget was one of the first describing the cognitive development of infants, including the understanding of goal-directed actions. According to Piaget (1952, 1954), young infants are now in the sensorimotor stage of development (from birth to 2 years), therefore they only get an understanding of the world in terms of their own overt, physical actions. Between 4 to 8 months, infants are also observing the external world and learn how to perform certain actions in order to achieve an interesting effect (motor recognition). Therefore, they gradually develop an understanding of intentional behavior. Around 12 months, infants are able to interpret means-end action sequences as goal-directed behavior through their own experience and observation (Lightfoot, Cole & Cole, 2009; Miller, 2002). Piaget thus stated that infants begin life in a asocial manner and gradually develop an understanding of the similarities between themselves and others. He opined that the recognition of other ones behavior through infants’ own behavior is an outcome of the developing social cognition (e.g. Meltzoff, 2007; Piaget, 1952, 1954).

Meltzoff (1995, 2007) extended Piaget’s work by stating a ‘like me’ framework of understanding other humans’ actions. Infants’ own motor activity does facilitate the early construction of knowledge. They recognize the behavior of others as representing their own behavior. Nine months old infants can understand other human actions by comparing them with their own actions. Thus, the ability to understand goal-directedness of others emerges from the ability to perform goal-directed actions themselves. However, other than Piaget, Meltzoff considered this ‘like me’ framework as the foundation of the developing social cognition of infants instead of the outcome. Social cognition develops through the perception of infants that others are ‘like me’. Therefore, they can use the self to understand actions and goals of others and can learn about the possibilities and consequences of their own actions by observing others' behavior (Meltzoff, 2007).

Soon, other theorists like Woodward and Gergely & Csibra started to extend their findings, claiming infants are already able to understand the basis of goal-directed behavior before their first year of life. These researchers extensively investigated the origins of understanding goal-directed behavior. Both groups of theorists did this from a different point of view, especially on what critical mechanism underlies the understanding of goal-directed actions. Woodward (1998, 1999) was one of the first researchers able to demonstrate that infants already at 5 or 6 months old are able to interpret a human direct reach and grasping movement as goal-directed, but only when the action was familiar to them. Woodward initially supported Meltzoff's "like me" framework (2007), claiming that infants are able to interpret goal-directed behavior of other peoples due to their own experience. This experience emerges from infants' own actions, thus their experience with performing goal-directed actions. Further, it develops from observing other people performing actions and thus imitating goal-directed behavior. Later, Woodward extended her view by stating that infants integrate different types and sources of information in order to perceive an observed action as goal-directed (Sommerville & Woodward, 2005; Woodward, 2009). For example, when 6 months old infants are habituated to a hand reaching for one of two objects on a stage, they show longer looking times during test trials when the goal relation is disrupted (when the hand reaches for a new goal) but not when the physical relation is disrupted (the hand takes a new path to the same goal; Gerson & Woodward, 2012; Woodward, 1998). This paradigm by Woodward is still commonly used as a basis to extend her findings, especially to investigate the role of outcome selection information within the situation an action is embedded in.

However, Gergely and Csibra investigated the perception of goal-directed actions by younger infants from another point of view (e.g. Gergely, Nadasdy, Csibra, & Biro, 1995). They proposed that infants for understanding goal-directed actions and intentionality can rely on an innate reasoning system. This understanding is an automatic process triggered by cues from both the actor and the action. According to their view, infants interpret human as well as nonhuman actions as goal-directed on the basis of the principle of rational action. They demonstrated that infants of 9 months old (and in later studies also from 6 months old; e.g. Csibra, 2008; Kamewari Kato, Kanda, Ishiguro & Hiraki, 2005) were able to infer that the movement of a ball was directed towards a goal. They based their idea on cues from the behavior of the ball, in this case the efficiency of its movement. Thus, according to them, infants rely on cues to reason about whether the observed behavior is efficient and therefore goal-directed.

Investigating infants' understanding of goal-directed behavior

A variety of methods have been used to test infants abilities in goal attribution, mostly relying on imitation (e.g. Meltzoff, 1995) and measures of visual attention (like preferential looking and violation of expectations). Especially the violation of expectations paradigm is used extensively, for example by Woodward (1998) and by Gergely and Csibra (Csibra & Gergely, 1998; Gergely and Csibra, 1994, 1997), providing us with evidence about the understanding of goal-directed actions in infancy.

The violation of expectations paradigm.

Initially, the looking time paradigm was used to examine the sensory capacities of infants by presenting them with a stimulus and observe their overt behavioral responses to it (in this case their looking behavior). Then, to determine if infants already have some preferences, researchers started to present two different stimuli at once to determine whether the infant had some preference by looking longer to one of the stimuli (the preferential looking paradigm; e.g. Spelke, 1985). Further, one can also present an infant with a complete new stimulus and continue presenting it until the infant looks away (gets bored). The next step is to change an aspect of the stimulus and explore if the infant's interest is renewed after this change (and thus perceived the change; e.g. Friedman, 1972). This kind of measures of infants' attention to stimuli can be used for understanding infants' developmental processes like attention, perception and cognition (Lightfoot et al, 2009).

To test infants' higher level cognitive abilities, one commonly used method is based on the tendency of infants to stare at events that violate their expectations. First, infants are habituated or familiarized to a particular event and then presented with two variants of the event. If infants are capable of mentally representing their experiences, they should develop specific expectations during the familiarization phase and then look longer at events that violate those expectations. Infants' developing representations is a joint consequence of evolutionary processes and experience (Hespos & Baillargeon, 2006; Wang, Baillargeon & Brueckner, 2004).

This violation of expectations paradigm has been used extensively by developmental psychologists to gain insights into how infants represent properties of objects and how they come to understand the nature of causal relationships. The logic underlying this paradigm is that individuals will look longer at events that are impossible or unexpected compared with events that are more consistent with their knowledge. In some sense they violate their knowledge of the world.

Familiarization versus Habituation.

As shortly mentioned, within the violation of expectations method one can use either a habituation or familiarization procedure to introduce a new stimulus to infants. Within a habituation procedure, the goal is to establish a pattern of dishabituation in infants: a recovery of the looking times after a decline in looking times during the habituation phase. During the presentation of the same stimulus during the habituation, infants commonly show a decline in looking times. This may indicate infants have remembered the stimulus and therefore lose interest. When presenting a new stimulus to infants, they initially should look a long time but as the novelty of the stimulus was reduced, they should look less and less (this is called habituation). A child is considered habituated when showing a certain amount of decrease in looking time. When this criterion is reached, the novel stimuli are introduced (Slater, Morison & Rose, 1984).

Within a familiarization procedure however, a stimulus is presented to the infant for a predetermined number of trials of a fixed duration. These presentations are not linked to the infant's behavior or visual attention: it does not matter if the infants looks or not, the procedure will continue. However, a drawback of this procedure is that it is not certain whether an infant is totally habituated or totally processed the stimuli. Therefore, there may be a difference in processing levels between infants and one of the factors that may influence this difference is age. However, within a habituation procedure the trial length is defined by the looking of the infant: the trial begins when the infant looks at the screen and ends when he first looks away. Trials are repeatedly presented in the same way until the length of the infants' look decreases below a certain criterion (Aslin, 2007; Bornstein, 1985; Pascalis & De Haan, 2003). However, it can be the case that infants does not meet the habituation criterion at all, and therefore you may have to exclude more participants then when using the familiarization procedure. It could be possible that other factors influenced the decline in looking times, for example fatigue or the attention span of infants.

The role of the direct environment in infants' action understanding

Little research has yet focused on the role of environmental factors other than specific factors within a situation (like having a choice within a situation). However, one can imagine that stimulation from the environment is important to develop an understanding of the intentions of others. Infants develop this understanding also by observing goal-directed actions performed by parents and siblings. Social interaction with both siblings and parents shapes infants' social and cognitive development, because through these interactions they may come to an understanding of the goals of other people by the combination of their actions and the results of that action (Barr & Hayne, 2003; Call & Carpenter, 2002; Dunn, 1989; Hohenberger et al., 2012).

However, these goal-directed actions of others are embedded into a particular situation and humans tend to rely on information from that situation to interpret the observed action as goal-directed. This information comes both from the environment in which the action takes place and from the actor itself, the person who performs the action. From the environment, one can identify information about outcome selection, we infer that a particular outcome is the goal of an actor (and thus an expression of a preference for that object) by the availability of alternative outcomes. From the actor itself, one can infer he acts in a goal-directed way when he displays means selection, he is able to adjusts his action to the situational constraints in order to achieve his goal. Both kinds of information have been extensively studied using two different types of experimental paradigms (as mentioned before): The violation of expectations paradigm introduced by Woodward (1998) provides us with evidence for infants' reliance on outcome selection information within the situation and another kind of violation of expectations paradigm originally developed by Gergely and Csibra (Csibra & Gergely, 1998; Gergely & Csibra, 1994, 1997) considers the importance of means selection by the actor. Both this planning behavior (based on selection between means) and preference within the situation (based on selection between outcomes) implies that the actor is making a choice regarding its actions. By investigating the fact that infants can connect these two aspects of choice making, one can support the idea that infants rely on this assumption in order to identify agents and to make sense of their behavior.

