# Infants' appreciation of others' mental states in prelinguistic communication

**Birgit Knudsen**

Cover picture: Little Elias Kolja Kraft insistently pointing for me into the direction of the sound of a passing car (Auto), vocalizing “to! to!”, Estepona, May 30th, 2011.

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# CHAPTER 1

## Introduction

## 1. Introduction

Interpreting others' actions in terms of underlying mental states is ubiquitous in adult human life. For example, if I were to see my brother reaching excitedly for the cookie jar, I would typically assume that he *wants* to get a cookie, that he *intends* to open the jar and that he *believes* the jar to contain cookies. That is, we commonly ascribe motives to the behavior of others by considering inner states such as wanting, thinking, intending or believing, e.g. 'He does X, because he wants/thinks/intends/believes, that Y' (also referred to as 'theory of mind'). Over the last 30 years, however, there has been much debate in psychology and philosophy with regard to when theory of mind arises in ontogeny and how it develops. The debate was recently revived by new accumulating evidence from looking-based studies showing that infants, in their first and second year, already experience others' behavior as being driven by inner mental states such as beliefs (e.g. Kovács, Téglás & Endress, 2010; Onishi & Baillargeon, 2005; Southgate, Senju, Csibra, 2007; Surian, Caldi & Sperber, 2007). The present work investigates whether infants in their second year - not only recognize others' beliefs - but also actively communicate their sensitivity to others' beliefs when interacting with another person.

The first chapter is organized into two parts. The first part gives a short overview of relevant empirical work on theory of mind development in young children. It also introduces recent looking-time results in infants and summarizes their theoretical interpretations, which focus mainly on cognitive information processing in the development of theory of mind skills. The second part of this chapter introduces a second person approach to mindreading that, in contrast to information processing accounts, considers engagement and interpersonal interaction crucial to the development of understanding others' minds. The second part also advocates pointing, as opposed to looking time, as a more advanced measure of infants' understanding of minds. In support of this claim, I also provide an overview of several pointing studies which are relevant to the topic of the current thesis.

## 1.1. Background

The debate on the development of mental state understanding focused on 'Theory of Mind' - a term coined by primatologists Premack and Woodruff (Premack & Woodruff, 1978). Theory of mind is broadly defined as the ability to attribute mental states such as goals, emotions, beliefs, intentions and desires to others. However, mounting evidence aimed at demonstrating mental state attribution is often criticized since many behaviours can typically be interpreted in both mentalistic and non-mentalistic ways. This is particularly true for the attribution of mental states that are consistent with reality, such as goals, perceptions and true beliefs (Johnson, 2000). Daniel Dennett (1978) suggested that the only convincing evidence for the attribution of mental state understanding is when a child is able to anticipate others' false belief based actions. As Dennett explains, this is because false beliefs drive behaviors not otherwise predicted by reality. As an example, he states,

> "Very young children watching a Punch and Judy show squeal in anticipatory delight as Punch prepares to throw the box over the cliff. Why? Because they know Punch thinks Judy is still in the box. They know better; they saw Judy escape while Punch's back was turned. We take the children's excitement as overwhelmingly good evidence that they understand the situation--they understand that Punch is acting on a mistaken belief" (Dennett, 1978, p. 569).

*1. Introduction*

Dennett's idea was put into practice by Wimmer & Perner (1983) as what has become known as the "false belief task". In the false belief task, a person places an object (e.g. chocolate) in a certain location (e.g. in a cupboard), which then is moved in her absence into a new location (e.g. the drawer) while the child is watching. Subsequently, the child is asked where the person, upon arrival, will look for the object. In order to answer the question correctly, the child has to consider that the person does not know that the object has been moved and is thus holding a false belief about the location of the object and, consequently, will look in the original location (the cupboard). Thus, the child needs to understand that the actions of others are guided by their actual knowledge states, which can be outdated and hence, be mistaken. Additionally, the child has to inhibit her own knowledge of the true location of the object ("pull of reality") when answering the question. Wimmer and Perner (1983) found that 4- to 6-year-olds correctly predict that the person will look in the location where she falsely believes the object is (cupboard), whereas younger children tend to answer that the person will look where the object really is (the drawer). This finding has been replicated reliably in hundreds of research papers demonstrating that 4-year-olds answer the question correctly, whereas younger children consistently fail. A meta-analysis (Wellman, Cross & Watson, 2001) showed that, despite attempts to make the test easier for younger children, for example by simplifying the language involved or by minimizing executive control demands by removing the object from the scene, no study selectively improved young children's performance above chance. From their meta-analysis, the authors concluded that the pattern of results reflected a genuine conceptual change in preschoolers' understanding of belief, and, relatedly, their understanding of the mind.

However, one interesting observation had to do with children's looking behaviour during the test. Just before answering the test question, about 75 % of the children younger than 4 years would look to the correct location even though they answered incorrectly (Clements & Perner, 1994). This finding led Clements & Perner to believe that children younger than 4 years might, at least implicitly (without conscious awareness), understand that people act according to what they know. That is, young children might actually understand considerably more than what was suggested by children's explicit verbal responses. Garnham & Perner (2001) followed up on this finding and conducted another study with children aged 2;5 to 4;7 that investigated whether implicit theory of mind understanding also manifests in infants' spontaneous action responses. In this study, children witnessed a puppet who left his ball at the bottom of one of two slides. He then climbed to the top of the slides, and while his back was turned, the ball was moved in front of the other slide. Children were then notified that the puppet was coming down to retrieve his ball and prompted to catch the puppet by moving a mat to the bottom of the appropriate slide. Results showed a difference between children's action responses and their verbal responses. Namely, they moved the mat reliably more often to the location where the puppet falsely believed the ball would be, as compared to when they answered the question 'Where is the puppet going to look?'. Indeed, this finding suggests that children from around 2;5 years onward implicitly understand that others will act in accordance with knowledge states other than their own, even when others' beliefs are mistaken.

## 1.2. Recent looking-based studies

The studies carried out by Perner and colleagues showed that there is a dissociation between verbal and behavioural responding in young children (Clements & Perner, 1994; Garnham & Perner, 2001; see also Low, 2010; Low & Wang, 2011). Young children were able to respond correctly and pass the false belief test in one modality (visual orienting, spontaneous action), but not in another (verbal), suggesting an implicit understanding of belief-based action. Onishi and Baillargeon (2005) were the first to test whether infants as young as 15 months would also show some implicit understanding of belief. In a violation-of-expectation paradigm infants were shown familiarization trials in which an actor repeatedly reached for an object in one of two locations. In the following belief-induction trial, the actor either saw the change of location of the object (true belief), or did not see the change of location of the object (false belief). At test, the actor reached into either the box that was congruent with her belief or into the box that was incongruent with her belief. Results revealed that, in both conditions, infants looked longer when the actor reached into the box that was incongruent with her belief. An additional condition was run to confirm that infants did not use low-level strategies or simply expect the actor to reach where the toy really was, to reach where she had reached previously, or to where she had last attended. Instead, infants were shown to keep track of what information the actor was given prior to her actions and to use the actor's informational state, rather than their own, when watching her behaviour. Surian, Caldi & Sperber (2007) replicated Onishi & Baillargeon's findings in a similar change-of-location task with 13-month-old infants. They showed that infants' expectations about an agent's future actions toward an object indeed differed depending on the agent's previous exposure to relevant information about an object's location (see also Senju, Southgate, Snape, Leonard & Csibra, 2011). Infants in this study expected a successful action only when the agent had informational access to the location of the desired object either by seeing the object (perceptual access) or by witnessing only its placement (true belief). In contrast, when the agent had no informational access to the new location of the object, infants expected the agent to be led by outdated information, gathered in previous familiarization trials (false belief) and to search for the object in the old location.

These findings are consistent with an accumulating number of other recent looking-based studies revealing that infants in their second year construe others' actions as resulting from mental states derived from an agent's visual information as well as the agent's tactile information (Träuble, Marinović & Pauen, 2010), false perceptions (Song & Baillargeon, 2008), object identity (Scott & Baillargeon, 2009) or non-obvious properties such as a rattling sound of an object (Scott, Baillargeon, Song & Leslie, 2010). In addition, several recent studies have used looking-based paradigms to demonstrate theory of mind capabilities in 13-month-old children, and most recently, even in 7-month-old infants (Kovács, Téglás & Endress, 2010). The interpretations of these data, however, differ vastly among researchers.

### 1.3. Theories and interpretations

Whereas 20 years of research on theory of mind development had consistently shown that children younger than 4 years are not able to use others' informational states in order to verbally predict behaviour, more recent looking based studies suggest that infants process others' actions in mentalistic terms. Some take this as evidence for a representational theory of mind in infancy while others are more reluctant to accept this interpretation. Moreover, it raises the question about why young children fail verbal false belief tasks while infants succeed in a variety of looking based tasks.

Baillargeon and colleagues (2005, 2008, 2009, 2010), who have provided a considerable amount of the looking time data, concluded that infants in their second year already possess at least an implicit form of a representational theory of mind which might stem from an inborn, abstract computational system which guides their interpretation of others' actions. This early system for psychological reasoning allows infants to represent others' reality-congruent (true belief/ignorance) as well as reality-incongruent (false belief) informational states. According to these authors, young children fail verbal false belief tasks because the tasks require additional response selections (e.g. choosing the right answer) and inhibitory processes (because infants must inhibit their own knowledge), which might exceed their limited attentional and working-memory resources. Looking based tasks, on the other hand, depend only on belief representation processes and don't require response selection or inhibition. Surian et al. (2007) agree with this interpretation in that they, too, take the looking time data as evidence for a rudimentary form of a representational theory of mind in infancy. They point out the fact that infants take into account information that had been perceptually available to the agent only prior to his action, which demonstrates ascription of mental content, thus, mindreading proper, however rudimentary it may be. In contrast, verbal false belief tests require the child to deploy conscious metacognitive inferences which might rely on linguistic and conversational experience that children do not develop until the age of four when they have become experienced verbal communicators.

An alternative interpretation is the ignorance interpretation, which comes in two versions. Southgate, Senju and Csibra (2007) argued that infants in Onishi and Baillargeon's study might have attributed only ignorance rather than a false belief to the agent, in which case children might follow the rule "ignorance means, you get it wrong" (Ruffman, 1996; Saxe, 2005). Based on this interpretation, infants might expect an ignorant person to err, and thus, search in the empty location. This would imply that infants do not keep track of information that had been perceptually available to the agent in familiarization trials, but simply notice what the agent had last seen happening. Consequently, it is possible that they might have only differentiated between a knowledgeable and an ignorant agent and applied a rule. Wellman (2010), too, favours an ignorance interpretation and comes to the same conclusion. He notes that looking time studies (violation of expectation) can only show that infants appreciate others being aware (knowledgeable) or unaware (ignorant) of a certain event. The fact that infants looked longer at belief-incongruent reaches merely shows that they did not expect this to happen. However, it does not show that infants did expect a belief-congruent reach. In other words, violation of expectation methods can not differentiate between ignorance and false belief (see also Hood, 2004).

Perner and Ruffman (2005) do not believe that infants are capable of mental state ascription at all, and hence disregard both the ignorance and false belief explanations. They propose an alternative interpretation according to which there is no need to assume that infants understand that mind mediates behaviour. They indicate that the looking time data can be explained more parsimoniously by either association (actor-object-location associations) or by applying innate behavioural rules (people look for objects where they last saw them). For example, the longer looking times for belief incongruent reaches in Onishi and Baillargeon's study might be due to the formation of a new combination of an actor-object-location association, since the combination of elements in incongruent test trials always deviates from those shown in previous trials. Based on this interpretation, infants' processing of others' actions is merely perceptual and does not involve a deeper mental understanding. They further argue that a deeper mental understanding develops only later through enculturation into a language community.

These interpretations vary in the extent to which they grant infants a mentalistic understanding of others' actions. Some assume that infants are born with an abstract psychological reasoning system, which allows them to attribute mental states to others without being aware, while others claim that the empirical findings are best explained by low-level processes such as association or rule use. Still others argue that a deeper mentalistic understanding hinges on linguistic experience. However, the common underlying assumption of these interpretations is that mental processes are hidden behind behaviour and somehow have to be inferred or cognitively constructed. Access to other minds is thought to be accomplished first and foremost through cognitive information processing from a third-person perspective. That is, infants are portrayed as being in a position of a detached observer, who comes to grips with others' inner motives for action through an inborn psychological reasoning system or the application of rules. Based on this view, infants' perception of others' actions entails either the processing of mere physical movements separated from its psychological meaning (Perner et al., 2005; see also Gergely, 2004, for a similar conception), or is thought to be implicit and run "off-line" by an abstract computational system (Scott et al., 2010; Leslie, Friedman & German, 2004). However, these interpretations focus exclusively on the mental architecture required for understanding the mind, but profoundly marginalize the role of social processes in the construction of this architecture (Carpendale & Lewis, 2010).

## 1.4. A second person approach to mindreading

When taking a second person approach to understanding others' minds, it is crucial to consider engagements and social interactions between individuals. "It [second person approach] sees active emotional engagement between people as constituting – or creating – the minds that each comes to have and develop, not merely providing information about each other" (Reddy, 2008, p. 27). Thus, the ability for infants to recognize others' mental states arises from embodied interactions with others instead of arising from passive third person observations, as is implied by information processing accounts of mindreading (Scott, et al., 2010; Perner et al., 2005; Perner 2010; Sirois & Jackson, 2007). This view emphasizes that interpersonal exchange is what bridges the gap between first person experience and third person ascription (Gallagher & Hutto, 2008; Herschbach, M., 2008; Fuchs & De Jaegher, 2009; De Jaegher & Di Paolo, 2007; Stawarska, 2009; Beebe, Knoblauch, Rustin & Sorter, 2005; Nahum, 2008; Stern, 2004).

A second person approach differs from pure information processing accounts in two important assumptions. First, in contrast to Perner and Ruffman's account, who consider infants' perception of others' actions as mere physical movements separated from its psychological meaning, second person approaches view the perception of others' actions as psychologically meaningful. That is, "[They see] minds as transparent within active, emotionally engaged perception" (Reddy, 2008, p. 26). For example, if we see an other's arm gesture, we don't experience its abstract physical qualities like timing, intensity and shape as such, but instead, we experience the 'how' of this very arm gesture. This may be 'forceful', 'threatening', 'inviting' or whatever inner state may be expressed by it. The abstract physical qualities of this arm gesture are rather the currency of our perceptual system (Stern, 1985; 2010). A great deal of other minds is therefore thought to be transparent to perception and manifested in others' embodied comportments (Gallagher & Zahavi, 2008; Gallagher, 2004, 2001; Reddy, 2008). Second, and most importantly, infants in second person approaches to mindreading, are seen as active participants rather than mere spectators (Hutto, 2008). Interpersonal interactions involve direct face-to-face connections in which both interactants are personally addressed. Being personally addressed entails the experience of being the object of others' attention in interpersonal interactions (Reddy, 2003; Stawarska, 2009). Further, it involves mutual responsiveness within the engagement. For example, it crucially matters whether someone's smile is directed at you in direct engagement as opposed to when it is directed at someone else. That is, I know you differently when I am directly engaged with you as compared to when I am merely watching you. "Not only is the experience of the other person more immediate and more powerful in direct engagement, but it calls out from you a different way of being, an immediate responsiveness, a feeling in response, and obligation to "answer" the person's acts" (Reddy, 2008, p. 27). Responsiveness is thus a key aspect of interpersonal engagement, which makes a second person approach especially valuable to the understanding of other minds. It highlights the notion that infants are not merely passive onlookers of others' actions, but instead active responders from the very beginning of their lives.

Towards the end of their first year, infants' begin communicating about objects in their environment and sharing attention with others (Bakeman & Adamson 1984). Their social interactions thus shift from being dyadic (which do not involve external objects) to being triadic (which do involve external objects). This shift is interesting for theory of mind research because it suggests that infants begin to take others' perspectives into consideration. The majority of studies examining the development of theory of mind abilities in infancy, however, have employed looking time methods. One major disadvantage of these methods is that they do not require the child to generate an overt response. As Scott et al. (2010, see also Wellman, 2010) rightly point out, in these tasks, there is no element of choice (response selection) on the infant's behalf. The possibility of choice, however, is particularly revealing in false belief paradigms since the relevant locations (location A versus location B) allow researchers to differentiate between self and other perspective. Interactive tasks that involve active engagement from the child are therefore especially informative. We can thus gain a clearer understanding of infants' developing theory of mind skills by looking into how infants spontaneously communicate within second person interactions in different belief contexts, for example through pointing (Stack & Lewis, 2008; Brune & Woodward, 2007).

### 1.5. Pointing in prelinguistic communication

Around nine to 12 months, infants begin to engage in triadic social interactions which are focused on external objects. Around the same time, they also begin communicating about objects using gestures such as showing and pointing. As Tomasello (2008) explains, the physical act of pointing by itself is meaningless. In order to understand why someone is pointing and to what they are referring depends crucially on the common ground that is shared between the communicator and the recipient. For example, if a person points to a bicycle, it is, without context, unclear to what that person is referring. The pointing gesture could refer to the bicycle as whole, its colour, its type or to only its tires. Without context, it would also be unclear as to why that person is pointing to the bike. It could be because she wants to steal it, because she had the same type of bike before, or perhaps to indicate that her friend, who owns that very bicycle, is somewhere nearby. In contrast, if it is mutually known between the communicator and the recipient that that very bike was recently stolen from the communicator, then the recipient would have no trouble interpreting the gesture. Thus, pointing involves three aspects: common ground (shared knowledge), a referential intention (to what the pointer is actually referring) and a social intention (the motive, or reason that someone is pointing). There are various social intentions underlying people's points, for example to share interest in objects, or to request objects. The focus of this thesis, however, is on informative pointing where one points with the underlying social intention to let the other person know something.

### 1.6. Infant studies using pointing

When interacting with another, infants keep track of what the person knows or does not yet know based on the information that was shared between them during contextualized episodes of joint-attentional engagement. This tracking of information is reflected in how infants comprehend others' verbal requests (Saylor et al., 2007; Moll et al., 2008; Grosse et al., 2010), how they comprehend others' pointing gestures (Liebal, Behne, Carpenter & Tomasello, 2009), as well as in their own production of pointing gestures (Liszkowski, et al., 2007; O'Neill, 1996). For example, in a recent study, Liebal, Carpenter & Tomasello (2010) showed that 18-month-old infants use shared experience to make communicative decisions. Infants in this study played with two different adults with one set of toys each (ducks and bears). Infants were then shown two photographs depicting a duck and a bear in the presence of one of the two adults. Infants selectively choose to point and communicate about the specific toy with which they had prior mutual experience playing with as opposed to the other toy which was played with by the other adult.

Importantly, a number of interactive studies using pointing show that infants from their first year onwards tailor their communicative acts to what others do or do not know (Saylor and Ganea, 2007; Moll, Richter, Carpenter & Tomasello, 2008; Grosse, Behne, Carpenter & Tomasello, 2010; Liebal, Behne, Carpenter & Tomasello, 2009; Liszkowski, Carpenter, & Tomasello, 2007; O'Neill, 1996). Such studies also show that infants are motivated to help others by providing them with relevant information. For example, by 12-months, infants use the pointing gesture selectively to help an adult find a sought-after object (Liszkowski, Carpenter, & Tomasello, 2008). In this study, infants informed an adult about an object's location, depending on whether or not the adult had seen the object disappearing. Infants only pointed to the object when the adult did not see the object disappearing (and was therefore ignorant about the object's actual location).

Recent work by Southgate, Chevallier and Csibra (2010) and Buttelmann, Carpenter, and Tomasello (2009) suggests that 18-month-old infants also respond appropriately to an adult who held a false belief about the location of a toy. In the study by Southgate et al. (2010), infants were familiarized with searching for one of two toys in two different boxes. The toys were swapped in either the adult's presence or in the adult's absence and, upon return, the adult pointed at one box and verbally requested the toy. Results revealed that, when the adult had witnessed the swap, infants consistently selected the toy contained in the box to which the adult had pointed. However, when the adult had not witnessed the swap, infants chose the toy in the other box. In a similar design, Buttelmann et al. (2009) showed that 18-month-old infants responded differently to an adult depending on whether he had or had not witnessed a toy's swap. After playing briefly with the infant, an adult introduced a novel toy and put it in one of two boxes. The toy was then moved to another box, in either the presence or absence of the adult. Subsequently, the adult went to the - now-empty - box and tried but failed to open it. In response to the adult's failure, infants opened the - now-empty - box when the adult had witnessed the transfer, but opened the other box when the adult had not witnessed the transfer. Only when the adult had not witnessed the transfer, did infants interpret the adult's action as being based on a false belief.

Taken together, previous research demonstrates that infants in their second year help others appropriately by taking into account what others know or do not know when responding to their actions. Two recent studies (Southgate et al., 2010 and Buttelmann et al., 2009) even suggest that 18-month-old infants also respond appropriately to an adult who held a false belief. However, one crucial aspect has not been addressed in previous research. That is, the *prediction* of others' actions based on their beliefs. The prediction of others' actions in belief contexts is considered important evidence of belief ascription (Dennett, 1978). However, in all of the looking time studies (see above) and interactive studies (Southgate et al., 2010; Buttelmann et al., 2009; Liszkowski et al., 2007, 2008) on infants' mental state understanding, infants were not required to predict an adult's mistaken action. Instead, infants were required to respond *after* a mistake was already made, for example, a mistaken request (Southgate et al., 2010), or a failed attempt to open a box (Buttelmann et al., 2009). Generating a response to a mistaken request or a failed attempt, however, is said to be easier for infants than predicting and anticipating a mistaken action. In the former case, infants are confronted with a situation where the adult's goal and belief is explicitly presented to the infant, for instance, when trying to open a box in Buttelmann et al.'s study, whereas in the latter case, infants need to predict and anticipate the adult's goals and beliefs. That is to say, when responding to someone's action mistake, infants are required to reason from this particular action mistake to goals and beliefs (backward reasoning). In contrast, when predicting someone's action mistake, infants are required to reason from goals and beliefs to actions (forward reasoning). Previous verbal false belief studies indeed suggest that predicting action mistakes is more demanding than explaining action mistakes (Bartsch & Wellman, 1989; MacLaren & Olson, 1993; Ruffman & Keenan, 1996). For example, in Bartsch & Wellman's (1989) deceptive container task, 3-year-old children were shown that Band-Aids were not actually in the Band-Aid box, but instead, in another similar box. Children were then introduced to a puppet who wanted a Band-Aid. In the prediction condition, children were asked to predict where the puppet would search. In the explanation condition, children first witnessed the puppet searching in the Band-Aid box, after which they were asked to explain why the puppet had searched in that particular box. Results revealed that only 25% of the children succeeded at predicting the mistaken action, whereas 71% succeeded at explaining the mistaken action.

To date, only one study (Southgate, Senju & Csibra, 2007) has shown the prediction of adults' mistaken actions by infants. However, this study used anticipatory eye-tracking methods as opposed to an interactive setting and, thus, did not measure infants' ability to use this knowledge when interacting with others. Furthermore, the only two studies that did investigate how infants use their knowledge about others' mental states (Southgate et al., 2010 and Buttelman et al., 2009) did not require infants to predict others' actions. Therefore, to date, it remains unclear whether infants can actively predict and anticipate others' belief-based actions in contextualized interactions. Furthermore, it is also important to consider the fact that infants in Southgate et al. (2010) and Buttelmann, et al. (2009) were trained beforehand on the behaviour that was being tested. Specifically, in Southgate et al. (2010), infants were only tested if they succeeded in choosing the correct toy that the adult requested twice in a row from each of the two boxes. Infants who did not succeed in the training phase were either excluded from testing (Southgate et al., 2010) or prompted to respond to another experimenter (Buttelmann et al., 2009). Therefore, the results of these studies are based on a selected group of infants who were taught, beforehand, how to respond in the test phase. Admittedly, this does not necessarily affect the observed differences between conditions, however, it also does not test the *spontaneous* usage of infants' mindreading abilities.

The current thesis attempts to deal with the shortcomings of previous research discussed above and investigates whether infants in their second year predict and anticipate others' belief-based actions and spontaneously communicate relevant information through pointing. In each of the three studies compiling this thesis, infants were required to anticipate the experimenter's actions. That is, the frequency of infants' pointing gestures was measured in the period before the adult acted in accordance with her belief. In addition, infants were never trained to point for the adult, nor were they familiarized with the procedure. Infants' responses were thus completely spontaneous and based on their situated understanding of the events.

## 1.7. Outline of the thesis

The next three chapters report on interactive studies examining infants' ability to use their sensitivity to others' belief-based actions. All three studies used pointing as a measure of infants' communicative responses. Chapter 2 reports on a study that investigated whether 18- and 24-month-old infants correct an adult who is mistaken about the location of an object in anticipation of her searching in the wrong location. The study presented in Chapter 3 asked whether 12- and 18-month-old infants inform an adult about the reappearance of an aversive object in anticipation of her encountering it again. Chapter 4 reports on a study that combined aspects of the studies presented in Chapters 2 and 3. This study investigated whether 18-month-old infants inform an adult differently about two contaminated locations depending on her holding a false belief or her being ignorant about the location of her toy. Finally, Chapter 5 summarizes the three studies and integrates their findings into the literature discussed in the first chapter. I conclude by situating the current findings into recent theoretical proposals offered by both psychologists and philosophers.

# CHAPTER 2

## 18- and 24-month-old infants correct others in anticipation of action mistakes

Based on:

Knudsen, B. & Liszkowski, U. (2012). 18- and 24-month-old infants correct others in anticipation of action mistakes. *Developmental Science,* **15***(1)*, 113-123.

**Abstract**

Much of human communication and collaboration is predicated on making predictions about others' actions. Humans frequently use predictions about others' action mistakes to correct others and spare them mistakes. Such anticipatory correcting reveals a social motivation for unsolicited helping. Cognitively, it requires forward inferences about others' actions through mental attributions of goal and reality representations. The current study shows that infants spontaneously intervene when an adult is mistaken about the location of an object she is about to retrieve. Infants pointed out a correct location for an adult before she was about to commit a mistake. Infants did not intervene in control conditions when the adult had witnessed the misplacement, or when she did not intend to retrieve the misplaced object. Results suggest that preverbal infants anticipate a person's mistaken action through mental attributions of both her goal and reality representations, and correct her proactively by spontaneously providing unsolicited information.

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## 2.1. Introduction

Much of human communication and collaboration is predicated on making predictions about others' actions. Predicting others' actions enables one to interact rapidly and in accordance with others' actions before these are executed. Many animals exploit others' actions for their own benefit, as it were with Machiavellian-like intelligence (Byrne & Whiten 1988; Hare & Tomasello, 2004). However, humans use their action predictions also to help others avoid mistakes and mishaps. For example, if you see your friend parking her car in the parking fee zone in front of your house you may anticipate her going to the parking meter and buy a ticket. However, if you know that the parking meter broke that very morning, you might spontaneously help her and indicate another parking meter to spare her walking to the broken one and loosing money. The current paper investigates the ontogenetic roots of what we call 'anticipatory correcting' and asks when children begin to intervene helpfully and correct a person in anticipation of her acting mistakenly, that is, before she initiates an action that will lead to a mistake or mishap.

Predicting others' actions is based on 'theory-of-mind' skills (Premack & Woodruff, 1978) which are most evident in the case of predicting others' action mistakes (Dennett, 1978). Cognitively, the prediction of action mistakes requires both an understanding of a person's goal prior to her acting ('prior intentions', Searle, 1983; e.g., getting a parking ticket); and an understanding of her incorrect representation of reality that will lead her to act mistakenly (e.g., going to a broken park meter). Both of these mental attributions are necessary and neither of them alone is sufficient to predict a mistaken action. In addition, predicting a goal-oriented action before it is initiated is based on some form of 'forward' inferences from the actor's mental representations to her action goal. This is different from the case of observing and making sense of completed, or ongoing goal-oriented actions, which is based on 'backward' inferences from the observed goal-oriented action to the actor's mental representations (e.g., Bartsch & Wellman, 1989).

Most infant studies have investigated social-cognitive attributions of goal and reality representations separately (for studies with verbal children, see also Leslie, German & Polizzi, 2005). For example, infants around their first birthdays interpret a completed action in terms of its goal, as revealed by habituation studies (Woodward, 1998; Gergely, Nadasdy, Csibra & Biro, 1995) and imitation studies (Carpenter, Akhtar & Tomasello, 1998). But infants also infer the unseen goal of an ongoing action. For example, in action-based imitation studies infants reproduce the unseen goal of a failed action attempt at 18 (Meltzoff, 1995) and 12 months of age (Nielsen, 2006). Further, a recent looking-time study shows that 12-month-olds will look longer at a single chasing event of two balls when it does not result in a catch than when it does (Southgate & Csibra, 2009). In other designs using multiple exposures to a goal-directed action, an eye-tracking study shows that 12-month-olds will look ahead of time to a bucket to which a human hand is transferring an object, but not when the object moves self-propelled (Falck-Ytter, Gredebäck & von Hofsten, 2006). And an EEG study of sensorimotor activation reveals that 9-month-olds are sensitive to others' goals during the online observation of a goal-directed grasping action (Southgate, Johnson, El Karoui & Csibra, 2010).

Around 12 months of age infants thus infer a goal when watching an ongoing action that is directed towards an occluded or unreached goal. Presumably, infants infer the unseen goal of an ongoing, goal-oriented action through backward reasoning from the ongoing action to the actor's goal representation (Gloss: "What is she doing? She must be trying XYZ"). It is less clear to what extent infants also make 'forward' predictions from an actor's goal representation to her action before it is directed towards a discernable goal. To do so, infants must know something about another's goal prior to the goal-directed action. An imitation study shows that 2-year-old children indeed consider others' *prior* intentions when observing an ongoing action demonstration. In the study, 2-year-olds understood the goal of an ongoing action demonstration in terms of what the demonstrator had done or intended to do *before* she demonstrated the to-be-copied action (Carpenter, Call & Tomasello, 2002; see also Southgate et al., 2009). Though based on backward predictions, the study shows that at least by 2 years of age children are sensitive to others' prior intentions, a necessary prerequisite for anticipatory correcting.

However, to predict that a person will act erroneously one also needs to consider the person's epistemic representation of reality. Recent looking-time studies suggest that infants in their second year of life are sensitive to another's epistemic relation to the world when interpreting her ongoing action. Infants will look longer at psychologically implausible events, for example when an actor reaches for an object in one of two locations that is incongruent with her last information about the object's location, whether she obtained the information through visual observation (Onishi & Baillargeon, 2005; Southgate, Senju & Csibra, 2007), communication, (Song, Onishi, Baillargeon & Fisher, 2008) or manual exploration (Träuble, Marinović & Pauen, 2010; for a recent overview see Baillargeon, Scott & He, 2010). Since violation-of-expectation studies require recognition of "after-the-fact incongruent events" (Keen, 2003, cited in Southgate et al. 2007) and are presumably based on backward inferences, Southgate et al. (2007) investigated anticipatory gaze shifts to test whether children also make forward predictions about an actor's action based on her representations of reality. In their eye-tracking study 25-month-old children were first trained with a discriminative cue to make a gaze shift to one of two doors (the doors lit up and a sound occurred) through which an actor subsequently reached to retrieved an object from a box in front of it. 61% of the 2-year-olds succeeded in making prospective gaze shifts at training and test. At test, after the discriminative cue, a significant majority of these children looked at the door through which the actor was about to reach for the object where she had last seen it - even when the object had been moved to the alternative box and was then removed altogether from the scene. The study thus shows that 2-year-olds engage in 'forward' reasoning from epistemic states to actions that have not yet been executed. With regard to anticipatory correcting, current research thus suggests that at least each of the two cognitive prerequisites, that is forward inferences about others' actions from goal representations and reality representations are present around 2 years of age.

Another question, however, is whether infants are able and motivated to use their forward action prediction skills productively to help others avoid prospective mistakes. Previous research has suggested that children use the cognitive skills productively in guiding their own actions only around age 4 when they begin to lie to others (e.g., Talwar & Lee, 2008) and become sensitive to misinformation (Sperber et al., 2010). When lying, one has to consider a person's prior goal and then induce an incorrect representation of reality, in anticipation of this incorrect representation leading the person to pursue her goal incorrectly and thus act mistakenly. But since human communication is truthful and cooperative by default and lying is the exception, it is entirely possible that before higher-order deceptive and competitive motives emerge, children make and use predictions of action mistakes to help others in collaborative interactions.

*2. 18- and 24-month-old infants correct others*

Recent studies reveal that infants are indeed motivated to help an adult who encounters a problem. For example, in the second year, infants will empathically help an adult who expresses sorrow over the loss of a toy (e.g., a broken teddy) by compensating the loss with a duplicate toy (Bischof-Köhler, 1991). And 18-month-olds will instrumentally help an adult who expresses dissatisfaction and struggles in attaining a goal by assisting in her task (e.g., open a door or box; Warneken & Tomasello, 2006). Further, 18-month-olds also seem to tailor their instrumental helping to the adult's epistemic relation to his goal. In a recent study (Buttelmann, Carpenter & Tomasello, 2009), infants were first trained how to open a box. At test, 64% of the 18-month-old infants who did not fuss then helped an adult who tried effortfully to open one of two boxes. In one condition, the adult had not witnessed that a toy had been swapped from one to the other box. In that condition, the children who helped in reaction to the adult's difficulty mostly opened the *other* box to retrieve the toy. The spontaneous helping response was moderately pronounced in that study, given that the behavior had been practiced just before. However, the cognitive interpretation that those infants who helped did so by considering the adult's representation of reality has recently been corroborated in a similar study (Southgate, Chevallier, & Csibra, 2010). In that study, 17-month-olds had to comply with an adult's request to retrieve one of two objects that were each in a box. First, infants practiced to retrieve a toy from a box when the experimenter requested it. At test, when the adult had not witnessed a swap of the objects and now requested an object by pointing to a box, the significant majority of infants retrieved the object from the *other* box. Although the study did not involve prosocial helping but compliance with a request, it supports the cognitive interpretation of previous looking time studies and suggests that infants interpret and react appropriately to an adult's mistaken action by reference to her representation of reality.