Situational cues.

When observing an action, infants rely on outcome selection information from the movement, this action expresses a clear choice of the agent between potential outcomes (Verschoor & Biro, 2011). As mentioned before, the paradigm introduced by Woodward (1998) gives evidence for this reliance on outcome selection information by infants as young as 6 months old to be able to infer a situation is goal-directed. Within this paradigm, infants are first habituated to an event in which an actor repeatedly acts upon one of two objects present. Infants thus watch the actor consistently choosing one of two target objects. In the following test events, the location of the objects is switched. Therefore, the actor has to either reach for the same toy at a novel location or for the novel toy at the old location. Infants look longer in the other toy compared to the same toy event, this can be interpreted as evidence that infants are able to interpret the action as directed towards a particular goal/outcome. Therefore, infants seem to expect an actor to continue to direct his action towards the same target after something in the choice situation is altered.

However, when there is no clear outcome selection information available, infants from 5.5 months old and older seem to have difficulties interpreting the situation as goal-directed (Luo & Baillargeon, 2005). By presenting only one target object instead of two during the habituation/familiarization phase, thus giving no clear choice situation, infants seem to not build up expectations that the actor will reach to the same object when a new object is introduced during the test phase. Infants look equally long in the two test events, therefore it seems that they do not make goal-directed action predictions. This result may indicate that such a simple action does not contain sufficient unambiguous means selection information to compensate for the lack of outcome selection information. Biro, Verschoor and Coenen (2011) also used one toy during the familiarization, but they added additional information about the means selection (thus the efficiency of the movement). They found that 12 months old infants were only able to interpret the situation as goal-directed when the means selection information was unambiguous. This is in line with and an extension of the findings reported by Luo and Baillargeon (2005). Before infants are 12 months old, they seem to rely at least at information from the situation to interpret a reach and grasp movement of a hand as goal-directed. One toy target situations seem to be more ambiguous for infants and therefore more difficult to interpret. However, when presented with unambiguous behavioral cues in clear means selection towards the target toy, infants from 9 months old seem to be able to interpret this one toy versions as goal-directed (Biro et al., 2011; Hernick & Southgate, 2012).

Behavioral cues.

Biomechanical cues in the form of bodily movements such as manual acts (Biro, Csibra & Gergely, 2007; Meltzoff & Moore, 1997), can give infants information that the behavior could be interpreted in psychological terms. Goal-directedness can be indicated by particular behaviors, which are called context-sensitive behavioral changes. These behaviors are characterized by adjustment to changes within the environment and by performing optimal and efficient actions towards certain means to an end (Csibra, Gergely, Biro, Koos, &

Brockbank, 1999; Gergely & Csibra, 2003). These goal-directed actions have several characteristics: they act directly towards their goal (instead of acting in an indirect matter) and they can go around obstacles when encountering an initial obstacle (instead of just stopping there; Phillips & Wellman, 2005).

Behavioral cues provide infants with specific means selection information, how the actor adjusts his action when presented with situational constraints in order to achieve a particular outcome (Csibra & Gergely, 1998; Gergely & Csibra, 1994, 1997). Infants are habituated to a situation in which there is only one outcome present, but the actor has to achieve this outcome by adjusting the action to a situational constraint present (in this case: approaching a target object by going around an obstacle). In the following test phase, the situational constraints are changed (the obstacle is removed) and the actor either adjusts his movement to the new situation or performs the same action. Infants looked longer when the actor did not adjust his movement to the new situation to make it more efficient within that particular situation compared to the other test event in which the behavior was efficiently adjusted. This implies that infants are able to understand the relation between the means and the goal of an actor.

However, it seems to be important that the information about means selection is unambiguous in order to ensure that infants attribute goals to actions (Biro et al., 2007; Csibra, Biro, Koos, & Gergely, 2003). For example, when the actor's action seems not to be efficiently adjusted to the situational constraints during the habituation phase (when the actors takes a detour even when it is clear that a more direct and shorter route is available), infants do not develop specific expectations about the actor's novel means to achieve the outcome. This also applies when the action does not show any adjustment due to a lack of situational constraints.

Phillips and Wellmann (2005) extended the paradigm by Gergely et al. (1995) but replaced the ball with a human hand as actor. They found that 12 months old infants found it more unexpected if the hand did not make a direct reach movement (thus adjusted its means) towards the goal when the obstacle was removed but instead makes the same movement as when the obstacle was still present. Kamewari et al. (2005) also extended the paradigm by Gergely et al. (1995) by using a human actor, a humanoid robot and a box with no humanlike features. They were partly able to replicate their findings with 6.5 months old infants, suggesting that 6.5 months old infants are able to attribute goals to humans. These infants found it more unexpected when the human or humanoid robot were making the more inefficient movement but did not display this pattern when they saw a box making an inefficient movement. However, this may have been due to the fact that the means towards achieving the end goal was not clear enough and therefore more unambiguous. Indeed, Csibra (2008) showed that 6.5 months old infants do attribute a goal to a movement of a box, but only if it varies its movement during the habituation phase thus providing richer cues for means selection.

Also, by using the paradigm of Woodward (1998), the role of the efficiency of the means was investigated. However, the action was then performed by a human hand instead of an animated nonhuman agent. For example, Woodward and Sommerville (2000) found that 12 months old infants only develop an expectation about a specific means action if this means earlier was causally and efficiently related to the goal of the action. Moreover, Biro and Verschoor (2007) found that both 7 and 9 months old infants were expecting the same goal to achieved but only if the means was efficiently related to the outcome. Therefore, infants seem to only consider the outcome of the goal-directed action if the means to an end was efficient.

The current research

As apparent from the results of the mentioned research, there is still some controversy about when infants are able to understand goal-directed actions. There is evidence that at an age of 6 months old, infants are able to at least interpret a simple goal-directed action (like a direct reach and grasp of a hand) as intentional. But not all research mentioned was able to replicate this finding by Woodward, suggesting that 6 months old infants are probably relying on specific cues to be able to attribute goals to actions. Thus, other factors (like observation) may play a more important role around this age then later in the development (as proposed by Hohenberger et al., 2012). Therefore, the goal of the current research is to gain more insight into the role of cues from the situation and cues from the actor's behavior in allowing infants to understand the goal-directedness of an action. To examine this, infants were presented with a simple direct reach action of a human hand, which does not provide infants with any cues at all. Within the control condition, a situational cue was added to make sure infants are able to perceive both the original reaching action and action adjustment as goal-directed.

Also, all previous mentioned research used either outcome selection information or means selection information (or a combination) to investigate how infants come to an understanding of goal-directed actions. Therefore, the current research is aimed at exploring how infants interpret a direct reach of a hand, presenting them with no additional information or cues. The way we tested this was by investigating their expectations using the violation of expectations method. In this manner, we want to explore what infants expect when shown a direct reach movement of a hand. Do they interpret a direct reach movement as directed to a particular goal or do they not even interpret a reach as goal-directed at all?

EXPERIMENT 1

In experiment 1, our aim was to investigate how infants interpret a goal-directed direct reach by a human hand. Do they interpret this action as performed to achieve a particular goal? We tested that by first familiarize the infants with a situation in which they observed a direct reach and grasp of an object. After this, we changed the situation by placing another object in front of the first object. This allowed us to investigate what infants would expect to happen in this situations based on the previous observed situation. For the new situation, there were two possible scenarios: The hand goes around the new object to grasp the same object as before (old goal) or the hand grasps the new object (new goal). We examined if there is a difference in what infants expect between an adjusted movement of a hand towards a familiar goal and a same movement of the hand towards a new goal. Do 6 and 9 months old infants, after observing a direct reach movement of a hand towards an object several times, expect the movement to be adjusted in order to achieve that same goal or do they expect to see the same movement resulting in a new goal?

Within this experiment, participants are either assigned to an experimental condition or a control condition. In the experimental condition, there are no additional situational cues to interpret the situation as goal directed. In contrast, the control condition differs in a way that it is clearer from the situation that the hand's behavior is goal directed. As mentioned before, from previous studies, it is already known that infants interpret a direct reach and grasp as goal directed when presented with a clear choice situation, when there was more than one target object available.