However, anticipatory correcting is based on the usage of forward predictions and a motivation to help others spontaneously, that is, before help is solicited. One troubling aspect of the previous helping studies is that infants always reacted *after* a problem or mishap had occurred. Thus, it is possible that infants reacted either to the adult's request for help (possibly as part of general compliance, e.g., Kärtner, Keller & Chaudhary, 2010), or directly to remedy the aversive situation (e.g., Preston & de Waal, 2002). However, anticipatory correcting as illustrated in our example requires intervening *before* any problem has yet occurred. It is possible that this kind of proactive helping is especially common in communicative acts, for example when warning others (Knudsen & Liszkowski, 2010), or informing them about changes that are relevant to future behaviors. Recent studies have shown that 12-month-olds indeed help an adult who searches for an object by informing her through communicative pointing (Liszkowski, Carpenter, Striano & Tomasello, 2006), more so when the adult has not seen the object than when she has (Liszkowski, Carpenter & Tomasello, 2008). However, in these studies, too, the adult was explicitly searching for an object and expressing some kind of puzzlement and frustration, so that it is entirely possible that infants simply complied with the request for information, or in an effort to remedy the problem. It is less clear whether infants would spontaneously help an adult who is not yet in problems by communicating to him relevant information. Such kind of intervening would not only constitute evidence for a spontaneous behavioral usage of forward action predictions. It would also corroborate theories of altruism in infancy (Warneken & Tomasello, 2009).

*2. 18- and 24-month-old infants correct others*

In the current study we investigated whether 18- and 24-month-old infants would correct an adult communicatively with a non-verbal pointing gesture when she was about to commit an action mistake. In particular we were interested whether such anticipatory correcting would occur fully spontaneously and be based on an integration of both the adult's goal representation and her representation of reality. We designed an interactive paradigm and manipulated independently both these factors. To manipulate the adult's prior intention, infants first watched an adult either enact her intention to find an object in a set of containers (*correct action* condition; *mistaken action* condition) or clean these containers (*different action* condition). In both cases she found an object and then left the scene. To manipulate the adult's representation of reality, a second experimenter subsequently changed the location of the object either in the absence (*mistaken action* condition; *different action* condition) or presence (*correct action* condition) of the adult. At test, the adult re-entered without discerning which container she would approach.

Based on the reviewed research we expected that infants would be motivated to help and intervene spontaneously to correct the adult *before* she would act mistakenly or display any signs of discomfort or problems. We expected that infants would intervene selectively by integrating *both* her goal representation and her representation of reality. We thus predicted that infants would point to the object's new location only when the adult intended to retrieve the object but had an incorrect representation of its location (*mistaken action* condition). In contrast, infants should not point to the object's new location in the *different action* condition, when the adult had an incorrect representation of the object's location but pursued a different goal. And infants should not point to the object's new location in the *correct action* condition, when the adult had a correct representation of the object's location and intended to retrieve it. Since we were interested in infants' truly spontaneous, action-based usage of action predictions, we did not administer any pre-training on pointing, informing, helping, or any other additional inclusion criteria. In addition, since we wanted to investigate 'forward' action predictions we were careful to test infants' behavior while the adult's action was still ambiguous, that is before it was apparent in the adult's orienting and reaching behavior on which container she would act.

## 2.2. Method

*Participants*

Forty-eight 18-month-olds (24 girls, 24 boys; M=18;10, range=17;28-18;27) and 16 24-month-olds (8 girls, 8 boys; M=24;14, range=24;9-24;28) participated in the study. Infants were recruited from a database of parents who volunteered to participate in infancy research. Seven 18-month-olds and six 24-month-olds were excluded because of fussiness (10), experimenter error (2), or parental interference (1).

*Set-up & Materials*

The testing room measured 4.60x4.60m (see Figure 1). Eighty centimetres to the side of the table a room-divider partitioned off 1m of the room. Two cameras recorded the infant and two cameras recorded the experimenter. Two sets of four identical opaque containers were used. They were equally spaced across the table on E1's side, approximately 70 cm away from the infant. For the 24-month-olds an additional two sets of containers were used. One novel object was used in each trial. For the 18-month-olds these were (i) a white plastic lid with yellow tape and (ii) a piece of a sponge. For the 24-month-olds, two additional objects were (iii) an O-shaped and a (iv) trapeze-shaped curtain holder.

*Procedure*

Infants sat on their parents' lap at a table facing the experimenter (E1). A second experimenter (E2) hid behind the room-divider. Parents were instructed to remain silent and not to interfere. The 18-month-olds were randomly assigned to one of three conditions. Each condition consisted of 2 trials which were separated by brief play. Each trial consisted of three phases. Each trial began with E1 lining up the four containers of a set on her side of the table. The order of container sets was counterbalanced across participants. Either the far left or the far right container contained one of the novel objects. The order alternated and was fully counterbalanced.

*Context-phase*: In the *mistaken action* and *correct action* conditions, E1 searched for the object. She opened the first container, showed it to the infant and said with mild disappointment: "No, it's not in here. Hmm, where could it be?" She proceeded in the exact same manner with the other containers. When she found the object in the last container, she said excitedly: "Hey! Here it is! That's neat!" In the *different action* condition, instead of searching, E1 cleaned the containers and then attached a sticker. She opened the first container, showed it to the infant and said: " I clean it." She wiped out the container and said "Look, what I do" and she marked the container with a small sticker to signal that she was done. When she found the object in the last container she acted surprised and said: "Hey! There's an object! That's a surprise!" In all three conditions, E1 then held up the object, pretending somebody had knocked at the door, and said that she had to leave quickly. She put the object back into the container making sure infants watched, stood up, tapped on the container and said she would be right back to continue.

*Switch-phase*: E2 appeared from behind the room-divider in a slightly conspicuous manner, greeted the infant and took the object out of the container, held it up and said "Oh, look". She alternated gaze between the door and the infant and said "Look! I'm putting it in here". She put the object inside the container on the opposite side, alternated gaze between the door and the infant, showed the object again and placed it back into the new container. Then she hid again behind the room-divider and E1 re-entered the room. In the *correct action* condition E1 re-entered the room earlier, stood at the door, and E1 and E2 greeted each other in a friendly manner saying “hello”. When E2 retrieved the toy she also called E1 and said "[E1's name], look!". When E2 put the object into the new container she also said to E1 "Look [E1's name], I'm putting it in here." E1made two steps towards the table to demonstrate that she witnessed where the toy was going, and said "Ah, ok!" alternating gaze between the new container and the infant. Then, E1 stepped back again to close the door and waited there to begin the test phase. E1 and E2 said goodbye to each other and E2 hid behind the room divider.

*Test*: The test phase took about 30 seconds and began with E1 standing at the door. In a predetermined and timed sequence she first said: "Good. Shall we continue playing?" and then approached the table steadily on an L-shaped path, walking confidently but never discerning which box she would approach, stopping twice on two predefined spots (see Figure 1). She first walked about 2 meters in parallel to the table, stopped briefly, looked at the infant and said "Okay, let's go on", and then turned to approach the table perpendicularly for another two meters, stopped again, looked at the infant and said again "Okay, let's go on." The test phase ended as soon as E1 had sat down and before she lifted her arms to reach for one of the containers. If the infant pointed during this period, E1 looked at the infant and said "Yes", but continued her predetermined and timed sequence. Only data obtained during this anticipation period were analyzed. Trials ended with E1 acting on the container congruent with her goal and reality representation by either putting a sticker on the empty container (*different action* condition), or retrieving the toy (*correct action* condition). In the *mistaken action* condition, if infants had not pointed, E1 first reached for and opened the now-empty box, showed it to the infant and said "Huh? How is this possible? It is empty!" (Search phase 1). If infants did not point, E1 continued "Where is the toy? [name infant], do you know where the toy is?" (Search phase 2). If infants had not pointed, E1 always found the object in the course of putting away the containers and said "Ah, look! Here it was!"

The 24-month-olds were tested after completion of the study with the 18-month-olds in an attempt to test for an increase in performance in the *mistaken action* condition and to replicate findings in a within-subject design. Since we expected infants would become restless after 4 trials, we administered only the *mistaken action* and *correct action* conditions with order fully counterbalanced.

*Coding and reliability*

Index-finger pointing was coded by the first author if it occurred during the test phase with the arm and index-finger either fully or half extended towards the current or previous locations of the object, or the room-divider. None of the points were addressed to the mothers who sat still behind their infants. A second coder who was naive to the hypotheses of the study recoded infants' number of points in each of the two test phases of 28% of the infants in each condition. Inter-rater reliability was excellent, Cohen's Kappa=.92 for the 18-month-olds and Cohen's Kappa=.88 for the 24-month-olds. A manipulation check on the test phase was conducted by a third coder who was unaware about the purpose of the study. Videos of 15 18-month-olds and 5 24-month-olds were randomly selected and cut to the test phases. The coder judged in a two-alternative forced choice task whether E1 would approach the left or right container. For both age groups the coder was at chance in predicting the container (18-months-olds, binomial test, $p$=.362; 24-months-olds, binomial test, $p$=.824) with no significant differences between conditions (at each age respectively, $\chi^2$ (n=30) =.659; $\chi^2$ (n=20) =.370).

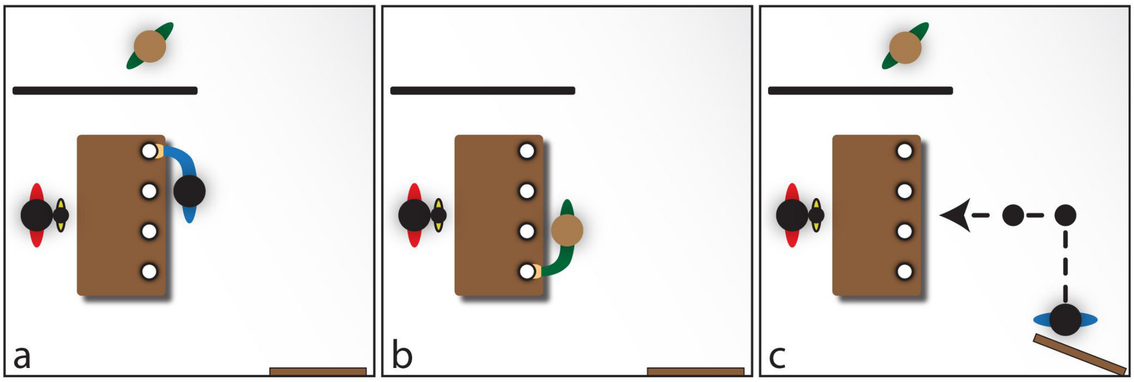


***Figure 1.*** Schematic depiction of the set-up and procedure. a): Context-phase. E1 either searches for an object which she finds in the last container (*mistaken action* and *correct action* conditions) or cleans the containers and accidentally finds the object in the last container (*different action* condition). E2 is hiding behind a room divider. b): Switch-phase. E2 places the object into the container on the opposite side, either unbeknownst to E1 (*mistaken action* and *different action* conditions) or while E1 is watching (*correct action* condition; not depicted here). c): Test. E1 enters the room and walks in a predefined L-shaped path, first in parallel to the table (2m), then slowly approaching the table (2m).

## 2.3. Results

The left panel of Figure 2 shows significant differences in the mean number of points across conditions, $F(2,45)=5.44$, $p$=.008. Following our predictions, planned LSD post-hoc tests (one-tailed, based on the pooled standard deviation of the ANOVA) revealed that 18-month-olds pointed significantly more to the object's new location in the *mistaken action* condition compared to the *correct action* or *different action* conditions, respectively, mean difference=.531, $p$=.005, Cohen's $d$=.782 and mean difference=.594, *p*=.002, Cohen's *d*=.939[1]. The left panel of Figure 3 shows that on the individual level significantly more 18-month-olds pointed at least once to the new object's location in the *mistaken action* (7/16) than *correct action* (1/16) or *different action* (1/16) conditions (Fisher's Exact tests, both *p*'s=.019). There were no significant differences between first and second trial performance, not with regard to the mean number of points (Wilcoxon, p=.931) nor with regard to the number of infants who pointed (McNemar, p=1). Although there were no differences across the two trials, when looking at the first trial only, the pattern of individual performance remained similar. It approached significance between the *mistaken action* and *correct action* conditions (Fisher's Exact tests, *p*=.086), and was significant between the *mistaken action* and *different action* conditions (Fisher's Exact tests, *p*=.022).

Additional analyses revealed little pointing to the object's previous location (*mistaken action* condition, M=.156, SD=.507; *correct action* condition, M=.000; *different action* condition, M=.094, SD=.272) or the second adult's hiding place (*mistaken action* and *correct action* condition, M=.031, SD=.125; *different action* condition, M=.344, SD=.889), and no systematic differences between the conditions, thus further excluding alternative possibilities of what infants were doing when pointing. Finally, in the *mistaken action* condition, after E1 had reached for and opened the now-empty box, three additional infants pointed to the other (target) box (totalling 62.5% of all infants; two pointed in the first trial of search phase 1; one in the second trial of search phase 2).

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[1] A 2x2 ANOVA with Condition as between-subjects factor and Location (old vs. new) as within-subjects factor revealed a significant interaction effect between Condition and Location, $F(2,45)=3.198$, $p = .025$. Infants pointed more to the new location than to the old location in the *mistaken action* condition ($t(15) = -1.959$, $p=.035$), but not in the *correct action* or *different action* condition (both, $t(15)=-1$, $p=.33$). An ANOVA comparing pointing towards the old location between conditions revealed no significant differences, $F(2,45)=.896$, $p = .415$.

*2. 18- and 24-month-old infants correct others*

At 24 months, more than half of the infants exhibited the target behavior in the *mistaken action* condition. Results were replicated in a within-subject design, see right panels of Figures 2 and 3, for both number of points ($t(15) = 3.72$, $p = .001$, Cohen's $d = .794$) and number of infants (McNemar, $p = .035$). Further, in the *mistaken action* condition, after E1 had reached for and opened the now-empty box, two additional infants pointed to the other (target) box (totalling 81% of all infants; both pointed in search phase 1).

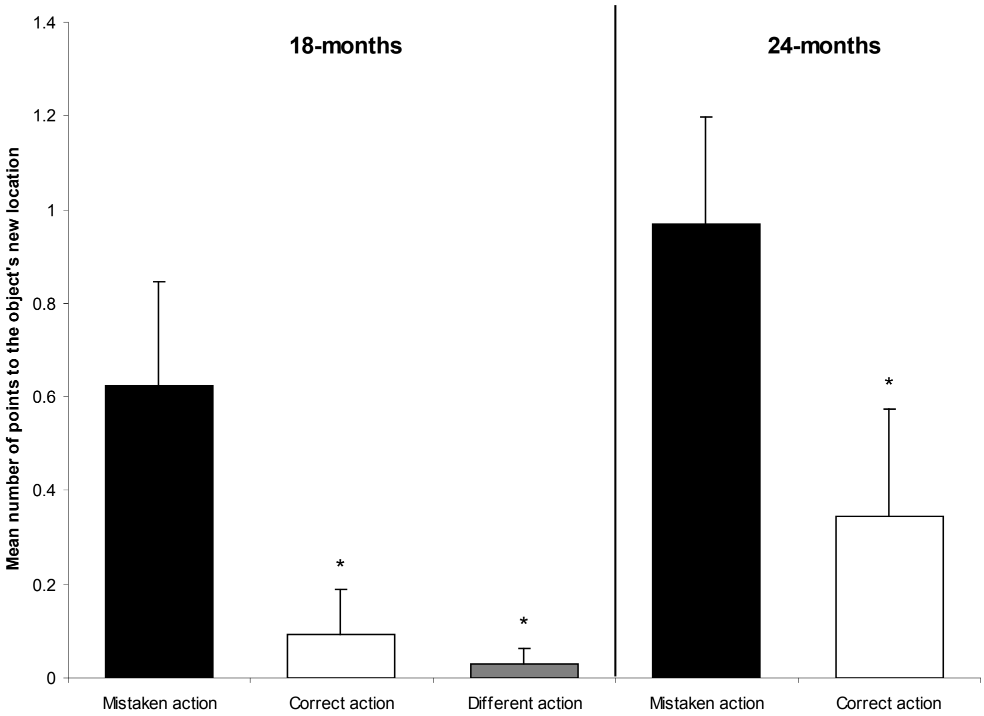


***Figure 2.*** Mean number of points per trial to the target container. 18-month-olds were tested in a between-subject design (left panel), 24-month-olds in a within-subject design (right panel). Stars indicate significant differences.

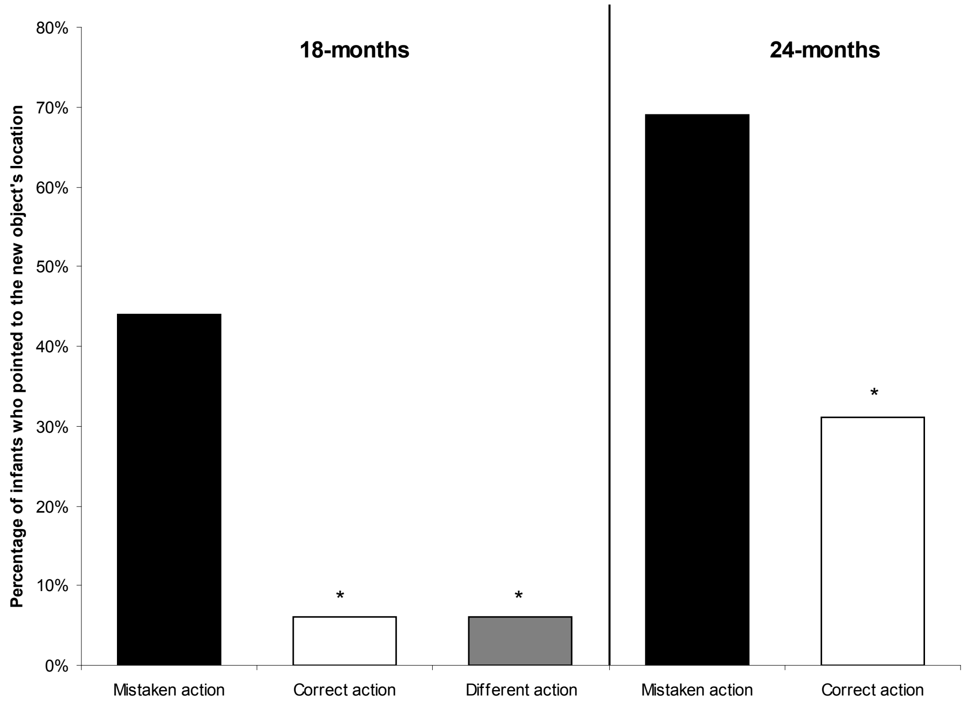


***Figure 3.*** Percentage of infants who pointed at least once. 18-month-olds were tested in a between-subject design (left panel), 24-month-olds in a within-subject design (right panel). Stars indicate significant differences.

## 2.4. Discussion

Infants used a non-verbal pointing gesture to correct an adult who was about to - but had not yet started to - act mistakenly and retrieve an object from a wrong location. Infants corrected the adult selectively depending on the adult's prior goal representation and her representation of reality. Such form of anticipatory correcting reveals an early manifestation of an unsolicited and spontaneous, behavioral usage of forward action predictions. The fact that infants helped even before an aversive situation, problem or request for help had occurred underscores infants' prosocial concern for others.

Infants pointed selectively in the *mistaken action* condition, when the adult had the goal of retrieving the object but an incorrect representation about its location. Importantly, infants provided the new information only when it was relevant to the combination of both the adult's prior goal representation and her representation of reality. When either of these factors was altered separately, for example when the adult had not witnessed the location change but intended to continue cleaning the container (*different action* condition), or when the adult intended to retrieve the object and had already witnessed the location change (*correct action* condition), infants did not point for the adult. Thus, infants integrated both goal and reality representations in generating predictions about the adult's next action. The integration of these two directions-of-fit (Searle, 1983) is a core aspect in the emergence of desire-belief psychology and theory of mind (e.g., Wellman, 1990).

At the same time the pattern of results excludes several alternative possibilities of what infants were doing when pointing. For example, if infants always pointed out for the adult what's new (e.g., Liszkowski, Carpenter & Tomasello, 2007) or what she had not witnessed (O'Neill, 1996), they should have pointed in both of the conditions in which the adult did not witness the location change. And they should have pointed to the second adult's hiding place when the adult had not seen her. Alternatively, if infants always wanted to comment on or request the next step in an action sequence, infants should have pointed to the object's new location irrespective of whether the adult had or had not witnessed the location change. Further, in the *different action* condition they should have pointed to the unmarked container where the action should continue. Finally, if infants pointed only egocentrically, they should have pointed in all three conditions equally, for example to request the object for themselves, or for other, non-communicative reasons. Instead, infants pointed only in the *mistaken action* condition, which is in accordance with the interpretation that infants corrected the adult in anticipation of her committing a mistake.

*2. 18- and 24-month-old infants correct others*

Infants pointed spontaneously and unsolicited, without prior training, before an action mistake of another person had happened. Previous looking-time studies have revealed infants' understanding of actions by measuring spontaneous increase of visual attention in response to erroneous actions (see Baillargeon, Scott & He, 2010), or by measuring anticipatory looking in cued choices about an expected action (at two years of age; Southgate et al., 2007). These studies reveal infants' information processing capacities (respectively, backward and forward inferences about others' mistaken actions). However, they did not address infants' behavioral usage of these cognitive skills. It is important to note that in the current study we neither excluded participants who did not show the target behavior, nor did we train participants to produce the target behavior, as has been the case in previous studies. For example, in the Buttelmann et al. (2009) study, the percentage of 18-month-olds who helped freely (64%) may be more comparable to our 24- than 18-month-olds. However, in that study (Buttelmann et al., 2009; see also Southgate et al., 2010), participants also received prior training on the target behavior. In the current study infants were not trained to point for the adult. It is possible that familiarizing infants with a searching and questioning adult beforehand, and engaging them in pointing activities, would have increased infants' pointing at test. However, this would have precluded measuring spontaneous behavior.

Another difference lies in the directionality of the predictions infants had to make in order to tailor their actions accordingly. In the previous action-based studies (Buttelmann et al., 2009; Southgate et al., 2010; Carpenter et al., 2002) infants presumably had to go through an inference of the kind 'she *is doing* X because she intends/believes Y'. In the current study, to correct someone in anticipation of an action mistake, infants presumably had to make an inference in the opposite direction:

'she intends/believes X and so *will do* Y'. For older, verbal children it has been suggested that the latter kind of 'forward reasoning' from others' goals and beliefs to their actions apparently emerges after 'backward reasoning' from others' actions to their goals and beliefs (Bartsch & Wellman, 1989; Robinson & Mitchell, 1995). When including infants' performance in the current study *after* the anticipation phase, that is when the adult was already acting mistakenly or expressing problems, target performance increased to 62.5% at 18 months (comparable to Buttelmann et al., 2009), and 81% at 24 months.

Beginning around 18 months of age (as conventionally indicated by the median age of emergence; e.g., Carpenter, Nagell & Tomasello, 1998), and developing throughout the second year, infants use forward inferences about a person's next action to spontaneously guide their own, uncued and unsolicited actions. Although results of the first trial only approached significance for one comparison for the 18-month-olds, it is more likely that this reflects reduced statistical power than that infants performance was based on procedural feedback of the first trial. First, there were no statistical differences in infants' performance between the two trials. Second, if anything, infants might have learned that the adult retrieved the object in the *mistaken action* condition anyway, which should have let them to point less in the second trial. The considerably large effect sizes and the within-subject replication at 24 months of age confirm the reliable and selective occurrence of the target behavior. The results suggest an increase in infants' anticipatory correcting over the second half of the second year of life, which is corroborated by Southgate et al.'s (2007) finding of predictive 'theory-of-mind' processing at 25 months of age. The developmental increase may reflect infants' increasing communicative competencies and experiences over the second year of life. Post-hoc inspections of the video recordings further revealed that some 24-month-olds (63%) also verbalized about the new object's location. The number of verbalizations about the target container, for example "Look here" or "In there", were more frequent in the *mistaken action* condition (72%) than in the *correct action* condition (28%), thus further supporting the interpretation that infants were communicating to the adult about the correct location of the object to spare her a mistake.

Recent research has revitalized the question whether chimpanzees (Call & Tomasello, 2008) and infants (Baillargeon et al., 2010) have a theory of mind. While traditional accounts accept convincing evidence for a representational theory of mind only from explicit, usually verbal false belief tasks (Perner, 1991; Carpendale & Lewis, 2004), other researchers have criticized the additional tasks demands and suggested to abandon the classic false belief task (Bloom & German, 2000; Roth & Leslie, 1998; Birch & Bloom, 2007). New implicit, looking-based tasks do not entail these additional demands like language and choice anymore, but researchers have usually maintained an interpretation in terms of 'false belief'. This interpretation has not remained uncontested. For example, some researchers have suggested two different theory-of-mind systems (Apperly & Butterfill, 2009), possibly operating on implicit versus explicit, or automatic versus conscious levels, the former being present in infancy, the latter developing well beyond the preschool period. Other alternatives to 'false belief'-based interpretations are that children expect a person to look for her object where she last saw or touched it (e.g., Perner & Ruffman, 2005), or attribute a lack of, rather than an incorrect representation of reality (e.g., Southgate et al., 2007; Wellmann, 2010). Most infancy studies to date acknowledge the possibility of an alternative interpretation of their data in terms of behavioral rules or ignorance (e.g., Onishi & Baillargeon, 2005, p.257; Baillargeon, 2010, p.33; Surian et al., 2007, p.583; Southgate et al., 2007, p.590; Soutgate et al., 2010, p.911; Buttelmann, 2009, p.341; Träuble, 2010, p.436), which suggests that the precise cognitive mechanisms of 'theory-of-mind' in infancy are not yet fully understood.

The current study investigated whether infants spontaneously use respective skills in guiding their own, unsolicited acting. We cannot rule out that infants' communicative actions were based on a general expectation that a person goes where she last saw an object, a general alternative interpretation for all change-of-location tasks. It is also at least possible that infants expected the person to do a mistake by attributing to her a lack of a representation, rather than an incorrect representation of reality. The latter account holds that children assume when a person doesn't know where an object is she will always err instead of getting it sometimes right by chance. However, studies pitting chance against error do not support this proposal in adults and children (Friedman & Petrashek, 2009) and in 18-month-olds (Scott & Baillargeon, 2009). Further, other studies have shown that infants keep track over time of what other people know (Moll, Richter, Carpenter & Tomasello, 2008; Saylor, & Ganea, 2007). It is reasonable to assume that infants kept track of what the adult knew also in the *mistaken action* condition and thus expected her to search in the container in which she had last seen the object. It is also important to note that the adult did not express any uncertainty or other signs of ignorance or search behavior as in previous studies (Liszkowski et al., 2006; 2008).

The current study neither tested infants' (visual) social-cognitive processing, nor children's (verbal) elaborations and theorizing about others' actions. Instead, it advanced a *usage-based* approach. Infants could freely choose to act or not in accordance with another's to-be-expected action, while the criteria for the kind of required forward action prediction were those typically used in verbal 'theory-of-mind' tasks with older children. Although even those verbal tasks have remained amenable to alternative rule-based interpretations, one argument in favour of a 'false belief' interpretation of those tasks is that children also exhibit spontaneous false-belief-based behaviors in a variety of other real-life situations when communicating and interacting with others. Similarly, to understand the scope of infant 'theory-of-mind', it is crucial to understand whether and how infants may use their putative social-cognitive skills. Previous research has shown that verbal children productively use forward predictions from goal and reality representations to others' mistaken actions when they begin to lie around age 4. In the current study, infants were given the chance to help an otherwise unfamiliar person in an unfamiliar setting. Helping is a primary aspect of human cooperative communication that logically precedes higher-order deceptive motives. Importantly, infants helped before the person even knew that she would need information. This finding provides new support for theories of altruism in infancy. In extension to previous findings (see Tomasello & Warneken, 2009), it is clear from the current design that infants did not simply react to an adult's expression of an emotional, instrumental or epistemic problem, a request for help, or in an attempt to directly remedy an aversive situation. Instead they helped proactively on the mental basis of an anticipated, not yet executed, action mistake. The type of proactive helping as revealed by anticipatory correcting is presumably mostly used for communication and primarily based on social-cognitive rather than empathic and sympathetic processes (for the latter, see Vaish, Carpenter & Tomasello, 2009). First, through communication one can coordinate with relatively little effort others' actions towards a shared goal and so achieve well-coordinated collaborations. Second, communication itself is a shared activity. Conversations require rapid predictions of others' turns in order to initiate one's own communicative act accordingly (de Ruiter, Mitterer & Enfield, 2006; Stivers et al., 2009). Conversations also require helping and correcting each other in maintaining a shared focus and common ground (e.g., Clark, 1996).

The usage-based approach of the current study reveals that infants are motivated to use action predictions productively in the service of unsolicited helpful collaborative interactions, several years before they begin to exploit their understanding to misinform and lie to others in competitive situation. Two other action-based studies (Buttelmann et al., 2009; Southgate et al., 2010) employed indirectly-elicited response tasks and revealed that infants react to another's erroneous action appropriately by helping or complying with a request, presumably through inferences from the ongoing goal-oriented action to the actor's misrepresentation of reality. The current study employed an elicitation-free action-based task and reveals that infants also spontaneously prevent others from committing a mistake, already before the respective object-oriented action is initiated, presumably through inferences from the actor's goal and reality representations to her expected action. Infants use these forward action predictions spontaneously and helpfully to communicate with others. We speculate that infants' behavioral usage of forward predictive 'theory-of-mind' skills emerges through, and is first put to service in uniquely human forms of collaborative communication.

# CHAPTER 3

## One-year-olds warn others about negative action outcomes

**Based on:**

Knudsen, B. & Liszkowski, U. (under revision). One-year-olds warn others about negative action outcomes.

3. One-year-olds warn others

**Abstract**

Warning others about unexpected negative action outcomes is a paradigm case of communicative helping and prospective action understanding. The current study addressed the ontogeny of warning in infants' gestural communication. We found that 12- and 18-month-olds (n=84) spontaneously warned an adult by pointing out to her an aversive object hidden in her way (*Problem* condition). In control conditions the object was either positive (*No Problem* condition) or the adult had witnessed its' placing (*Problem known* condition), which resulted in significantly less pointing. Results show that infants intervene spontaneously and in foresight through communication, in order to help others avoid a problem before it has occurred. These acts of warning are presumably based on an understanding of others' negatively defined goals (to avoid an outcome) and their incorrect representations of reality. The demonstration of warning in infants lends support to theories of altruism and social-pragmatic communication competencies before linguistic communication has emerged in earnest.

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3. One-year-olds warn others

### 3.1 Introduction

The ability to anticipate others' actions is a core aspect of successful human social interaction and communication. In most, if not all of our daily social activities, for instance, when navigating through traffic, action anticipations help us plan our own actions. But humans also use action anticipations to help others. For example, humans warn others spontaneously and altruistically of harmful things that should be avoided, like an approaching car, a hot object, or poisoned liquid in a falsely labelled bottle.

Social-cognitively, warning requires one to anticipate and evaluate a person's action outcome. First, one needs to understand the person's goal to avoid a certain undesired outcome in the course of her action. Second, one needs to understand that the person acts on a misrepresentation of reality which leads her inadvertently toward the undesired outcome. Motivationally, warning is predicated on a spontaneous prosocial motivation for helping and intervening, already before a problem has occurred. The communicative act of warning is thus premised on both the social-cognitive anticipation of a person's undesired action outcome and the prosocial motivation to use this understanding productively and intervene helpfully.

The ontogeny of spontaneous warning behavior is still unknown. Most relevant to this question is the finding that 18- and 12-month-olds help others communicatively by providing relevant information through informative pointing. For example, in response to a searching experimenter infants will help her by pointing to the sought-after object more often than to an irrelevant object (Liszkowski, Carpenter, Striano & Tomasello, 2006), and more often when she has not seen its new location than when she has (Liszkowski, Carpenter & Tomasello, 2008). These studies thus suggest that infants understand something about others' goal and reality representations, and are motivated to help by providing relevant information.

The cognitive interpretation of these studies is supported by recent looking-time studies. First, with regard to goal understanding, 13-month-olds look longer at a single event in which a goal-directed action does not result in the expected outcome than when it does, suggesting that infants infer unseen action outcomes (Southgate & Csibra, 2009). Second, with regard to understanding others' reality representations, infants in the first half of the second year look longer at action outcomes when these are incongruent with the agent's representation of reality than when they are congruent (Scott, Baillargeon, Song & Leslie, 2010; Träuble, Marinović & Pauen, 2010; Scott & Baillargeon, 2009; Song & Baillargeon, 2008; Surian, Caldi & Sperber, 2007; Onishi & Baillargeon, 2005). Anticipatory eye-tracking studies reveal more directly that infants indeed make predictions about others' actions. For example, 12-month-olds anticipate the location of an action outcome before it is achieved (Falck-Ytter, Gredebäck & von Hofsten, 2006), and by 25 months of age infants anticipate the location of an action outcome based on the actor's representation of reality that is guiding her action (Southgate, Senju & Csibra, 2007).