There are several possible hypotheses regarding the looking behavior of the infants:

1) Infants are able to interpret a direct reach situation as directed to achieve a particular goal only when presented with clear situational cues, thus when presented with a clear choice situation between two targets. They interpret a direct reach towards one target not as performed to achieve a particular goal. *Thus, only infants within the control condition will display longer looking times when presented with the new goal event compared to the same goal event. Infants within the experimental condition will not show differences in looking times between both test events.*

2) Infants are able to interpret a direct reach situation as directed to achieve a particular goal regardless of whether they are presented with clear situational cues (in this case a clear choice situation between targets). *This results in longer looking times of infants during the new goal/same path test event compared to the same goal/new path test event in both test conditions. This suggests they are able to interpret this situation as goal-directed by expecting that the hand would grasp the same goal.*

Further, we want to explore if there are any developmental differences between the two age groups of 6 and 9 months old infants. The following hypotheses are taken into account:

3) There is a difference between 6 and 9 months old infants in how they interpret a direct reach situation without any situational cues. Infants of 6 months old will interpret the direct reach as not directed to a particular goal, while 9 months old infants in fact do interpret the direct reach as goal-directed. *Six months old infants within the control condition will show longer looking times during the new goal event compared to the same goal event. However, 6 months old infants within the experimental condition will not show this difference. For the 9 months old infant, it will be the case that they will look longer at the new goal event compared to the same goal event, regardless of if they are assigned to the experimental or control condition.*
4) There are no differences between the two age groups, both 6 and 9 months old will not interpret a direct reach as goal-directed when they are not presented with any cues. When giving them additional cues (in this case a clear choice situation between two targets), they are able to interpret the direct reach as performed to achieve a particular goal. *Thus, both 6 and 9 months old infants within the experimental condition will not look longer at the new goal event compared to the same goal event. However, infants within the control condition actually will show longer looking times during the new goal event compared to the same goal event.*

As mentioned earlier, this experiment consists of an experimental and a control condition. In the experimental condition, there is only one target toy present, thus giving the infant no additional situational cues. However, in previous studies infants were presented with a choice situation (e.g. Woodward, 1998), and all of these studies found that infants' interpreted the action as goal-directed. Therefore, we added a control condition in which there is a choice present (by presenting 2 toys), expecting infants in the control condition will indeed attribute goals to the action.

Methods

Participants

In this first experiment, participants were twenty-seven 6 months old infants (M_{age} = 27.93 weeks, *SD* = .92, *Range* = 4.73, 16 boys/11 girls). In addition, 1 infant was excluded due to not reaching the criterion for minimum looking time for the outcome of the test events (see procedure) and 1 infant was excluded due to procedural error. Also, thirty 9 months old participated (M_{age} = 39.49 weeks, *SD* = 1.21, *Range* = 4.56, 17 boys/13 girls). Additional, 5 infants were excluded because they did not meet the outcome criterion and 1 infant was excluded due to procedural error. All participants of both age groups were randomly assigned to the experimental or the control group, leading to the following distribution of participants (see Table 1).

Table 1
Descriptives for the participants of Experiment 1.

Age group		*N*	N_{boys}	N_{girls}	M_{age}	*SD*	*Range*
6 months	Experimental condition	12	6	6	27.66	.89	3.02
	Control condition	15	10	5	28.15	.91	3.59
	TOTAL	27	16	11	27.93	.92	4.73
9 months	Experimental condition	15	8	7	39.04	1.16	4.16
	Control condition	15	9	6	39.91	1.14	4.56
	TOTAL	30	17	13	39.49	1.21	4.56

All participants were recruited from Leiden and its surroundings. Parents were send some information about the Babylab of Leiden University and invited to register their baby. If parents were willing to participate with their infants in research conducted by the Babylab, they were asked to give some background information about their infant (name, date of birth, gender) as well as further contact information. When infants where approximately 6 or 9 months old, we contacted parents by phone to invite them to participate in the current research. When they agreed to participate in this study, we sent them an e-mail with further information about the aim and procedure of the research and a confirmation of our appointment. Furthermore, this experiment is approved by the Ethical Committee for Psychological Research of the Leiden University.

Stimuli

In the experimental condition, infants were shown several video recordings (see Figure 1). In the first pre-familiarization event, they are presented with a still image of 5 seconds showing only 1 toy (a green plastic toy car) at the right side of the screen. After this, they see four identical familiarization events each starting with a still image of 2 seconds showing, in addition to the toy, a hand present at the left side of the screen. After 2 seconds, the hand makes a direct reach movement (with a duration of 5 seconds) and grasps the toy. Each familiarization event ends with a still image of the hand grasping the toy for 5 seconds. After showing the familiarization event four times, infants are shown a pre-test event of 5 seconds introducing a still image of a beige block standing in front of the toy.

In the following test phase, we show infants 2 different test events. In the same goal/new path event, the event starts with a 2 seconds still image of a hand on the left side and the toy on the right side, and standing between them the same block. After 2 seconds, the hand first reaches straight (going towards the block) but then reaches around the block and grasps the same toy as in the familiarization. This reaching and grasping movement lasts for 5 seconds, followed by a still image of the hand grasping the toy (with a maximum duration of 60 seconds). The other test event presented to the infants is the new goal/same path event. This event starts identical, showing a still image of the hand and toy with a block between them. Then, the hand makes a direct reach movement of three seconds towards the block ending with grasping it (instead of going around it like during same goal/new path condition). This is followed by a still image of the hand grasping the block, this is shown with a maximum of 60 seconds. The order in which we show these test events is counterbalanced across the participants. In the control condition, all eight events are exactly the same except that instead of presenting the infants with only 1 toy, 2 toys (the green plastic toy car and a brown soft toy dog) are present now at the right side of the screen (see Figure 1).

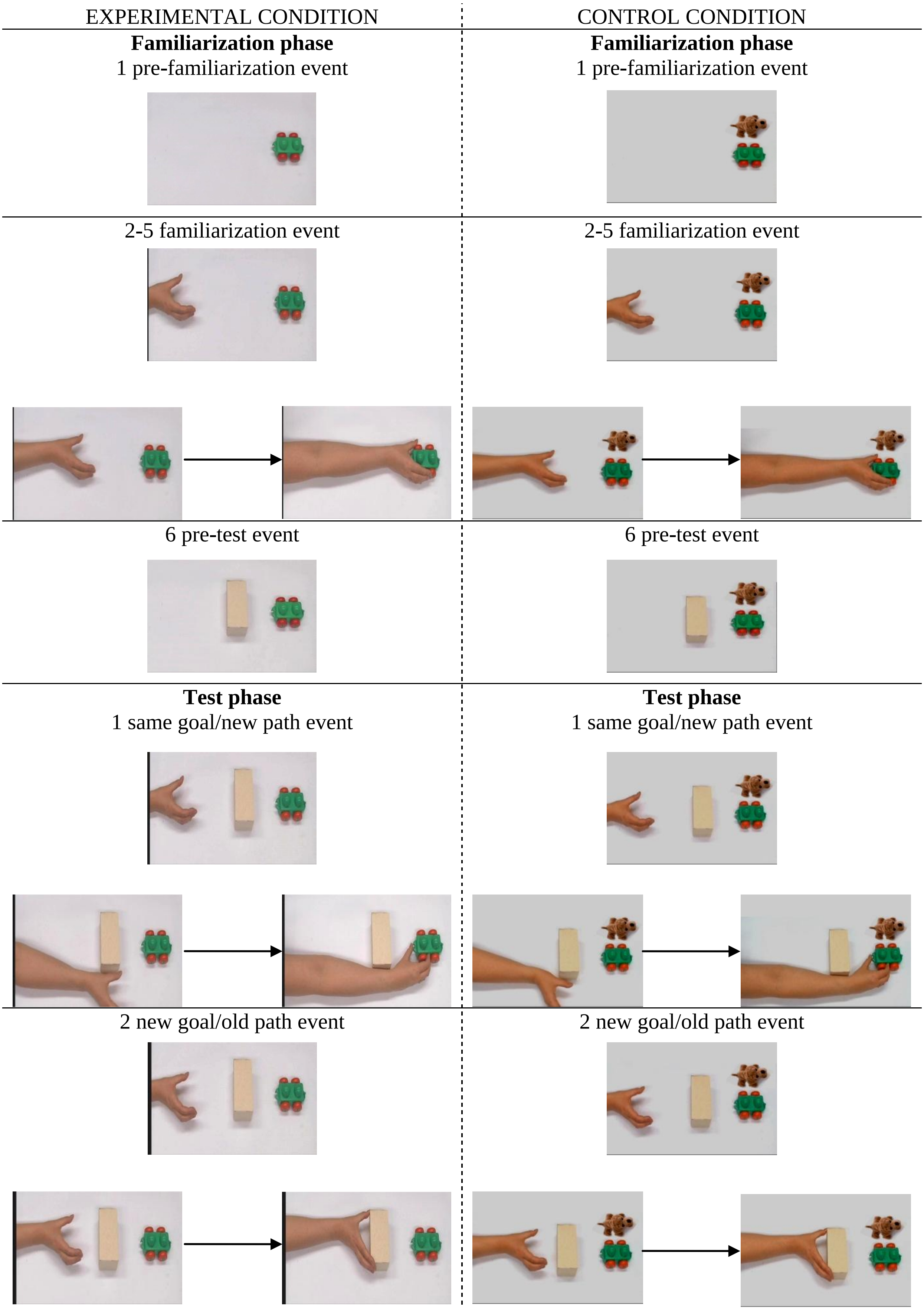

Figure 1. Overview of all events in both the experimental and control condition of Experiment 1.

Apparatus

All videos were shown on a 31-inch TV screen placed into a filming booth. This booth stands inside the Babylab of Leiden University and can be isolated from the rest of the room using a dark curtain. Infants sit on their parents lap in front of the TV screen with approximately 70 centimeters distance. Recordings are made of both the TV screen and the infants' face using two separate camera's. A split image can be created in order to see both the videos and the infant's face at the same time.