However, it is less clear whether infants also attribute to an agent the goal of *avoiding* an action outcome. Studies with older children suggest that when confronted with an understanding of others' representations of reality, understanding a negatively defined desire is somewhat more challenging than understanding a positive desire (Leslie, German & Polizzi, 2005). Further, a recent looking-time study suggests that 14-month-olds may not yet understand that an actor's action can be governed by the goal of *avoiding* a certain action outcome (Vaish & Woodward, 2010). In the looking-time study, infants were first familiarized with an actor attending and emoting either positively or negatively toward one of two objects. Then the actor reached for the attended or unattended object. Infants looked equally long at the events in which the actor reached for the attended object, irrespective of whether she had previously emoted positively or negatively about it. Results suggest that infants ascribe goals only on the basis of attentional cues. They may not yet understand negative emotions as a cue to the actor's intention to *avoid* a certain outcome, which is a necessary cognitive requirement for the act of warning.

With regard to the motivational interpretation of informative pointing, further studies on instrumental helping corroborate the interpretation that infants have a prosocial motivation. For example, 14-month-olds will help an adult instrumentally in attaining his goal when he encounters a problem in achieving the goal on his own (Warneken & Tomasello, 2007). Further, 18-month-olds will help an experimenter instrumentally when she mistakenly tries to retrieve a toy from a wrong location (Buttelmann, Carpenter & Tomasello, 2009). One caveat of these studies of instrumental and communicative helping (for empathic helping, see Bishof-Köhler, 1991), however, is that infants always reacted in response to a problematic situation, to an adult expressing difficulties, or to an adult's request for help. The studies thus did not test whether infants intervene spontaneously on the basis of an anticipated problem that has not yet occurred, which is a key motivational aspect of warning.

Taken together, previous findings on informative pointing and infants' social-cognitive processing suggest that the act of warning may be within infants' reach in their second year of life. Motivationally, it is still somewhat unclear to what extend infants will intervene fully spontaneously, without external response elicitation. Cognitively, it is still unknown when infants begin to understand others' goals of *avoiding* certain outcomes. In the studies on informative pointing infants always pointed to an object which the adult desired, with the intention that she would find it and approach it. When warning, however, one draws attention to an undesirable object with the intention that it should be avoided. Thus, one has to understand another's negative, not positive, desire for a particular object. To date it has not been addressed whether infants also point at negative, undesirable entities or events.

In the current study we investigated whether 12- and 18-month-old infants inform others about a prospective negative action outcome. We tested whether infants would anticipate others' undesired action outcomes based on goal and belief attributions, and be motivated to intervene on the basis of this anticipation. In three conditions, infants watched an adult act on a toy and accidentally bump into an object in the course of her actions. Subsequently, she always removed the object from the scene. Later another adult accidentally pushed the object back to its previous location. We manipulated the first adult's goal towards the object by altering its relevance for the adult's ongoing action: The adult emoted either positively surprised about the object, but the object was otherwise irrelevant to her action (*No Problem* condition), or she expressed distress and negative emotions (pain or disgust) about the object, clearly wanting to avoid it (*Problem* condition). In addition, we manipulated the adult's information about the location of the object. Either she did not witness that the second adult re-placed the object back to its original location (*Problem* condition), or she did (*Problem known* condition). At test the first adult re-entered the scene. We measured infants' spontaneous, uncued pointing behavior toward the object upon the adult's return. Previous research has established that infants point communicatively from 12 months of age (Bates, Camaioni & Volterra, 1979; Liszkowski et al., 2004; 2008). Based on the reviewed literature, we expected that infants would point out the aversive object for the adult in the *Problem* condition, when she wanted to avoid the object and had incorrect information about its location. However, they should point less in the *Problem known* condition, when the adult already knew about the object's location; and they should point less in the *No Problem* condition, when the object was irrelevant to her acting. We also coded for point accompanying negative emotional behaviors which may provide some further indication for the act of warning.

### 3.2. Method

*Participants*

Infants were recruited from a database of parents who volunteered to participate in infancy research. Forty-eight 18-month-olds (26 boys; M age= 18;27, range = 18;8-19;9) and 36 12-month-olds (17 boys; M age= 12;19, range = 12;7-13;3) participated in the study. Nine 18-month-olds had to be excluded: one in the *Problem before* condition for fussiness, five in the *Problem after* condition (three for fussiness, two for parental interference), and three in the *Problem known* condition (two for parental interference, one for fussiness). Two 12-month-olds had to be excluded, one in the *Problem* condition for fussiness, one in the *Problem known* condition because of technical failure. Five individual trials of the 18-month-olds had to be discarded: three in the *Problem before* condition (one for parental interference, two because of experimenter error), one in the *Problem after* condition, and one in the *No problem* condition (both for parental interference). Five individual trials of the 12-month-olds had to be discarded: three in the *Problem known* condition for fussiness, and two in the *No problem* condition for parental interference. Seven 12-month-olds participated only in three trials.

*Materials*

The right panel of Figure 1 displays four different, self-designed marble toys (35 x 47 x 15 cm). A marble track led to a dish on the right bottom of the toy. At the bottom middle of the toy was a horizontal transparent plastic tube with one opening to the left and one opening to the right. The right side of the opening led to the marble dish. All toys made interesting sounds when the marbles were rolling down, and they were covered up from the backside, so that E1 could not see through. One of four different objects was used for each marble toy: (i) a drain covered with red tape, (ii) a grey, crumpled-up tissue (iii) a plastic slice of a toy-pomegranate that was painted brown, and (iv) a small, plastic bag containing a black toy-substance..

*Set-up*

The left panel of Figure 1 displays the schematic set-up. Infants sat on their parents lap at a table in the back of a testing room (4.60 x 4.60 m). They faced E1 who sat on the other side of the table. The marble toy was placed on the infant's right side of the table, in front of E1 and approximately 65 cm away from the infant. A small opaque barrier (22 x 38 cm) was positioned on the infant's left side of the table. The entrances to the scene were at the front of the room to the infants' left and right. A room divider (2.00 x 1.45 m) about 80 cm to infants' left of the table partitioned off 2 x 1 m of the room. Behind the room divider hid E2 and watched the procedure on a video screen that was hooked up to four cameras providing full view on the entire room.

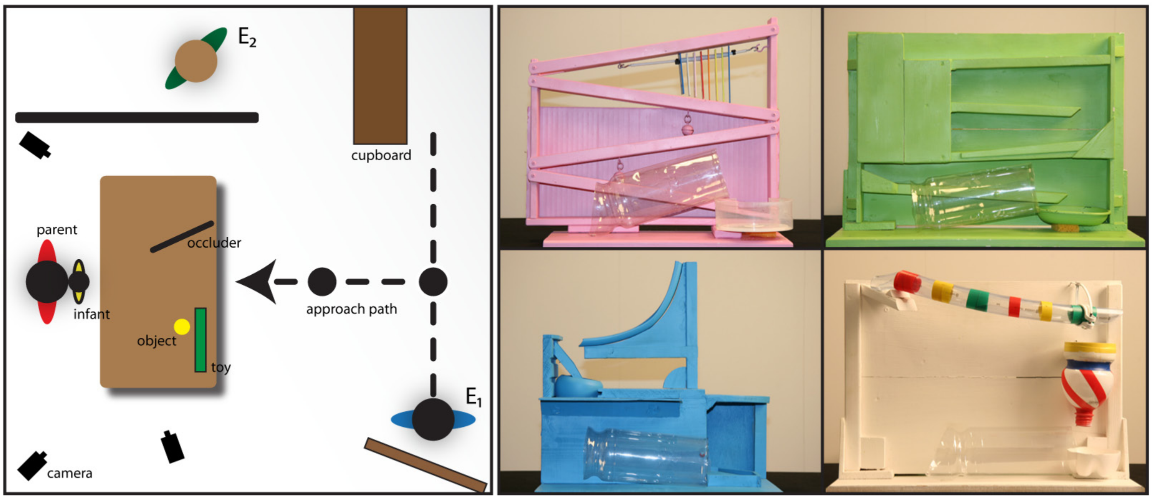


***Figure 1.*** Left panel: Schematic drawing of the set-up. An overhead camera that was mounted onto the ceiling right above the middle of the table is not depicted here. E1 sat with the parent and the infant across the table. E1 had a marble toy placed in front of her. E2 hid behind a room divider. During test E1 approached the table on a predefined approach path (entering via the door or appearing from behind the cupboard). Right panel: Marble toys, one for each trial. E1 reached around the toy from her right side through the tube to the dish containing the marbles. Objects were placed in front of the tube.

*Procedure*

Infants were randomly assigned to one of three conditions. All conditions consisted of 4 trials with a brief play break after two trials. Each trial included a demonstration phase, a switch phase and a test phase.

*Demonstration phase*: E1 put the marble toy on the table. The order of the marble toys was fixed across subjects (green, blue, white, pink; see right panel Figure 1). She said: "Let's play with this one. Look what I can do!" She inserted three marbles one by one and let them roll down the track into the dish. After she had inserted the last marble she said: "This is fun, let's play with it again". With her right hand she reached around the marble toy through the plastic tube to the dish with the marbles. As she was reaching, her hand bumped into an object that was lying in front of the tube. The order of objects was quasi-counterbalanced, with half of the subjects receiving the order of objects (i), (ii), (iii), (iv); the other half the order of objects (iii), (iv), (i), (ii).

In the *Problem* condition, E1 acted as if the object was either disgusting or hot (for two consecutive trials). The order was counterbalanced across participants. She emoted negatively with facial expressions of disgust or pain, saying: "Yak (Ouch)! What is this?" She pushed the object with the back of the hand to the middle of the table, saying with the same facial expression: "Yak (Ouch), this is disgusting (hot)! I need to put it away." Then she pushed the object behind the barrier, out of her - but not the infant's sight, and said with satisfaction "Well, now we can play again." With every comment E1 alternated gaze with the infant. For the 18-month-olds, we administered two variants of the problem condition to ensure that infants did not simply perceive the object as an obstacle for the experimenter to achieve her goal: In the *Problem before* variant (12 infants) E1 bumped into the object before she could retrieve a marble from the dish. In the *Problem after* variant (12 infants), she bumped into the object after she had already retrieved a marble from the dish. Since we did not find any differences between these variants (see Results), we administered in our follow-up experiment with 12-month-olds only the *Problem after* variant. The latter is a more stringent test of empathic rather than goal-oriented warning since the actor fulfills her goal of retrieving marbles and experiences the aversive situation only afterwards.

In the *No problem* condition, the procedure was the same as in the *Problem* condition. E1 emoted equally saliently but positively about the object with facial expressions of positive surprise, acting as if the object was either nice or soft (in two consecutive trials). She said with positive surprise: "Oh (Wow)! What is this?” She put the object in the middle of the table and said “This is nice (soft)! I can put it here." She took the object with her hands and put it behind the occluder. E1 established during the procedure that infants attended in both conditions to the salient object encounters and the object transpositions. Infants attended to these aspects equally since E1 addressed them directly and since it was the only thing that happened on stage.

All conditions continued with E1 retrieving and playing with one more marble. After that, she reached again around the marble toy to the dish but then interrupted her activity, pretending that she had to leave for a moment. She tapped on the marble toy and said "Oh, I have to leave. But we go on with it in a minute, okay?" Then she left the scene.

*Switch phase*: E2 appeared from her hiding place, greeted the infant and started to clean the table with a cloth. She accidentally bumped into the object lying behind the occluder and emoted as E1 had done before, depending on the condition.

She emoted three times, first upon touching it, then when pushing the object with the back of the hand to the middle of the table. Then she continued cleaning but bumped into it again, emoted a third time and put the object without gaze alternation, while looking into a different direction, unintentionally back to its original location on the marble toy. She cleaned the last bit of the table and said with satisfaction: "Well, now it's clean again" and hid. In the *Problem* and *No problem* conditions E1 was outside the room.

In the *Problem known* condition, the procedure was the same as in the *Problem* condition, but E1 came back into the room earlier. She greeted E2 and then watched the entire sequence from about a meter away from the table. When the object had been removed back to its original location, E2 addressed E1 by calling her name, whereupon E1 approached the table and looked at the object. She said in a neutral tone of voice "Ah, okay" and looked to the infant. Then E1 and E2 took leave. Finally, to equate for the absence of E1 across conditions, E1 left the room again for a few seconds saying: "I quickly have to check something". From piloting and the actual testing procedure it was clear that infants did look at E1 when she entered the room and greeted E2, and when she approached the table after E2's sequence. E2 established that infants attended to her cleaning actions, emotional expressions and object transpositions by addressing them directly, just like in the other two conditions.

*Test phase*: This phase was the same in all three conditions. E1 came back into the room, stood still at the door and said “Now we can play again.” Then she walked an L-shaped path toward the table, first in parallel (2m) then approaching it perpendicular (2m). On two predefined spots E1 stood still and said "Okay, let's go on". The test phase (about 30 seconds) was over as soon as E1 had sat down. If infants pointed during this period, E1 responded by saying “Yes” and continued with her predetermined sequence. The test phase ended with E1 reaching around the marble toy and bumping into the object again. She then cleaned up the marble toy in order to get another one to play with.

*Coding and data analysis*

Hand- and index-finger pointing with half or fully extended arm to the object during the test phase were coded from video tapes. We also coded points to the marble dish during the test phase, to measure infants' request to go on with the game ('proto-imperative pointing', e.g, Carpenter, Nagell & Tomasello, 1998). The latter were coded to explore whether infants in the *Problem* condition would find it more relevant to point out the aversive object than to request going on with the marble game. Excellent inter-rater reliability was obtained from 25% of the data coded, Cohen's Kappa=.88. The percentage of agreement only for the points that main and reliability coders coded was 74%. Inspection of the video recordings revealed that all infants looked at E1 upon her return and as she was approaching the table. Therefore, and since previous studies have found problems with its validity (see Liszkowski et al., 2008), gaze alternation was not coded as an indication of communicative intent. However, previous experimental studies on pointing have shown that infants point as a function of social-communicative contexts. In addition, test phases with a point to the object were coded for the presence or absence of features indicative of warning behavior. These were behaviors like turning away, saying 'yak' or 'ouch', negative facial expressions (frowning, wrinkled nose, protruded tongue), shaking head or saying 'no' in response to 'let's go on', negative vocalizations like 'ew' and hand shape (open hand with palm forward or arm, hand or fingers moving sideways or up and down as in "no" or "not"). Cohen's Kappa for the presence or absence of any of these accompanying warning features was .84. Data diverged significantly from the normal distribution (Kolmogorov-Smirnov tests, $p < .05$) and were analyzed non-parametrically for each age group separately. The experimental manipulations were set up to make two planned one-tailed comparisons following our expectations: (i) *Problem* vs. *Problem known* condition, and (ii) *Problem* vs. *No problem* condition. No alternative pattern other than that of the null-hypothesis was predicted.

### 3.3. Results

*18-month-olds*

The two variants of the *Problem* condition did not differ significantly from each other with regard to the number of infants who pointed at least once to the object (*Problem before*: 9 of 12 infants; *Problem after*: 8 of 12 infants, Fisher's Exact, $p$=1) and the mean number of points to the object (.597 vs. .785; Mann-Whitney U, $p$=.799). Therefore, the two variants of the *Problem* condition were collapsed in subsequent analyses. The left panel of Figure 2 shows that significantly more 18-month-olds pointed at least once to the object in the *Problem* condition (17/24) compared to the *Problem known* (3/12) and the *No problem* condition (3/12), Fisher's Exact $p$'s=.012, Cramer'sV's=.435.[2] Similarly, the left panel of Figure 3 shows that 18-month-olds' mean number of points to the object were significantly higher in the *Problem* compared to the *Problem known* and *No problem* conditions, Mann-Whitney U, $p$=.023, r=-.35; $p$=.034, r=-.32, respectively. This pattern of results was already present in the first trial: More 18-month-olds pointed in their first trial in the *Problem* condition (13/22) compared to the *Problem known* (3/12) or *No Problem* conditions (2/12), Fisher's Exact, $p$=.06, Cramer'sV=.326, $p$=.02, Cramer'sV=.408, respectively. Similarly, 18-month-olds pointed in the first trial more often in the *Problem* condition

[2] The pattern remained significant when comparing the *Problem before* (9/12) and the *Problem after* (8/12) conditions separately to the *Problem known* and the *No problem* conditions (respectively, Fisher's Exact's, $p$=.02, $p$=.02, $p$=.05, $p$=.05).

(M=1.18) than the *Problem known* (Mean=.33) or *No Problem* conditions (Mean=.25), Mann Whitney U, *p*=.04, r=-.41, *p*=.022, r=-.48, respectively. The number of infants who pointed to the object in the *Problem* condition decreased over trials, Cochran's Q (n= 20), *p*=.011, possibly indicating fatigue or familiarization effects, but excluding learning of the target behavior within the experiment. The type of negative expressions in the *Problem* condition (disgust vs. hot) had no effect, Wilcoxon, *p*=.551.

*12-month-olds*

As depicted in the right panel of Figure 2, 12-month-olds also performed according to our predictions: significantly more infants pointed to the object in the *Problem* condition (10/12) as compared to the *Problem known* (4/12) and the *No problem* conditions (4/12), both Fisher's Exact *p's*=.018, Cramer'sV's=.507. The right panel of Figure 3 shows that 12-month-olds' mean numbers of points to the object were significantly higher in the *Problem* condition compared to the *Problem known* and *No problem* conditions, Mann-Whitney U, *p*=.024, r=-.47; *p*=.051, r=-.36, respectively. This pattern of results was similar in the first trial, but failed to reach significance: More 12-month-olds pointed in their first trial in the *Problem* condition (6/12) compared to the *Problem known* (2/12) or *No Problem* conditions (3/11), Fisher's Exact, *p*=.097, Cramer'sV=.354, *p*=.247, Cramer'sV=.233 respectively. Similarly, 12-month-olds pointed in the first trial slightly more often in the *Problem* condition (M=.67) than the *Problem known* (Mean=.42) or *No Problem* conditions (Mean=.55), Mann Whitney U, *p*=.133, r=-.28; *p*=.174, r=-.24, respectively. The number of infants pointing towards the object did not differ across trials Cochran's Q (n=12, based on three trials), *p*=.895, thus excluding learning of the target behavior within the experiment. The type of negative expressions in the *Problem* condition (disgust vs. hot) had no effect (Wilcoxon, $p$=.504).

When comparing the 12-month-olds with the 18-month-olds in the *Problem* condition, there were no significant differences with regard to the number of infants who pointed at least once (Fisher's Exact Test, $p$=.86), nor with regard to the mean number of points to the object (Mann-Whitney U, $p$=.69).

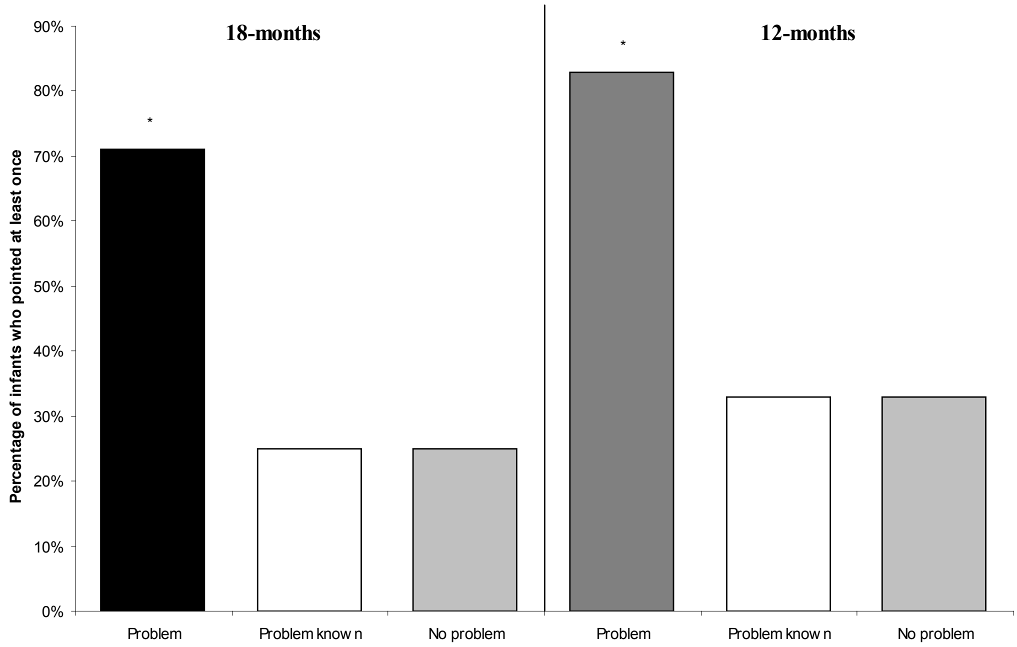


***Figure 2.*** Number of infants who pointed to the object at least once. Left: Results for the 18-month-olds. Right: Results for the 12-month-olds.

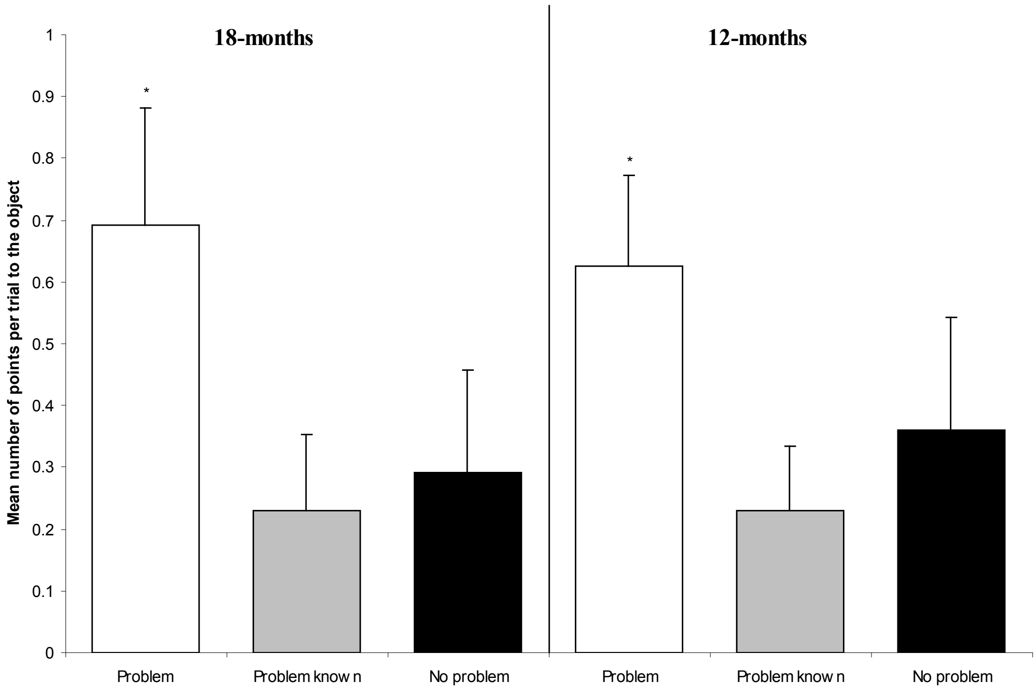


***Figure 3.*** Mean number of points per trial to the object. Left: Results for the 18-month-olds. Right: Results for the 12-month-olds. Error bars represent the standard errors of the means.

*Additional analyses*

To further explore infants' pointing in the *Problem* condition we looked at the frequency of point-accompanying features possibly indicative of warning. In the *Problem* condition, 18- and 12-month-olds expressed accompanying warning behaviors respectively in 21% and 24% of the trials with a point. In the *Problem known* condition these accompanying features occurred only half as often in respectively 11% and 14% of the trials with a point. In the *No problem* condition, when there was nothing to warn about, these accompanying features never occurred. The condition differences were statistically not significant, presumably since the cell numbers were low, especially in the *Problem known* and *No problem* conditions, when infants rarely pointed (1's and 0's, respectively).

To investigate whether infants found it more relevant to inform about the aversive object than to request going on with the marble game we investigated the distribution of points to the object compared to the marbles on the marble dish. In the *Problem* condition, 18-month-olds pointed significantly more often to the object (M=.69) than the marbles (M=.30) (Wilcoxon, *p*=.011, two-tailed), whereas the reverse was true for the *Problem known* condition (object M=.23 vs. marbles M=.90) and the *No Problem* condition (object M=.29 vs. marbles M=.77), Wilcoxon, both *p*'s=.007, two-tailed. Thus, when there was an object to be warned about, infants mostly pointed out that object. When there was nothing to warn about, infants mostly pointed to the marbles, presumably to request continuing the game. In contrast, the 12-month-olds pointed about the same amount to both locations across conditions (*Problem* condition: object M=.63 vs. marbles M=.85; *Problem known* condition: object M=.23 vs. marbles M=.32; *No Problem* condition: object M=.36 vs. marbles M=.38).

**3.4. Discussion**

Twelve- and 18-month-old infants spontaneously pointed out an aversive object that was in the adult's way. Infants intervened before the undesired outcome occurred, that is, already before the adult showed signs of contacting the object. The pattern of pointing across the experimental manipulations suggests that infants intervened by anticipating and evaluating the adult's action with regard to her goal and current representation of reality. These findings suggest that infants have expectations about others' future actions, and that they are motivated to help others avoid unintended outcomes spontaneously, that is, even in the absence of an external response elicitation.

Regarding infants' social-cognitive skills, results suggest that both age groups anticipated and evaluated the adult's action relative to (i) her goal about the object, and (ii) her representation of its location. First, when the adult had not witnessed the location change, infants pointed significantly more often to the object in the *Problem* condition in which the adult wanted to avoid it, compared to the *No Problem* condition in which the object was otherwise irrelevant to her action. In accordance with other studies (Southgate & Csibra, 2009; Falck-Ytter et al., 2006) infants presumably understood the adult's positive goal of retrieving the marbles. However, in addition, and contrary to recent findings (Vaish & Woodward, 2010), infants also understood the adult's negatively defined sub-goal of avoiding the object when it was aversive. It is important to note that when the object was positive, infants did not treat it as the adult's positively defined goal of approaching it. This is presumably because the adult did not express any signs of wanting or searching for the object, and because she removed it out of her sight despite emoting positively about it. The difference between the current and the Vaish and Woodward (2010) findings is likely due to procedural differences. For example, in the current study there was a hierarchy of goals, with the overall goal being the marble game, within which one sub-goal was to avoid a specified negative outcome. Instead, in Vaish and Woodward (2010) the actor's reach was not embedded in further activities. One possible interpretation of their 'incongruent' test events could thus be that the agent reached for the negative object to remove it. Another difference is that the adult in the current study acted live and pretended fairly convincingly that she hurt herself badly or was severely disgusted when removing the object, thus expressing her negatively defined desire very clearly.

Second, when the adult wanted to avoid the object, infants pointed significantly more when she had not witnessed its location change (*Problem* condition) compared to when she had witnessed the change (*Problem known* condition). Presumably, infants understand that others can hold information which does not correspond to current reality. This interpretation is corroborated by previous findings on informative pointing (Liszkowski et al., 2008; Knudsen & Liszkowski, 2011) and other recent false belief studies (Southgate, Chevallier & Csibra, 2010; Buttelmann et al., 2009; Onishi & Baillargeon, 2005; Scott & Baillargeon, 2009). One should note that procedural aspects of the current design excluded the possibility that infants attributed correct information states only on the basis of perceptual co-presence (Fabricius, Boyer, Weimer & Carroll, 2010), since after the adult had witnessed the object change she still left the scene and only then re-entered.

In the current study, our measure was recorded in an anticipation phase, that is, before the test outcome. Previous action-based tasks have confronted infants with an experimenter's goal-directed action (Buttelmann et al., 2009, Liszkowski et al., 2008; Southgate et al., 2010). In those paradigms infants thus had to make sense of the ongoing goal-oriented action presumably by reasoning backwards to the actor's goals. Instead, in the current design infants had to reason forward and anticipate and evaluate an action outcome based on an understanding of the adult's goal and reality representations. This suggests that infants use their social-cognitive skills also prospectively to predict others' actions and intervene communicatively. Motivationally, the study reveals a form of proactive helping. In earlier helping paradigms infants complied with an adult’s request for help (e.g. Liszkowski, et al., 2006; Warneken & Tomasello, 2007) or acted in response to an adult's distress (Bischof-Köhler, 1991). In this study, however, at test, the adult did not request any help nor did the adult show any signs of distress. Infants thus provided unsolicited help to an adult, revealing their prosocial motivation to help others, which gives further support for theories of altruism in early infancy (Warneken & Tomasello, 2009).

The age comparison of the main measures revealed no significant differences between the age groups, indicating that the social-cognitive skills and the prosocial motivation to warn others already emerge by 12 months of age, when infants have just begun pointing. Additional analyses suggested subtle differences between age groups. First, at 18 months infants showed the expected pattern between conditions already in their first trial, while 12-month-olds' first trial performance showed only a trend towards the expected direction but did not reach statistical significance. One should note, however, that the sample size was also smaller, possibly reducing statistical power. Second, the additional analysis on the points to the marble dish revealed subtle differences. In contrast to 12-month-olds, 18-month-olds pointed in the *Problem* condition more to the object than to the marbles. For 18-month-olds it was presumably more relevant to warn about the object than to request going on with the game. This could suggest that between 12 and 18 months infants learn to structure their communicative acts with respect to what is most relevant in a given situation. Communicative experience in contextualized second-person interactions may provide the grounds for age-related, more subtle refinements in the use of pointing. Overall, however, the similar pattern of results in the main measure, and the significant condition differences at both ages, suggest that infants begin to warn others' about negative action outcomes around 12 months of age.

Additional analyses on the point accompanying features support the interpretation that infants pointed to warn the adult about the presence of a harmful object. Infants' pointing in the problem conditions was accompanied by warning features that have previously not been observed with other types of pointing. These were absent in the *No Problem* condition, although the differences failed to reach statistical significance. Pointing to warn others is a subtype of the previously demonstrated informative motive. Current findings establish that infants provide relevant information spontaneously, without any elicitation, and that infants also inform about objects that are *not* desired by them or others and should be avoided, not approached. The findings thus support the social-cognitive and prosocial interpretation of informative pointing. It is also important to note that all conditions were matched for saliency in acting, and that it was made sure during testing that all infants watched the relevant steps. While it is theoretically possible that infants process negative stimuli deeper or differently from positive stimuli, this alone cannot explain the differences in pointing we found - since then the two conditions with negative stimuli (*Problem* versus *Problem known* condition) should not have differed from each other. It was also not the case that infants allocated less attention to the object in the *Problem known* condition when there were two adults. This is because the adults acted sequentially, and E2 made sure that infants watched her acting and the object transpositions just as in the other conditions; only after this did E1 step forward and elicited infants' attention.

The findings moderate previous suggestions that infants point exclusively to request information (Southgate, van Maanen & Csibra, 2007). First, in the current design the adult had already expressed information about the object (i.e. positive or negative valence) before the infant pointed in the test phase. Thus, the object was not new to the infant, and the infant had already obtained relevant information. Second, there is no a priori reason why infants should request less information about a positive than a negative object. In the same vein, it is not apparent why infants would request less information about a negative object when the adult had witnessed the object's replacement as opposed to when she had not. While we certainly do not doubt that an interrogative motive may exist (Baldwin & Moses, 1996; Liszkowski, 2005), the current findings are better understood as a demonstration of infants' rich and flexible use of pointing for various motives (Tomasello, Carpenter & Liszkowski, 2007), including such things like helpfully informing and warning others.

Human social interaction and communication are predicated on social-cognitive skills and a cooperative motivation. The current study adds to the accumulating ontogenetic evidence that both these aspects are present by 12 months of age, when infants have just begun pointing, and before they communicate with language in earnest. Warning is a paradigm case of helpful and prospective intervening. It is a reasonable speculation that acts of prospective intervening originate within cooperative communication. The flexibility with which infants pointed across conditions supports social-cognitively 'rich' accounts and reveals an action-based usage of social understanding in the case of prospective helpful warning.

## 3. One-year-olds warn others

# CHAPTER 4

## 18-month-olds predict specific action mistakes through attribution of false belief, not ignorance, and intervene accordingly

Based on:

Knudsen, B. & Liszkowski, U. (in press). 18-month-olds predict specific action mistakes through attribution of false belief, not ignorance, and intervene accordingly. *Infancy*.

**Abstract**

The current study employed a new 'anticipatory intervening' paradigm to tease apart false belief and ignorance-based interpretations of 18-month-olds' helpful informing. We investigated in three experiments whether 18-months-old infants inform an adult selectively about one of two locations depending on the adult's belief about which of the two locations held her toy. In Experiment 1 and 2 the adult falsely believed that one of the locations held her toy. In Experiment 3 the adult was ignorant about which of the two locations held her toy. In all cases, however, the toy had been removed from the locations, and the locations contained instead materials which the adult wanted to avoid. In Experiment 1 and 2, infants spontaneously and selectively informed the adult about the aversive material in the location the adult falsely believed to hold her toy. In contrast, in Experiment 3 infants informed the ignorant adult about both locations equally. Results reveal that infants expected the adult to commit a specific action mistake when she held a false belief, but not when she was ignorant. Further, infants were motivated to intervene proactively. Findings reveal a predictive action-based usage of 'theory-of-mind' skills at 18 months of age.