The experiment is running using a special designed Looking Time Program (Schrama & Biro, 2005). This program is both used for controlling the stimulus presentation and for measuring the looking time of the infant. For the familiarization part, the experimenter starts every event by pressing a button. During the test phase, the experimenter can directly measure the looking time of the infant by pressing a key. A computer program calculated the specific looking times for both test events.

Testing procedure

First, parent and infant are welcomed in the Babylab and introduced with the testing procedure. After this introduction, the parent is asked to fill in an informed consent and then the experiment could start. Parents were also told that they could always stop the experiment, for example when their infant started to cry or was fussy. Parent and infant were seated inside the special filming booth and the experimenter moved the camera to make sure the infants' face is recorded clearly. Then, the curtain is closed and the presentation of the video recordings of the events could be started. If the infant was not looking, the experimenter uses a bell sound to attract the attention of the infant towards the TV screen. During familiarization, this bell sound can be used several times to make sure the infant perceived the complete situation. After the familiarization phase, the parent is asked to close her eyes before the experiment continues with the test phase. This specific instruction is given to avoid any distraction or influence from the parent. Before showing each test event, the same bell sound is used. The experimenter starts directly at the beginning of each test video with measuring the looking time of the infant simply by pressing or releasing a button on the computer. After finishing the second test event as well, each infant received a diploma and a small gift to thank them for their participation.

The criteria used for measuring the looking time during the test events are the following: the event still continues if the infant does not look away for more than 2 seconds; however, when the infants looked less than 5 seconds, the trial was ignored and started again (this is the minimum time to ensure the infants saw the complete movement of the hand); when infants looked longer than 60 seconds, the test trial stopped and a new one begun (or the experiment was ended). Looking times are both measured online and measured by a second coder. Also, looking times for the familiarization phase are measured offline using the same looking time program. Finally, an outcome measure is created by measuring looking times for both test events from the point at which the actors' hand reaches for the toy or the block. This special outcome measure is created because the time-path of the hand movement differs between the two test events. To rule out differences in looking time due to a difference in duration of the actual movie, this measure was included in the further analysis. To assess the reliability of the online coding of the looking times, a second coder recoded the test events offline. The inter-coder reliability between the online and offline measurements of the total looking time during the test events was measured using Cronbach's alpha. The reliability was = .87.

Results

Looking times during the familiarization phase

First, we tested if there were any differences in the looking times of the infants during the familiarization phase between the experimental and the control condition for both age groups using a multivariate analysis of variances (MANOVA). We looked at the looking times for the pre-familiarization event, the mean looking time for the four identical familiarization events and the looking times during the pre-test event. The between-subjects factors taken into account are age group (6 or 9 months) and test condition (experimental or control condition). Between the two test conditions, there are no significant differences for the 3 measures of looking time (pre-familiarization: $F(1,46) = .09$, $p = .77$; mean familiarization: $F(1,46) = 1.69$, $p = .2$; pre-test: $F(1,46) = .32$, $p = .57$). Also, there is no significant main effect for age group (pre-familiarization: $F(1,46) = .19$, $p = .66$; mean familiarization: $F(1,46) = 3.89$, $p = .055$; pre-test: $F(1,46) = .1$, $p = .75$), but there can be seen a tendency towards a difference in the mean looking times of the four familiarization events: 9 months old infants tend to look longer than 6 months old infants (9 months: $M = 9.37$ seconds; 6 months: $M = 8.18$ seconds). Furthermore, there is no significant interaction effect between age group and test condition (pre-familiarization: $F(1,46) = 1$, $p = .32$; mean familiarization: $F(1,46) = .35$, $p = .56$; pre-test: $F(1,46) = .09$, $p = .56$). Thus, there are no significant differences in looking time during the familiarization phase between infants within the experimental and control condition of both 6 and 9 months old.

Furthermore, we tested whether there could be found a decline in the looking times of the participants during the four separate familiarization events for both age groups using a repeated measures MANOVA with looking times for the four familiarization events as within-factor and age group and test condition as between-factors. First, there is a significant main effect for familiarization ($F(3,138) = 5.51$, $p = .001$, $\eta_p^2 = .11$), in which the mean looking time during familiarization declines significantly from 9.6 seconds during the first event to 8.29 seconds during the fourth event. Further, there is a tendency towards a difference between the two age groups ($F(1,46) = 3.89$, $p = .055$, $\eta_p^2 = .08$). For test condition, there is no significant main effect ($F(1,46) = 1.69$, $p = .2$, $\eta_p^2 = .04$). Also, there are no significant interaction effects between familiarization and age group ($F(3,138) = .14$, $p = .94$, $\eta_p^2 = .003$), familiarization and test condition ($F(3,138) = 1.24$, $p = .0297$, $\eta_p^2 = .03$), age group and test condition ($F(1,46) = .35$, $p = .56$, $\eta_p^2 = .01$) and familiarization, age group and test condition ($F(3,138) = .49$, $p = .69$, $\eta_p^2 = .01$). In sum, this means that the mean looking time during all familiarization events declines, regardless of the test condition and this is the case for both age groups. But, 9 months old infants tend to look longer during the familiarization events compared to the 6 months old infants (see Figure 2).

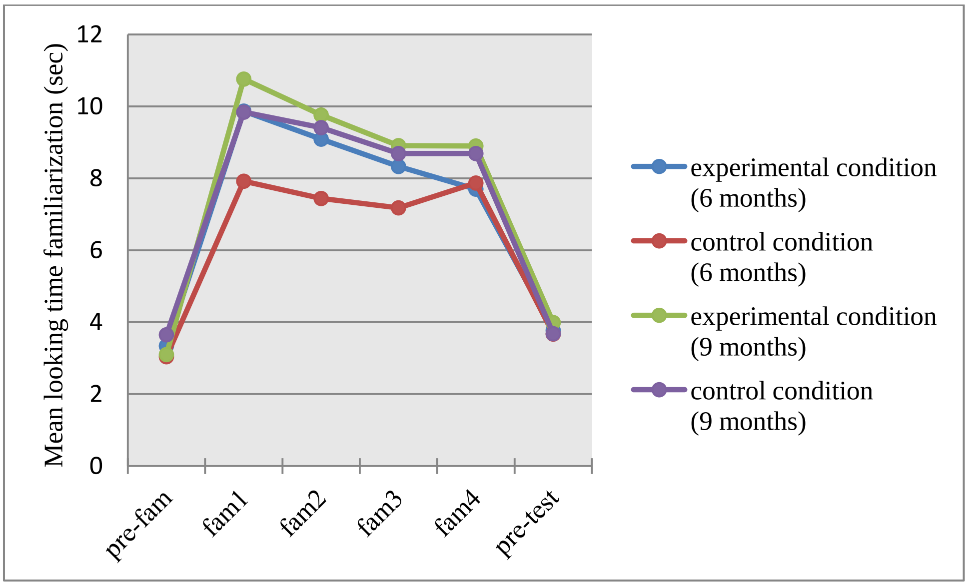

Figure 2. Mean looking times in seconds during the familiarization phase.

Looking times during the test phase

For analyzing the test events, we were interested to see whether there were differences in looking time patterns between the two age groups, taken into account several other factors like test condition and test order. Because gender did not had any main or interaction effects, we omitted this factor from further analyses.

Looking times for 6 months old infants.

First, we explored whether there were any differences in the mean looking times during the test events for the 6 months old participants using a repeated measures MANOVA. The within-subject factor consisted of the outcome measures of both test events (consisting of looking time in seconds), the between-subject factors were test condition (experimental or control condition) and test order (same goal event first or new goal event first). There are no significant main effects for test event (F(1,23) = .01, p = .92, η_p^2= .001), test condition (F(1,23) = .09, p = .77, η_p^2 = .004) and test order (F(1,23) = .31, p = .58, η_p^2 = .01). Also, there are no further interaction effects found between test condition and test event (F(1,23) = .69, p = .41, η_p^2 = .03), test order and test event (F(1,23) = .53, p = .48, η_p^2 = .02), test condition and test order (F(1,23) = .23, p = .63, η_p^2 = .01) and of test event, test condition and test order (F(1,23) = .26, p = .62, η_p^2 = .01). In sum, this means that 6 months old infants did not look significantly longer at the new goal/same path test event than at the same goal/new path event. This was the case for both the experimental and control condition and test order did not make any difference (see also Figure 3).

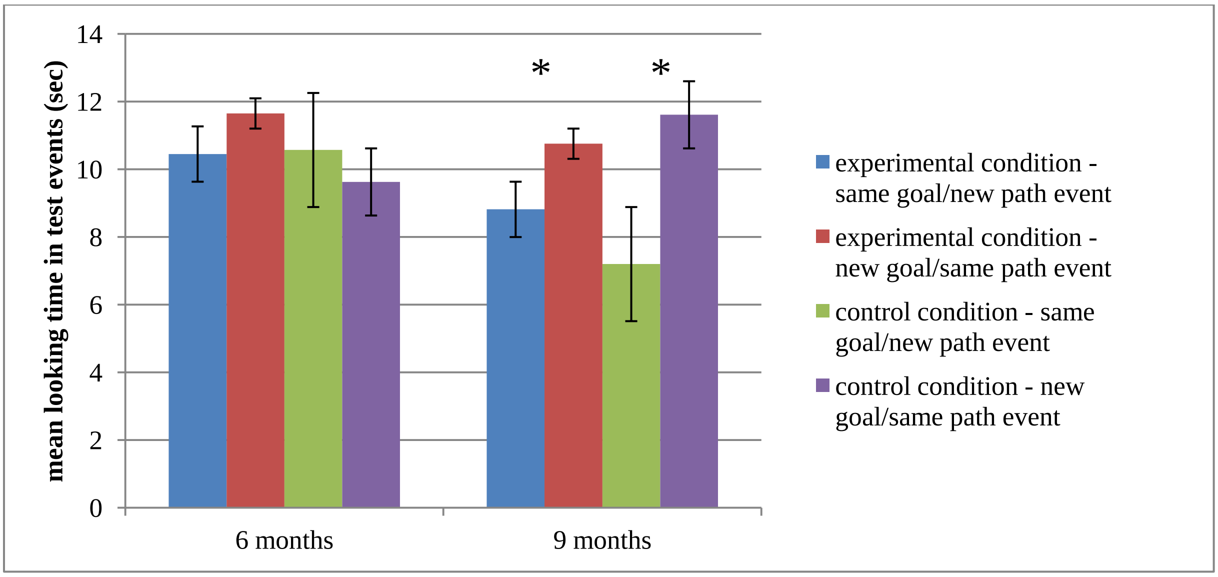

Figure 3. Mean looking times in seconds during the test phase for both age groups and test conditions.

Looking times for 9 months old infants.

For the 9 months old infants, we also used a repeated measures MANOVA with the outcome measure of both test events for the 9 months old infants as the within-subjects factor and with test condition and test order as between-subjects factors. There was a significant main effect for test event (F(1,26) = 4.35, p = .047, η_p^2 = .14), infants looked significantly longer at the new goal/same path condition (M = 11.19 seconds) compared to the same goal/new path condition (M = 8.01 seconds). Furthermore, the main effect of test condition was not significant (F(1,26) = .02, p = .88, η_p^2 = .001) neither was the main effect of test order (F(1,26) = .098, p = .76, η_p^2 = .004). There were not found any significant interaction effects between test event and test condition (F(1,26) = .66, p = .43, η_p^2 = .03), test event and test order (F(1,26) = 1.77, p = .2, η_p^2 = .06), test order and test condition (F(1,26) = 2.31, p = .14, η_p^2 = .08) and between test event, test order and test condition (F(1,26) = .77, p = .39, η_p^2 = .03). These results indicate that 9 months old infants looked significantly longer at the new goal/same path test event compared to the same goal/new path condition regardless of the test condition or test order (see also Figure 3).

Conclusion

We investigated whether 6 and 9 months old infants interpret a direct reach as goal-directed. Our results are partly in line with our third hypothesis, stating that there is a difference in how 6 and 9 months old infants interpret a direct reach situation. We expected to find that 6 months old infants looked longer to the new goal test event compared to the same goal test event, but only when provided with additional situational cues (in a choice situation between two target objects). In addition, we hypothesized that the 9 months old infants would display longer looking times for the new goal test event than the same goal test event, regardless of adding situational cues.

For the 6 months old infants however, there was no difference in looking times between the test events in none of the test conditions. This means that they did not find it more unexpected that the direct reach had a new outcome compared to achieve the same outcome and this was the case for both the experimental and control condition. Thus, for the 6 months old infants it did not matter if they were provided with additional situational cues with regard to how they interpreted the direct reach. When presented with a clear choice situation between targets, they generated no further expectations about the hand reaching for a particular goal. This can indicate they found both test events equally unexpected, therefore they showed no differences in looking times between the two test events. It can also be the case that they need more cues to interpret the situation as goal-directed, for example further behavioral cues or more additional situational cues. Another possibility is they simply did not interpret the situation as goal-directed at all, they do not perceive a direct reach as directed to a particular goal. This in contrast to earlier findings by Woodward (1998, 1999). Therefore, we conducted a second experiment to investigate whether infants would expect a direct reach of a hand to achieve a goal and thus find it more unexpected when the hand seems to and his movement without achieving any goal at all.

The 9 months old infants did actually show differences in their looking behavior between the two test events: They looked longer in the new goal test event compared to the same goal test event. Surprisingly, this was the case in both the experimental and control condition, indicating they did not need to rely on additional situational cues to interpret the direct reach as performed to achieve a certain goal. This raises questions about on what kind of information they rely on to interpret an action of a hand as goal-directed. Therefore, a second experiment was conducted.

EXPERIMENT 2

In Experiment 1, we found that there is a difference in how infants of 6 and 9 months old interpreted the direct reach situation. Six months old infants seemed to interpret the direct reach as not aimed at a particular goal. This raises the question whether it is possible that infants have difficulties with perceiving that there is any goal at all? In order to investigate this question, we conducted a second experiment. Within this experiment, we included a test event in which the hand stops at the first object on its direct path (without grasping any object) and thus does not achieve a goal at all. Do infants interpret the direct reach and grasp of a hand as goal-directed at all? Would it therefore be more unexpected for them to see a direct reach without achieving any goal compared to a direct reach performed to achieve a particular goal?

There are several possible hypotheses regarding the looking behavior of the infants:

1) Infants are able to interpret a direct reach situation as goal-directed even when they are not presented with clear situational cues (in this case a clear choice situation between targets). When presented with a direct reach which seems to end without achieving any goal at all, they find this more unexpected because they expected the hand to perform the direct reach to achieve a goal. *This results in longer looking times of infants during the no goal/same path test event compared to the same goal/new path test event, suggesting they are able to interpret this situation as goal-directed by expecting that the hand would grasp the same goal. Further, we expect this to be the case for both the experimental and control condition.*

2) Infants are able to interpret a direct reach situation as goal-directed only when presented with clear situational cues, thus when presented with a clear choice situation between two targets. They interpret a direct reach towards one target not as performed to achieve a goal and thus are not more surprised when the direct reach movement seems to end without achieving any goal at all. *Thus, only children within the control condition will display longer looking times when presented with the no goal event compared to the same goal event. Children within the experimental condition will not show differences in looking times between both test events.*

Further, we want to explore if there can be found any developmental differences between the two age groups of 6 and 9 months old infants. The following hypotheses are possible:

3) There is a difference between 6 and 9 months old infants in how they interpret a direct reach situation without any situational cues. Infants of 6 months old will interpret the direct reach as not directed to a goal, while infants of 9 months old in fact do interpret the direct reach as goal-directed. *Six months old infants within the control condition will show longer looking times during the no goal event compared to the same goal event, but 6 months old within the experimental condition will not show this difference. For the 9 months old it will be the case that they will look longer at the no goal event compared to the same goal event, regardless of if they are assigned to the experimental or control condition.*
4) There can be found no differences between the two age groups, both 6 and 9 months old will interpret the direct reach situation as goal-directed event when they are not presented with a clear choice situation. *In this case, both 6 and 9 months old infants will display longer looking times during the no goal event compared to the looking times during the same goal event and this will be the case for infants in both the experimental and the control condition.*

Methods

Participants

In this second experiment, twenty-seven 6 months old infants participated (M_{age} = 27.67 weeks, *SD* = .71, *Range* = 2.73, 16 boys/11 girls). One additional infant was excluded because of not meeting the outcome criterion (see procedure Experiment 1). Also, thirty-two 9 month olds participated (M_{age} = 40.21 weeks, *SD* = 1.28, *Range* = 5.59, 16 boys/16 girls). In addition, 2 infants were excluded due to not reaching the outcome criterion. The same as in experiment 1, all participants came from Leiden and its surroundings. The procedure used to recruit the parents and infants is the same as described in Experiment 1. Infants were randomly assigned to either an experimental or a control group, leading to the following distribution displayed in Table 2.

Table 2
Descriptives for the participants of Experiment 2.

Age group		*N*	N_{boys}	N_{girls}	M_{age}	*SD*	*Range*
6 months	Experimental condition	16	11	5	27.57	.74	2.29
	Control condition	11	5	6	27.8	.68	2.29
	TOTAL	27	16	11	27.67	.71	2.73
9 months	Experimental condition	17	9	8	40.1	1.59	5.58
	Control condition	15	7	8	40.36	.84	3.55
	TOTAL	32	16	16	40.21	1.28	5.59

Stimuli

The design of Experiment 2 is identical to the design of Experiment 1: Infants were assigned either to the experimental or control condition, both consisting of a familiarization phase and a test phase (see Figure 3). Within the experimental condition, the stimuli shown during the familiarization phase are exactly the same as the ones used in Experiment 1. However, the stimuli of the test phase differ from the stimuli used in Experiment 1. There are two test events: the same goal/new path condition is identical to the same event in experiment 1, showing a direct reach movement of a hand towards the toy, while going around the block between them. The other test event is the no goal/same path event. During this test event, infants first see a still image of two seconds showing the hand on the left side and the toy on the right side with between them a block. After this still image, the hand moves with a direct reach towards the block and just stops there after 3 seconds. The event then continues with showing a still image of the hand in front of the block with behind the block the toy. This still image lasts for a maximum of 60 seconds. Infants saw both test events, only the order differed for half of them. Infants assigned to the control condition saw exactly the same events, the only difference was that there are 2 toys present at the right side of the screen instead of 1 toy.