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## 4.1 Introduction

Recent action-based studies suggest that infants in their second year of life use false belief understanding to guide their social actions. Findings show that infants interact differently with an adult who is misinformed about the referent of an interaction compared to an adult who is accurately informed. For example, in one study 17-month-old infants were first trained to retrieve an object from one of two boxes to which an adult pointed (Southgate, Chevallier & Csibra, 2010). Subsequently, the objects in the boxes were swapped. In a true belief condition, the adult saw the swap. At test, infants retrieved the object from the box to which the adult pointed. However, in a false belief condition the adult did not witness that the objects in the boxes were swapped. When the adult now pointed to one of the boxes to request an object, infants retrieved the object from the opposite box. Thus, infants apparently appealed to the adult's false belief and inferred that she wanted the object that was currently in the other box (for a similar paradigm with slightly older, verbal children, see Carpenter, Call & Tomasello, 2002).

Similarly, in another study 18-month-old infants were first trained to help an adult open one of two boxes (Buttelmann, Carpenter & Tomasello, 2009). Subsequently, in a false belief condition, the adult had not witnessed that someone had switched a toy from one to the other box. When the adult then attempted to open the now-empty box, infants opened the opposite box for the adult. However, in a true belief condition, when the adult had seen the switch and now tried to open the empty box, infants helped him to open that box. Thus, depending on what the adult had seen previously, infants apparently attributed different goals to her (respectively, either the goal to retrieve a toy from a box, or to open an empty box). The two studies suggest that infants consider an adult's epistemic state when reacting socially. However, the studies also raise important questions regarding the usage and the kind of mental attributions infants make when acting socially.

One question is whether infants act helpfully and appropriately not only in reaction to but also in anticipation of an adult's mistaken action. Predicting others' action mistakes and intervening accordingly is a key skill of efficient and helpful collaborative interaction and communication. The aforementioned action-based studies follow the 'explanation'-type structure of classical theory-of-mind tasks ("*Why* is she pointing to/acting on that box?"). Relatively less is known about infants' active and helpful intervening in 'prediction'-tasks ("Where *will* she search for her toy?"). Two recent action-based paradigms suggest that 12- to 18-month-olds infants help a misinformed adult by communicating to her relevant information *before* she will act mistakenly. In one study, 18-month-old infants corrected an adult in anticipation of her searching for an object in a wrong location (Knudsen & Liszkowski, in press). In the experiment, infants watched as an adult searched for an object and found it in the last of four containers. In her absence the object was then moved to the first container. At test, when the adult re-entered the room, infants spontaneously helped her find the object by pointing to the object’s new location. In contrast, infants did not inform the adult in control conditions, when she had either seen the transfer of the object, or when it had not been her intention to find the object. In a second study, Knudsen & Liszkowski (2011) found that 12- and 18-month-olds warned an adult in anticipation of her acting towards an undesired outcome. In the experiment, infants watched as an adult pretended to hurt herself on an object and subsequently avoid it. In her absence, the object was then moved into her way. At test, when the adult re-entered the room, infants spontaneously pointed to the object the adult intended to avoid. Infants pointed significantly less in control conditions, when the adult had witnessed its reappearance, or when the object had previously caused no harm and the adult did not intend to avoid it. These two studies thus suggest that infants in their second year use mental state attributions about others' intentions and epistemic states not only when reacting to others' actions, but also to intervene proactively and spare others mistakes or harm.

However, a second question is what kind of epistemic states infants attribute. It has been argued that infants simply attribute ignorance - the lack of knowledge - rather than a false representation of reality. For example, in the experiments infants may have realized that the experimenter did not witness the transfer of an object and therefore did not know where it was (as opposed to believing it was in the wrong location). They may have then applied a rule of the kind ‘Doesn’t know - gets it wrong’ and inferred the correct response without attributing false belief (Ruffman, 1996; Garnham & Ruffman, 2001; Fabricius, 2003). Looking-time studies, which measure reactions to action outcomes (e.g., Keen, 2003), however, suggest that this is not the case. 18-month-old infants apparently differentiate between false belief and ignorance, as indicated by longer looking-times to an agent who has a false belief but acts correctly compared to an agent who is ignorant but acts correctly (Scott & Baillargeon, 2009; Scott et al., 2010). However, for action-based explanation-type tasks the alternative explanation is still troublesome, since one may help an adult for both reasons, either because of her lack of knowledge, or because of her misguided assumption about reality.

Action-based prediction-tasks can in principle be solved in this alternative way, too. Another non-verbal prediction-task has employed visual anticipation measures. Southgate, Senju, and Csibra (2007) trained 25-month-olds to make anticipatory gaze-shifts to one of two windows through which an adult would make a reach to obtain a toy from an opaque box in front of that window. Subsequently, the adult did not witness that the object was switched from one to the other box and thereafter removed from the scene all together. The finding was that infants anticipated a reach through the window where the adult falsely believed the object to be (i.e., where she had last seen it). The study suggests that 2-year-olds attributed false belief and not ignorance, because the desired object had been removed all together from the scene and so the locations to which the actor could potentially make a reach were technically both wrong. Had infants expected the actor to simply "get it wrong" they should have expected her to reach in either location. This was not the obtained pattern, thus making an ignorance-based interpretation less likely. On the other hand, the study did not administer an ignorance condition to compare performance under such conditions more directly. Either way, current action-based studies of both the 'explanation'-type paradigm (Southgate et al., 2010; Buttelmann et al., 2009) and the new 'anticipatory intervening' paradigm (Knudsen & Liszkowski, in press, 2011) are still amenable to an ignorance-based interpretation.

In the current study, we sought to tease apart the ignorance and false belief interpretations in a predictive action-based paradigm. We employed a paradigm that combined the logic of the anticipatory looking study by Southgate et al. (2007) and the action-based measure of anticipatory intervening previously used by Knudsen and Liszkowski (in press; 2011). In three experiments we tested whether 18-month-old infants would expect an adult to approach one of two boxes, depending on her belief about it containing a desired toy. In Experiment 1 an adult falsely believed that her desired object was in one of two boxes, when in reality it had been removed from the scene all together (as in Southgate et al., 2007). In addition, both boxes were 'contaminated' with aversive, to-be-avoided material (as in Knudsen & Liszkowski, 2011). Following Knudsen and Liszkowski (2011) we expected infants to intervene when appropriate and try to spare the adult the mishap of reaching into the aversive material by pointing it out to her in advance. Based on the recent findings that infants' looking-times differentiate between false belief and ignorance-based actions (Scott & Baillargeon, 2009; Scott et al., 2010), infants should attribute a false belief to the adult and expect her to approach the box which she falsely believed to contain her desired toy. Thus, we predicted that infants would inform the adult selectively about the aversive material in that location (e.g., to warn her appropriately). Experiment 2 addressed procedural aspects and controlled for possible alternative explanations of Experiment 1. To confirm that infants did not use ignorance attributions in Experiments 1 and 2, we tested infants' performance in an ignorance condition in Experiment 3. Experiment 3 used the same paradigm as Experiments 1 & 2, except that the adult was ignorant about which of the two boxes held her object. Consequently, if infants correctly attributed ignorance to the adult (Scott & Baillargeon, 2009; Scott et al., 2010), they should expect her to approach either box by chance and inform her about the aversive material in both locations equally.

## 4.2. Experiment 1

### 4.2.1 Method

*Participants*

Infants were recruited from a database of parents who had volunteered to participate in infancy research. Nineteen 18-month-olds (8 boys; M age= 18;12, range=

17;26-18;27) participated in the study. Five additional infants had to be excluded from analyses, because of fussiness (2), parental interference (2) or technical failure (1). Eight individual trials of seven infants had to be discarded, because of parental interference (2), experimenter error (1), technical failure (1), or fussiness (4).

*Set-up*

Infants sat on their parents' lap at the long side of a table. The table was centered in the back of the testing room. Infants faced the main experimenter (E1) who sat across the infant at the table. Behind E1, approximately 1 meter to her left and right, stood two square pillars on the floor (about 1 meter high, 34 cm wide). Behind E1's chair, a straight path was roped-off with four posts (0.5m high). The path diverged after about 2 meters in a T-shape to the left and to the right of the room (approximately another 2 meters). The left path led behind a cupboard (2 meters high), the right path led to the door of the room. Both sides served as entrances to the scene. About 1.5 meters to the infant's left, perpendicular to the table's long side, stood a 2 meters long room divider (1.45 m high). Behind the room divider hid a second experimenter (E2), watching the procedure on a video screen that was connected to the cameras which provided a full view on the scene. There were five cameras in total. Two cameras were positioned to the far left and right corners on the infant's side, recording the experimenter and the room behind her. A spy camera was attached to the ceiling above the table providing a bird's eye view on the infant and the table. Two additional cameras were each hidden in the pillars left and right from E1, providing a close-up view on the infant.

*Materials*

There were four different sets of three identical containers. Each set was used in one of four trials. All containers had an opening on the front side, big enough to reach in. Two containers of each set were hidden inside the left and right pillars, the third container was hidden under the table. Each of the containers under the table contained one toy: (i) a marble (ii) a plastic duck (iii) a ladybug (iv) a spring with a spinning top and a silver ball attached. Each of the four containers under the table also contained objects marked as aversive: (i) grey crumpled-up tissues (ii) green wads of elastics (iii) pieces of crumpled, red-grayish plastic nets (iv) green crumpled-up tissues. Four additional, identically looking aversive objects were hidden behind the top of the right pillar out of infants' sight.

*Procedure*

There were 4 trials with a brief play break after two trials. Each trial consisted of four phases: demonstration, epistemic induction, switch, and test. Parents were instructed to remain silent during testing and not to interfere with the procedure.

*Demonstration*: E1 placed an empty container from inside each pillar on top of each pillar. The opening of the containers faced the infant. Then she sat down at the table and placed the corresponding container of that set from under the table on the table in front of her, with the opening facing the infant. The infant - but not she - could see the toy and the aversive object inside the container. She said: "Let's play with this." She reached from behind into the front opening of the container and bumped into the aversive object (see Figure 1, photo 1). She emoted with facial expressions of disgust, saying: "Yak! What is this?" She pushed the object to the left side of the table, saying with the same facial expression: "Yak, this is disgusting! I have to clean this up." She picked up the object with her thumb and index finger and put it behind the container on top of the left pillar, out of the infant's sight (see Figure 1, photo 2). Then she reached again into the container on the table. This time she grabbed the toy. She said "Hey, look at this!" and began to playfully insert and then retrieve the toy from the container, saying "Now it's in there….now I'll get it out again" (see Figure 1, photo 3).

Next, E1 took the toy out of the container and removed the container under the table. She turned to one of the two containers on the pillars and playfully inserted and retrieved the object in the same manner as before. Then she turned to the other container and played in the same manner (see Figure 1, photos 4-5). The play sequence on both pillar containers was then repeated, thus totaling four play episodes, two on each of the containers on the pillars. The side where the play began was counterbalanced across participants and alternated in an a-b-b-a design across the four trials. Then E1 interrupted the play saying "Oh, I have to leave". She held up the toy and said "We go on playing with this in a minute, okay?"

*Epistemic induction*: This phase served to establish E1's belief about the toy's final location. Before leaving, E1 put the toy into one container (target container). This was always the opposite container with which she had played last (following the counterbalancing above; see Figure 1, photo 6). She said: "Well, I'll leave it here. See, there it is." To equate for this step toward the target container she then turned to the other container (distractor container), adjusted its position by shuffling it around and said "All right". With every comment E1 alternated gaze with the infant. Subsequently, she left the scene either through the door or by hiding behind the cupboard, saying "Okay, I'll be back in a bit." For half of the infants, E1's side of entrance was on the same side as the target container in the first two trials, and on the opposite side in the next two trials. The other half got the reverse order.

*Switch*: In this phase, E2 removed the toy from the scene all together and baited both containers with the aversive objects E1 wanted to avoid. E2 appeared from behind the room divider, greeted the infant and started to clean the target container. She accidentally found the toy inside the container, took it out, held it up and said "Oh. Well, I put it here". She put it into the distractor container (see Figure 1, photos 7-8). Then she turned back to continue cleaning the target container. Accidentally she bumped into the aversive object behind the container. She emoted with facial expressions of disgust and said: "Yak! What is this?" She picked up the object with her thumb and index finger, placed it on the table and continued cleaning the container. Then she moved on to clean the table and bumped into the object again. She said with the same facial expression: "Yak, this is disgusting!" and moved the object from the table into the target container (see Figure 1, photo 9).

Then she turned to the distractor container and the sequence was repeated: She encountered the toy inside the distractor container, took it out, and held it up. She said: "Oh. Well, I take this with me," and put the toy demonstratively into her trouser's pocket (see Figure 1, photo 10). She continued cleaning the container, bumped into the aversive object behind the container and emoted disgust. She put the object on the table and continued cleaning the container. Then she turned to clean the table, bumped again into the object, emoted disgust, and moved it from the table into the distractor container (see Figure 1, photo 11). Then she finished cleaning the table, said with satisfaction "Well, now all is clean," and hid behind the room divider. By the end, E1's toy had thus been removed from the scene and both containers were baited with aversive material.

*Test*: E1 came back into the room (see Figure 1, photo 12). First she stood still and said “Now we can play again.” Then she walked the roped-off path toward the table (2 x 2m). On two predefined spots (at the T-junction, and half way towards her chair) E1 briefly stopped, looked at the infant, and said "Okay, let's go on". The test phase (about 30 seconds) was over as soon as E1 had sat down. If infants pointed during this period, E1 responded by saying “Yes” and continued her predetermined sequence. All trials ended with E1 reaching into the target container, bumping into the aversive object, and emoting disgust. Then she removed the containers to get "other ones to play with" for the next trial.

*Coding and data analysis*

Pointing was defined as a half or fully extended arm with the open hand palm down or the extended index-finger. The arm was extended in the air and towards discernable direction. The arm extension had to have a clear onset and end, with a clear trajectory towards the target or distractor container. The direction could easily be coded from the recording of the bird's eye spy camera above the table. Points were coded by an assistant blind to the hypothesis, if they occurred during the test phase and were directed to the target or distractor container. A second coder, blind to the hypothesis, recoded a random subset of 6 infants. Excellent inter-rater reliability was obtained, Cohen's Kappa=.92. In addition, in order to ascertain that E1 did not show in her behavior which container she would approach during the test phase, a third coder, blind to the hypothesis, judged for all infants in a two-alternative forced choice procedure which container E1 would reach into during the test phases. The third coder was at chance in predicting the location E1 would reach into, Binominal, $p$=1. Analyses were non-parametric and one-tailed when following our planned comparisons.


A
Demonstration
B
Switch
1.
7.
2.
8.
3.
9.
4.
10.
5.
11.
Epistemic induction
Test
6.
12.

***Figure 1.*** Staged photos of the general procedure of Experiments 1, 2 and 3. **(A)** *Demonstration*: 1. E1 unintentionally bumps into aversive material. 2. E1 removes the aversive material behind the right pillar. 3. E1 plays with the toy. 4 & 5. E1 plays with the toy alternately at both containers on the pillars. *Epistemic induction:* 6. E1 has put the toy in one container (target container) and leaves (Note: this step differed in Experiment 3). **(B)** *Switch*: 7. E2 finds the toy in the target container. 8. E2 puts the toy into the distractor container. 9. E2 has bumped into the aversive material and moves it into the target container. 10. E2 has taken the toy from the distractor container and puts it demonstratively into her pocket. 11. E2 has bumped into the aversive material and moves it into the distractor container. *Test*: 12. The toy is removed from the scene and both boxes are baited with aversive material. E1 re-enters the room and states her intention to continue playing. She walks a roped-off L-shaped path towards the table.

### 4.2.2. Results and Discussion

As depicted on the left of Figure 2, infants pointed more often to the target container than the distractor container (mean number of points per trial, .711 vs. .410, respectively; Wilcoxon Signed Ranks Test, Z=-2.63, *p*=.004). This pattern was stable across infants, with the majority of infants pointing more to the target container than the distractor container (63.2%), and only one infant (5%) pointing more to the distractor than the target container, Binomial test, *p*=.002. Similarly, infants' mean proportion of trials in which the first point was directed at the target container was higher (*Mean Proportion*=.373) than the mean proportion of trials in which the first point was directed at the distractor container (*Mean Proportion*=.184), Wilcoxon Signed Ranks Test, Z=-2.17, *p*=.02 (see left side of Figure 3). Thus, infants informed the adult selectively about the aversive object in the container from which she was about to retrieve her toy, supporting the interpretation that infants attributed to the adult a false belief. The possibility that infants attributed only ignorance to the adult and applied the rule 'She doesn't know, she gets it wrong' (Ruffman, 1996; Garnham & Ruffman, 2001), appears thus less likely, because then infants should have pointed randomly to the containers which had both been emptied and now contained an aversive object.