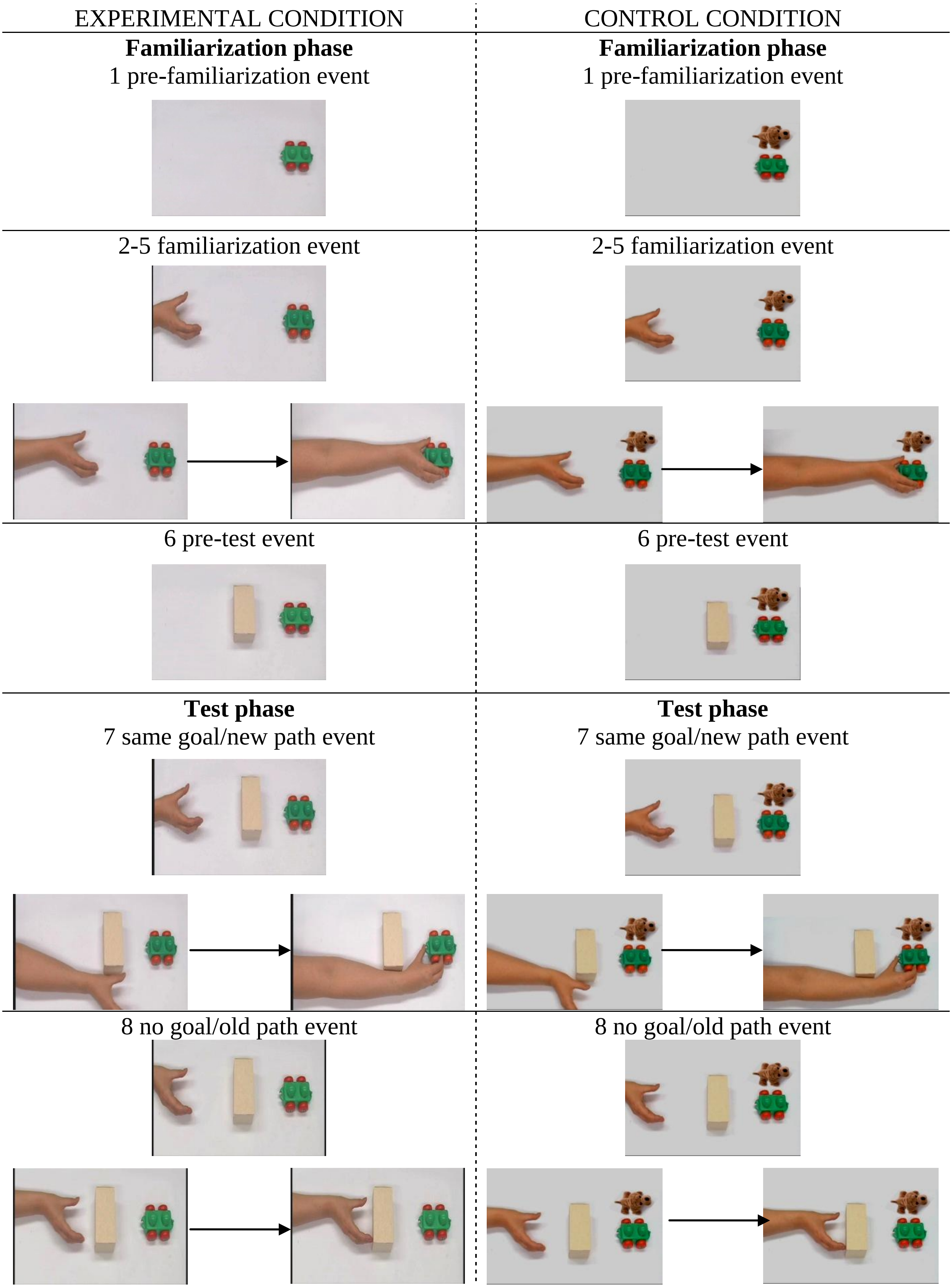

Figure 4. Overview of all events in both the experimental and control condition of Experiment 2.

Apparatus & Test Procedure

The apparatus and test procedure are identical to the ones used in Experiment 1. As in Experiment 1, the inter-coder reliability is assessed using Cronbach's Alpha (= .9).

Results

Looking times during familiarization phase

As in Experiment 1, we first tested if there are differences in the looking times of the familiarization phase between the experimental and control condition and between the two age groups using a MANOVA. For test condition, no significant main effect was found for the pre-familiarization event ($F(1,49) = .098$, $p = .76$) and the mean of the four familiarization events ($F(1,49) = .22$, $p = .64$). But, there is a tendency towards a difference in looking times during the pre-test event ($F(1,49) = 3.9$, $p = .053$). Infants assigned to the experimental condition looked longer to the pre-test event ($M = 4.2$ seconds) than infants within the control condition ($M = 3.54$ seconds). Also, there was a significant main effect of age group for the mean looking times during the four familiarization events ($F(1,49) = 8.4$, $p = .01$). Six months old participants looked shorter during these events than 9 months old infants did (6 months: $M = 8.07$ seconds; 9 months: $M = 9.89$ seconds). This main effect of age group did not apply to the pre-familiarization ($F(1,49) = .001$, $p = .98$) and the pre-test ($F(1,49) = 1.31$, $p = .26$) Furthermore, no significant interaction effect was found between test condition and age (pre-familiarization: $F(1,49) = .08$, $p = .78$; mean familiarization: $F(1,49) = .07$, $p = .79$; pre-test: $F(1,49) = .86$, $p = .36$). In sum, this means that there are some small differences between the infants during the familiarization phase.

Also, we wanted to test if there was a decline in looking time during the actual familiarization events using a repeated measures MANOVA. There is a significant main effect for the familiarization ($F(3,150) = 11.94$, $p < .001$, $\eta_p^2 = .13$) with a decline in mean looking time from 9.99 seconds during the first event to 8.58 seconds during the fourth event. Also, there is a significant main effect for age group ($F(1,50) = 9.26$, $p = .004$, $\eta_p^2 = .16$), 9 months old infants looked significantly longer to the events than the 6 months old infants (9 months: $M =$ 9.97 seconds; 6 months: $M = 8.07$ seconds). For test condition, there was no significant main effect ($F(1,50) = .36$, $p = .55$, $\eta_p^2 = .01$). Further, there are no significant interaction effects between familiarization and age group ($F(3,150) = 1.69$, $p = .18$, $\eta_p^2 = .03$), familiarization and test condition ($F(3,150) = 3.12$, $p = .08$, $\eta_p^2 = .06$) and familiarization, age group and test condition ($F(3,150) = .22$, $p = .64$, $\eta_p^2 = .004$). The interaction effect between age group and test condition was also not significant ($F(1,50) = .02$, $p = .9$, $\eta_p^2 = .02$). This means that there is a decline in the looking times during the four separate familiarization events, despite of the test condition for both age groups. However, the 9 months old infants showed overall longer looking times during the familiarization events compared to the 6 months old infants (see Figure 5).

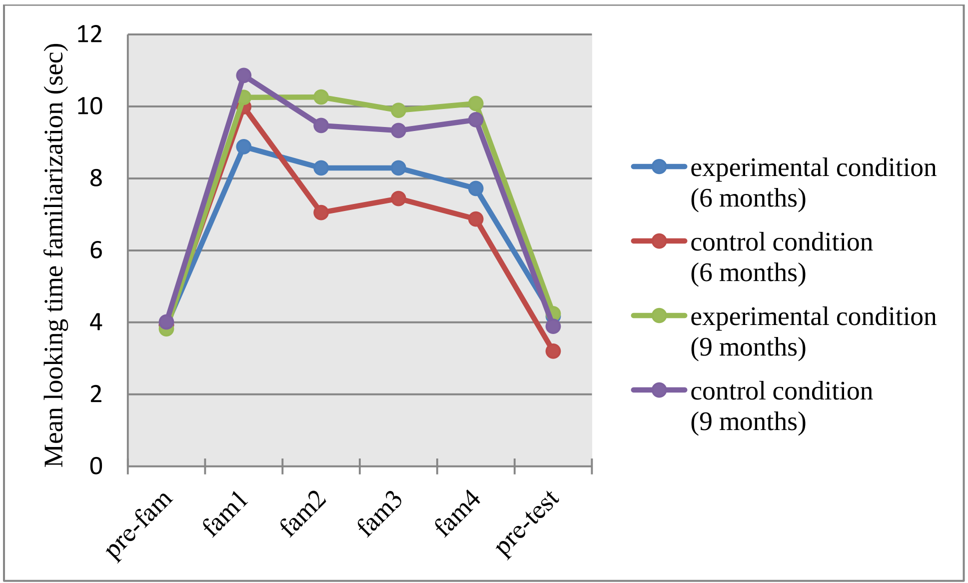

Figure 5. Mean looking times during the familiarization phase.

Looking times during the test phase

As in Experiment 1, preliminary analyses revealed that there were no significant effects of gender. Therefore, we decided (as in Experiment 1) to omit gender as between-subjects factor in the further analyses.

Looking times for 6 months old infants.

We tested differences in looking times during the test phase for 6 months old infants using a repeated measures MANOVA, with the outcome measure for the two test events as within-subjects factor and test condition and test order as between-subjects factors. We did find a significant main effect for test event ($F(1,23) = 4.66$, $p = .04$, $\eta_p^2 = .17$), indicating that 6 month olds looked significantly longer at the no goal/same path test event compared to the same goal/new path test event (Figure 6). Also, there was a significant main effect of test order ($F(1,23) = 6.48$, $p = .02$, $\eta_p^2 = .22$), indicating that the infants looked significantly longer when the no goal/same path condition was shown first ($M = 18.71$ seconds, $SD = 3.52$), than when they were first presented with the same goal/new path condition ($M = 6.99$ seconds, $SD = 2.97$). Furthermore, there was no significant main effect of test condition ($F(1,23) = .08$, $p = .78$, $\eta_p^2 = .003$) and there were no significant interaction effects between test event and test condition ($F(1,23) = 3.08$, $p = .09$, $\eta_p^2 = .12$), test event and test order ($F(1,23) = 3.79$, $p = .06$, $\eta_p^2 = .14$) and test condition and test order ($F(1,23) = .07$, $p = .8$, $\eta_p^2 = .003$). However, a significant interaction effect between test condition, test order and test event was found ($F(1,23) = 12.33$, $p = .001$, $\eta_p^2 = .37$).

To further investigate this three-way interaction effect, we investigated the effects of test event and test order separately for the experimental and control condition. Within the experimental condition, there were no significant main effects and interaction effects for test event and test order (all with a *p*-value of < 0.14). Within the control condition however, there is a significant main effect of both test event ($F(1,9) = 6.49$, $p = .03$, $\eta_p^2 = .42$) and test order ($F(1,9) = 6.78$, $p = .03$, $\eta_p^2 = .43$) and a significant interaction effect between test event and test order ($F(1,9) = 13.28$, $p = .005$, $\eta_p^2 = .596$). As shown by further t-tests, infants looked significantly longer to the no goal test event compared to the same goal event, but only when the no goal test event was shown first ($t(9) = -3.46$, $p = .007$; see also Figure 7). In sum, this indicates that only 6 months old infants within the experimental condition looked significantly longer to the no goal test event than the same goal test event, but only when this was presented first (thus before the same goal test event). Infants within the experimental condition however did not display looking time differences between the two test events.

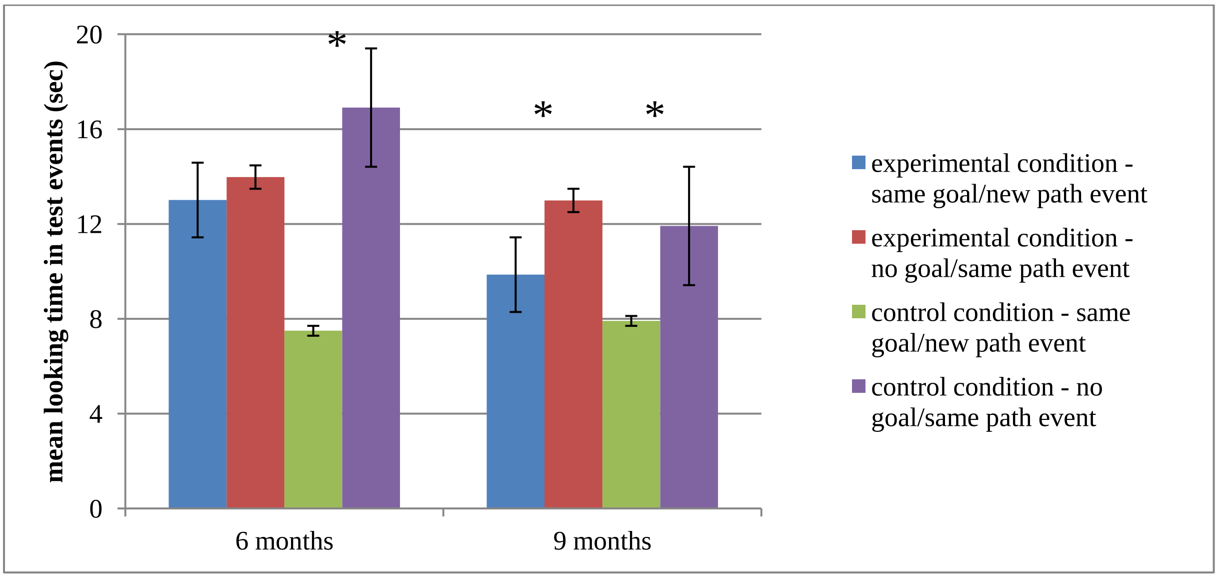

Figure 6. Mean looking times in seconds during the test phase for both age groups and test conditions.

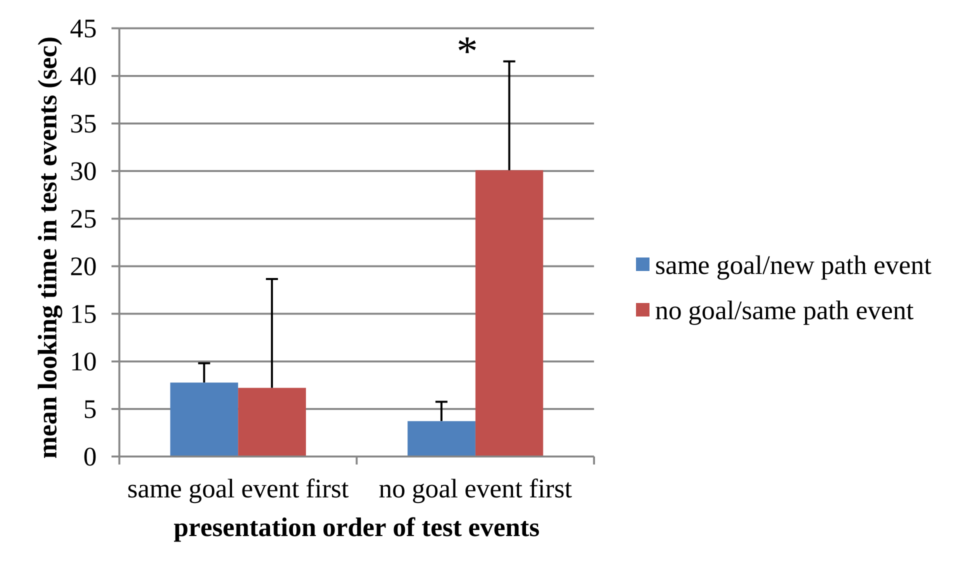

Figure 7. Mean looking times in seconds during the test phase for the control condition of 6 months old infants by test order.

Looking times for 9 months old infants.

Differences in looking times during the two test events between 9 months old infants were tested with a repeated measures MANOVA, with the outcome measure for both test events as within-subjects factor and test condition and test order as between-subjects factors. We found a significant main effect for test event ($F(1,28)=4.49$, $p=.04$, $\eta_p^2=.14$), the mean looking time during the no goal/same path condition was 12.46 seconds and thus significantly higher than the mean looking time during the same goal/new path condition (M = 8.89 seconds). Further, there are no significant main effects of test condition ($F(1,28)=.27$, $p=.61$, $\eta_p^2=.01$) and test order ($F(1,28)=1.49$, $p=.23$, $\eta_p^2=.05$). Also, there were no interaction effects of test event and test condition ($F(1,28)=.07$, $p=.8$, $\eta_p^2=.002$), test event and test order ($F(1,28)=.31$, $p=.58$, $\eta_p^2=.01$), test condition and test order ($F(1,28)=.53$, $p=.47$, $\eta_p^2=.02$) and test event with test condition and test order ($F(1,28)=.03$, $p=.86$, $\eta_p^2=.001$) In sum, this means that 9 months old infants looked significantly longer at the no goal/same path condition, despite of test condition and test order (see also Figure 6).

Conclusion

The aim of Experiment 2 was to examine whether 6 and 9 months old infants would interpret a direct reach as goal-directed and therefore find it more unexpected when the direct reach seems to end without reaching any goal at all compared to when the direct reach was aimed at achieving a particular goal. For both age groups, it was the case that they looked longer when the hand just stopped at the new object in front of the toy compared to when the hand reached and grasped the same goal. This indicates that around 9 months, infants are already able to interpret a simple direct reach as goal-directed in general. Furthermore, they do not need to rely on any situational cues.. This may indicate that they always assume that a hand movement is goal-directed, thus the features of the hand takes over the behavioral cues.

For 6 months old infants however, the relation is somewhat more complicated, suggesting there are indeed developmental differences. Six months old infants looked significantly longer when the no goal/same path event was shown first to them and when presented with additional situational cues (in 2 toys present).

These findings are in line with our third hypothesis, in which we expected to find a difference between the two age groups in how they interpret a goal-directed action.

General discussion

Both Experiment 1 and Experiment 2 were conducted in order to investigate the role of behavioral and situational cues in interpreting a direct reach as goal-directed by infants. When combining the results, there can be seen different patterns among the age groups of 6 and 9 months old infants. Nine months old infants do in fact interpret a direct reach as goal-directed in general. They seem to find it more unexpected when the hand does not reach a goal at all. Further, they also expect a direct reach movement to be directed at a particular goal and therefore find it more unexpected when the hand grasps instead of that particular goal a new goal. This interpretation pattern did not seem to differ between the experimental and control condition, thus infants did not need to rely on the provided situational cues, they still interpreted the situation the same when not presented with a clear choice situation.

However, based on previous research (e.g. Luo & Baillargeon, 2005), we expected to find that 9 months old infants would rely on additional situational cues to be able to interpret both the new goal and no goal test events as unexpected in the light of goal-directed behavior of the hand. Thus, we expected that only infants within the control condition would display longer looking times within the new goal and no goal test events compared to the same goal test event. But, despite of our expectations, both infants within the experimental and control condition looked longer to those test events than to the same goal test event. This may indicate that infants did not need to rely on additional situational cues to interpret the situation as goal-directed. For their interpretation, they used other information or cues than the choice possibility between two possible target objects. Biro and Verschoor (2007) for example found that infants of this age only expected the same outcome to be achieved when the means was efficiently related to the outcome. Another possible explanation is that 9 months old infants rely on featural cues from the actor to infer that its movement is goal-directed. It is possible they already categorized a hand movement as goal-directed and therefore expect the hand always to act to achieve a goal (Biro & Leslie, 2007; Csibra, 2008; Kamewari et al., 2005). For example, Kamewari et al. (2005) did demonstrate that infants attribute goals in the absence of behavioral cues when the agent is part of or looks like a familiar actor category (a human or a humanoid robot). Thus, featural identification of actors can have influence on goal attribution in early infancy.

For the 6 months old infants however, we revealed another pattern in looking times during Experiment 1 and 2, suggesting there are some developmental differences between the two age groups. First, 6 months old infants seemed not to expect the hand movement to be directed towards the same goal, even not when they were presented with a choice situation (Experiment 1). This suggests that maybe they had difficulties with the novelty of both test events. We were not able to replicate the findings by Woodward (1998): she found that 6 months old infants could recognize a direct reach as directed towards a particular goal when there was a clear choice situation present. Maybe the situation was too confusing or demanding for them and they would have needed more familiarization trials. Another possibility is that the situation was too complicated because the hand did choose the new obstacle as goal, maybe they build up other expectations and therefore found both test event equally unexpected. Another possibility is that they needed more clear behavioral cues to rely on for interpreting the situation: why is the hand now grasping the first object on its way and not its initial goal object? Within the first series of movies during the familiarization, one could see the hand making a direct reach action towards a target object several times. Therefore, one could expect that this object is the goal of the hand. When a new object is introduced standing in front of the other object, maybe it is more natural to expect the hand to just remove the new object in order to achieve the same goal (and thus expect an action sequence of goal-directed behavior; Verschoor & Biro, 2011). According to Verschoor and Biro (2011), young infants can evaluate the causal efficiency of a sub action, leading to an overarching goal. Possibly, it was the case that 6 months old infants expected a more familiar action and thus thought that the grasping of the object was just part of a behavioral sequence and therefore assumed that the hand just did not finished its movement. This is more in line with the findings of Woodward (1998), because when 6 months old infants where confronted with an action they were not familiar with (like reaching for a target object but instead of grasping it touching it with the back of a hand), they also did not display looking time differences between touching the original object and touching the other object.

Familiarity with a hand (and more specifically a reaching and grasping movement of a hand) may also play a role in the findings for the 6 months old infants in Experiment 2. We found that only infants within the control condition looked significantly longer to the no goal-same path event compared to the same goal-new path event, but only when the no goal event was shown first to them. First, this may indicate that 6 months old infants do rely on situational cues in order to be able to interpret a simple reaching action as goal-directed. They had difficulties interpreting the reaching movement as goal-directed when there was no clear choice situation present, but this altered when we provided them with a choice for the actor. In this case, they found it more unexpected when the hand just stops at the new object in front of the 2 toys compared to when the hand showed a clear choice for one of the 2 toys. This is in line with other findings, suggesting that such a simple action may not contain sufficient unambiguous means selection information (e.g. Luo & Baillargeon, 2005).

The order in which infants were presented with the test events also played a role. Six months old infants within Experiment 2 only displayed longer looking times for the no goal event when this event was presented first to them. When they first saw the same goal event, they did not display this differences in looking times between both test events. Similar patterns are sometimes reported, for example Csibra et al. (2003) found that both 6 and 9 months old infants looked longer to the no obstacle event but only when this was presented first to them. Other research also revealed the influence of the presentation order of the test events on infants' looking times in infants of 12 months old (Csibra et al., 1999; Csibra et al., 2003, Hohenberger et al., 2012). A possible explanation lies in the break between the familiarization phase and the test phase, this may have facilitated a recovery of the interest for both of the test stimuli. Also, the degree of perceptual dissimilarity of the first test event showed compared to the pre-test event may have caused infants to look longer to the first test event they see. Due to showing them the first test event, this degree of perceptual dissimilarity declines, which is also a possible explanation for infants' shorter looking times during the second test event.

Another possibility is that the delay between the familiarization phase and test phase (caused by giving the parent new instructions to close their eyes), was too long and therefore infants did not represent the situation properly anymore. A developmental growth in the capacity of representing can be found: Young infants are capable of representing objects they cannot see but quickly forget their location. The younger the infant, the shorter this delay must be in order to make infants able to remember where the object was placed within the situation (Lightfoot, Cole & Cole, 2009). In that case, they may have profited from using habituation instead or using more familiarization trials (Bornstein, 1985; Pascalis & De Haan, 2003).

Turning back to the possible influence of familiarity for both the interpretation of both 6 and 9 months old, one can also consider the influence of the direct environment of young infants on how they perceive, understand and interpret goal-directed actions. Little research has yet focused on the role of environmental factors other than specific factors within a situation (like having a choice within a situation). However, one can imagine that stimulation from the environment is important in order to develop an understanding of the intentions of others. Infants develop this understanding also by observing goal-directed actions performed by parents and siblings. Social interaction with both siblings and parents shapes infants' social and cognitive development, because through these interactions they may come to an understanding of the goals of other people by the combination of their actions and the results of these actions (Barr & Hayne, 2003; Call & Carpenter, 2002; Dunn, 1989). Recently, a series of studies by Hofer and colleagues (Hofer, 2005; Hofer, Hohenberger, & Ascherleben, 2008; Hohenberger et al, 2012) provided the first evidence for the specific role of mother-infant interactions and the understanding of goal-directed actions by infants. Hofer et al. (2008) used a modified version of the Woodward paradigm (1998) to assess understanding of goal-directed actions by 6 months old infants and the CARE-index to assess maternal interaction styles. Infants were first familiarized with a goal-directed hand action towards one of two objects, followed by two types of test events: the path change event in which the hand adjusts its path to achieve the same goal and the object change event in which the hand follows the same path but contacts the other object. They found that infants with modestly controlling mothers are better at interpreting human goal-directed actions, they looked longer at the path change test event compared to the object change test event. This indicates that infants already are able to encode the action as goal-directed. Interestingly, they were not able to replicate the findings of Woodward (1998), not the whole group of 6 months old infants were able to interpret the hand action as directed towards a particular goal, only infants of modestly controlling mothers did perceive the direct reach as goal-directed. A possible explanation for this finding is that moderate controlling mothers structure their interactions more strongly, introduce new objects earlier and more frequently.

Extending this results, Hohenberger et al. (2012) explored this relationship in both 6 and 10 months old infants by using the same tasks. They found the same pattern as did Hofer et al (2008) in 6 months old infants, only infants of modestly controlling mothers interpreted the hand reach as directed towards a particular goal. In 10 months old infants however, this effect of maternal interaction style does not seem to play a role anymore. Infants within this age group showed longer looking times during the object change test event compared to the path change test event. Together, this suggests that mother-infant interaction plays a role within a certain time span during the social cognitive development.

Overall, our findings suggest that 9 months old infants are able to interpret a simple direct reach movement of a hand as both goal-directed in general and directed to a particular goal. Six months old infants however, experienced difficulties in interpreting the simple directed reach movement as directed towards a particular goal, even when presented with outcome selection information. This may indicate that this simple action does not contain sufficient unambiguous means selection information, which is reported as a possible explanation for why infants do not make goal-directed action predictions (Luo & Baillargeon, 2005). However, when presented with a simple reach action which seems to end without achieving any goal at all, 6 months old infants are able to make goal-directed action predictions when presented with outcome selection information but not when there is a lack of information from the situation itself. Our findings may indicate a developmental shift of which information is important for infants to interpret daily situations. As indicated by Hohenberger et al. (2012), younger infants may rely more on information from observing and interacting with their caregivers, because their own goal-directed behavior is not fully developed. On a later age however, infants may also rely more on their own experience with goal-directed behavior and therefore have more knowledge of how actions can be efficiently adjusted to achieve a particular goal. They are able to experiment themselves with goal-directed behavior they observe. Therefore, they do not need to rely on explicit situational choice situations to understand such simple actions, but they may need this kind of information when the actions become more complicated.

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