There was no indication that infants learnt this behavior over trials. If any, infants tended to point more to the target in the first half of the experiment (Mean number of points per trial= .84) than in the second half (Mean number of points per trial= .44), Wilcoxon Signed Ranks Test, Z=-1.69, *p*=.091, two-tailed. Previous action-based studies (Southgate et al., 2010; Buttelmann et al., 2009) tested performance on a single trial only. However, in those studies, infants were first trained to produce the target behavior, and if they did not, they were excluded from the analyses. In our sample, 11 of the 14 infants who pointed at least once (79%) pointed already on the first trial. The first point in the first trial was more often directed towards the target container (7/11) than the distractor container (4/11), but this did not reach statistical significance (Binominal test, *p*=.27). Thus, although there was no learning over trials and the pattern of mean differences was already there on the first trial, the first-trial differences failed to reach statistical significance, presumably due to the reduced power of single-trial analyses and fewer participants.

Additional analyses revealed that infants' pointing to the target container was not biased by the side of the experimenter's entrance, Wilcoxon Signed Ranks Test, Z=-1.41, *p*=.158 (two-tailed; Mean number of points per trial, Congruent side= .500; Incongruent side= .833). Further, the experimental procedure of the *epistemic induction* excludes the possibility that infants pointed simply to the container E1 last attended, since E1 always last attended to the distractor container before she left the scene. The experimental procedure of the *switch* excludes also the possibility that infants pointed simply to where they had last seen the toy, because E2 always moved the toy into the distractor container before she removed the toy completely by putting it into her pocket.

However, it might be that infants pointed more to the target container because it was more salient or easier to remember. For example, during the *epistemic induction* E1 spent slightly more time acting on the target container when saying “Well, I leave it here. See, there it is" than on the distractor container when saying “All right”. This might have rendered the target container more salient to the infant. It is theoretically also possible that infants only paid attention to the first container E1 acted on during the *epistemic induction*. Since this was always the target container, infants might have simply pointed more to it, because they remembered it better. In Experiment 2 we therefore aimed at replicating the effect while controlling for these alternative possibilities.

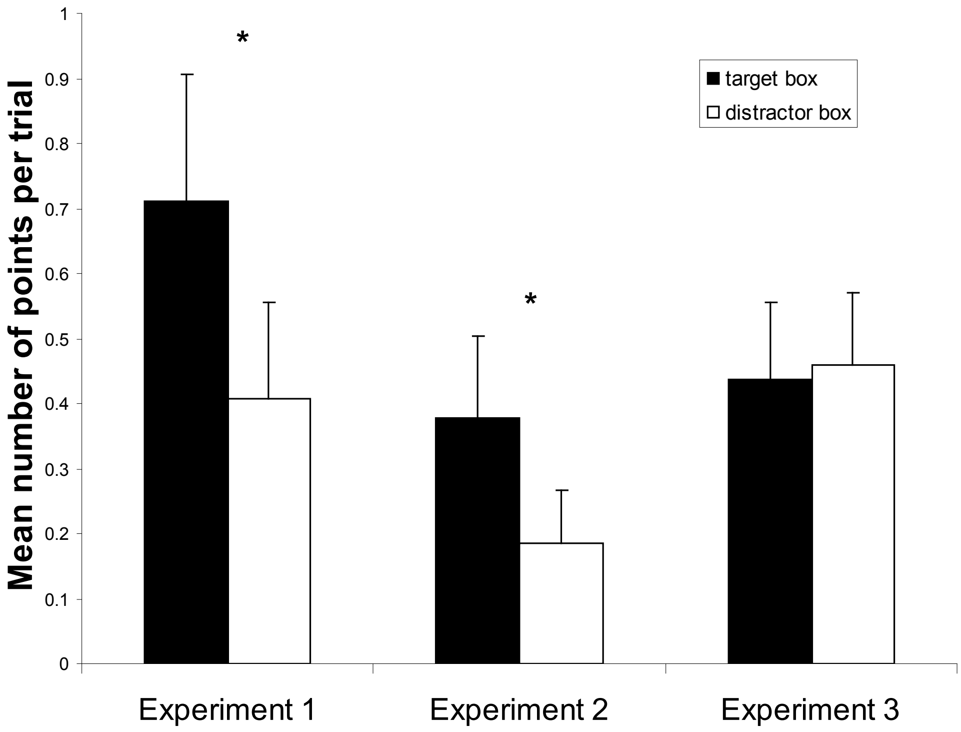


***Figure 2.*** Mean number of points per trial to the target and distractor containers in Experiment 1, 2 and 3. Error bars represent the standard errors of the means.

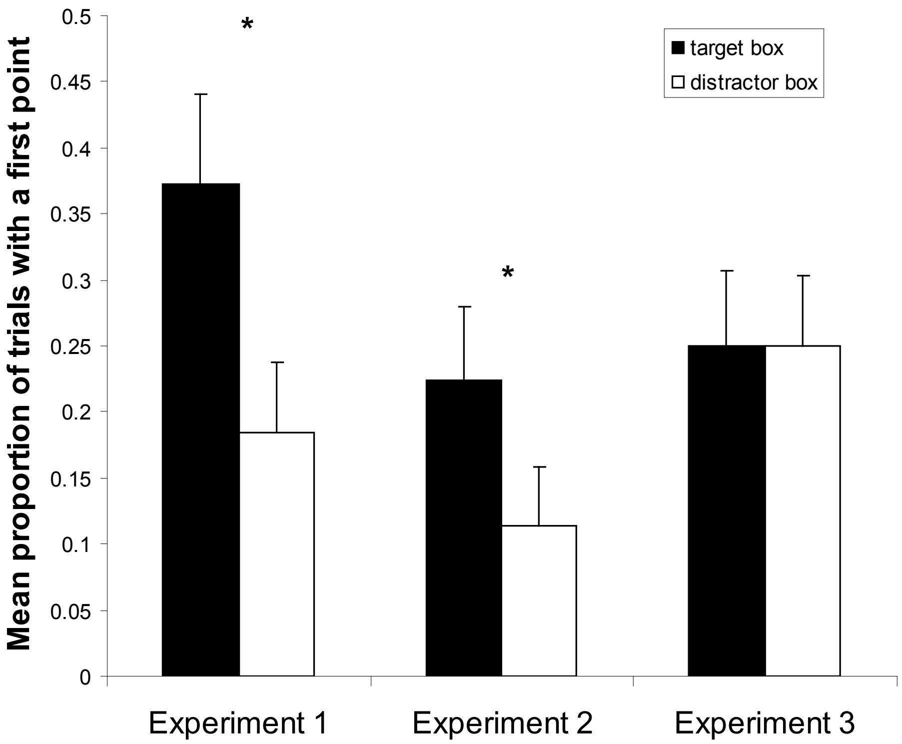


***Figure 3.*** Mean proportion of trials in which a first point was directed to the target or distractor container in Experiment 1, 2 and 3. Error bars represent the standard errors of the means.

## 4.3 Experiment 2

### 4.3.1. Method

*Participants*

Nineteen 18-month-olds (10 boys; M age= 18;20, range = 18;6-18;28) participated in the study. Five additional infants had to be excluded from analyses because of fussiness (2), parental interference (1), technical failure (1), or experimenter error (1). Six individual trials of 6 infants had to be discarded, because of experimenter error (2) or fussiness (4).

*Set-up and Materials*

The set-up and the materials were exactly the same as in Experiment 1.

*Procedure*

The procedure was identical to that in Experiment 1 except for two aspects during the *epistemic induction*. First, E1 now acted the same towards each container and the sentences were equated for content, length and intonation: In the *epistemic induction* E1 put the toy into the target container and said "Well, I leave it here. See, there it is." Regarding the distractor container, E1 reached into the distractor container and said "Well, I leave this one empty. See it is empty". Second, the order in which E1 acted on the containers (target container first vs. distractor container first) was counterbalanced. E1 acted on two consecutive trials either first on the target container or on the distractor container. The order was counterbalanced across infants. As in Experiment 1, E1 left the scene by saying "Okay, I'll be back in a bit". Due to a slight imbalance in the design, for eight infants E1’s side of entrance was always congruent with the side of the target container, but this did not affect the results (see below), and the previous experiment had revealed no side bias.

*Coding and data analysis*

The coding and analyses were exactly the same as in Experiment 1. Inter-rater reliability on infants’ number of points to either location was excellent for a randomly chosen 6 infants, Cohen's Kappa=.80. The third coder was at chance in predicting the location E1 would reach into in all test phases of all infants tested (one test phase of one trial could not be coded due to failure of the cameras directed towards E1), Binominal, $p$=.282.

**4.3.2. Results and Discussion**

Experiment 2 replicated the main finding of experiment 1. As depicted in the middle of Figure 2, infants pointed more often to the target container than the distractor container (respectively, mean number of points per trial, .377 vs. .184, Wilcoxon Signed

Ranks Test, Z=-1.89, *p*=.03). This pattern was stable across infants, with the majority of infants (47.4%) pointing more to the target container than the distractor container, and less infants pointing more to the distractor than the target container (10.5%), Binomial test, *p*=.033. Similarly, infants' proportion of trials in which the first point was directed at the target container (*Mean Proportion*=.224) were higher than the proportion of trials in which the first point was directed at the distractor container (*Mean Proportion*=.114), Wilcoxon Signed Ranks Test, Z=-1.80, *p*=.036 (see middle panel of Figure 3). Thus, infants informed the adult selectively about the aversive object in the container from which she was about to retrieve her toy, even when the saliencies of the containers were controlled. Also the order of the containers on which E1 had acted first during the *epistemic induction* did not make a significant difference, neither with regard to the mean number of points to the target container, Wilcoxon Signed Ranks Test, Z=-.99, *p*=.321, nor with regard to the number of infants that pointed at least once to the target container, McNemar, p=.774. Thus infants did not attend to or remembered the target container better when it was acted on first or second.

As before, there was also no indication that infants learnt the target behavior over trials. Infants tended to point to the target equally often in the first and in the second half of the experiment (respectively, mean number of points per trial .32 vs. .45), Wilcoxon Signed Ranks Test, Z=-.79, *p*=.427. Eight of the 11 infants who pointed at least once (73%) pointed on the first trial. The first point in the first trial was more often directed towards the target container (5/8) than the distractor container (3/8), but this did not reach statistical significance, Binominal test, *p*=.36. Additional analyses revealed that infants' pointing to the target container was not biased by the side of the experimenter's entrance, (mean number of points per trial, same side= .500 vs. different side= .591, Wilcoxon Signed Ranks Test, Z=-.33, *p*=.739). Infants in Experiment 2 pointed overall slightly less compared to Experiment 1, possibly reflecting individual differences in the spontaneous use of pointing. However a direct comparison on the mean number of points across the two experiments revealed no significant differences, Mann-Whitney U, Z=-1.53, *p*= .138, two-tailed.

Thus, in two experiments infants informed the adult selectively about an aversive object in the container they expected her to act on according to her false belief. Had they expected the adult to have no representation of the object's location whatsoever, infants should have guessed at chance which container she would approach. That is, if infants had intervened based on attributing ignorance instead of false belief, they should have informed the adult about the aversive materials in both containers equally. In order to test this prediction directly, we administered an Ignorance-condition in Experiment 3.

## 4.4. Experiment 3

In Experiment 3 we tested whether infants would correctly attribute ignorance to an adult who did not know in which of the two containers her toy was and whether, in contrast to the false belief conditions, infants would inform the adult about the aversive objects in both locations equally.

### 4.4.1. Method

*Participants*

Nineteen 18-month-olds (10 boys; M age= 18;20, range = 18;7-18;27) participated in the study. Five additional infants had to be excluded from analyses, because of fussiness (3) or experimenter error (2). Thirteen individual trials of 11 infants had to be discarded, because of experimenter error (5) or fussiness (8).

*Set-up and Materials*

The set-up and the materials were exactly the same as in Experiment 1 and 2.

*Procedure*

The procedure was identical to that in Experiment 2 except for a minimal change during the *epistemic induction*. After E1 put the toy into one container (henceforward also called target container) and said "Well, I leave it here. See, there it is" she simply took the toy out of the target container again. As in the previous experiments, she then turned to the other container (henceforward also called distractor container), reached into it and said "Well, I leave this one empty. See it is empty." The order was counterbalanced as in Experiment 2. Subsequently, she stood up and said as in Experiment 1 and 2 "Okay, I'll be back in a bit". At that moment, E2 appeared from behind the room divider and E1 and E2 greeted each other friendly. E1 handed E2 the toy, clearly visible to the infant and said again to the infant "I'll be back in a bit" and left the scene. The *switch* started with E2 putting the toy into the target container and continued as in Experiment 1 & 2.

*Coding and data analysis*

The coding and analyses were exactly the same as in Experiment 1 and 2. Inter-rater reliability on infants' number of points was excellent for a randomly chosen 6 infants, Cohen's Kappa=.84. The third coder was at chance in predicting the location E1 would reach into in all test phases of all infants tested, Binominal, $p$=.45.

**4.4.2. Results and Discussion**

As depicted on the right Figure 2, infants pointed equally often to the target container and the distractor container (respectively, mean number of points per trial .439 vs. .461, Wilcoxon Signed Ranks Test, Z=-.21, $p$=.838). This pattern was stable across infants, with most infants pointing equally much to both containers (47.3%), and about the same number of infants pointing more to the target than the distractor container (21.1%) or more to the distractor than the target container (31.6%), Binomial test, *p*=.754. Similarly, infants' first points were equally likely to be directed to the target container (mean proportion of trials with a first point to the target= .25) or to the distractor container (mean proportion of trials with a first point to the distractor= .25), Wilcoxon Signed Ranks Test, Z=-.28, *p*=.778 (see left panel of Figure 3). Thus, infants indeed expected the adult to reach into either container in order to retrieve the toy, and informed her correspondingly about the aversive objects in both containers equally.

When looking only at the first trial, 79% (11/14) of the pointing infants pointed on that trial. The first point in the first trial was equally often directed towards the target container (5/10) or the distractor container (5/10), Binominal test, *p*=1, and one infant pointed with both arms to both containers at the same time. Additional analyses[3] revealed that infants' pointing to the target container was not biased by the side of the experimenter's entrance, Wilcoxon Signed Ranks Test, Z=0, *p*=1 (two-tailed; mean number of points per trial to congruent side= .441 vs. incongruent side= .471), and the order of containers on which E1 acted first did not make a significant difference, neither with regard to the mean number of points per trial to the target container, Wilcoxon Signed Ranks Test, Z=-1.19, *p*=.233, nor with regard to the number of infants that pointed at least once to the target container, McNemar, *p*=.375.

[3] A 2x2 ANOVA with Experiment as between-subjects factor and Location (target vs. distractor) as within-subjects factor revealed a significant interaction effect between Condition and Location, $F(2, 54) = 2.66$, $p = .04$. Infants pointed more to the target container than to the distractor container in Experiment 1, ($t(18)=3.026$, $p=.004$) and Experiment 2 ($t(18)=1.871$, $p=.039$), but not in Experiment 3, ($t(18)=-.218$, $p=.83$).

### 4.5. General Discussion

The current study teased apart false belief and ignorance-based interpretations of infants' prospective informing in an action-based anticipation paradigm. In Experiment 1 and 2 infants informed an adult selectively about the container which the adult falsely believed held her toy. Importantly, the procedure excluded a "pull of the real", since the toy had been removed from the scene all together (see Southgate et al., 2007). Therefore it is unlikely that infants expected the adult to make a mistake due to her lack of knowledge - since both locations were wrong. Thus, if infants would have attributed only ignorance or followed the rule ‘doesn’t know - gets it wrong’ (Ruffman, 1996; Garnham & Ruffman, 2001), they should have informed the adult about both containers equally. As Experiment 3 showed, infants indeed informed the adult about both containers equally, but only when the adult was ignorant about the location of her toy - not when she had a false belief about its location. The specific procedures of the three experiments excluded also several other, lower level explanations which invoke the adult's or infant's first or last place of attention, the presence of the toy, or other saliency or order effects. The findings thus reveal that infants expect an adult to make a specific mistake when the adult has an incorrect representation of reality - they inform her selectively; and that infants expect the adult to act at chance when she is ignorant - they inform her globally.

The current study further shows that infants were motivated to intervene spontaneously and make active use of their social understanding by communicating. Infants did not have to learn a behavioral response in advance, since the adult never pointed or engaged the infant in pointing before the experiment. Infants also did not learn the behavior over trials, as the comparison of the first and second half of the experiment showed. However, not every infant pointed on the first trial. At first this may seem at odds with the action-based helping study by Buttelmann et al. (2009), in which infants helped on a single first trial. However, it is important to recall that that study excluded infants who did not show the response behavior. In addition, in that study some of the infants reacted only after a prompt from another person. When taking this into account, the percentages of spontaneous first trial helping become comparable between the studies. However, it is also possible that infants more readily react to a mistaken action than that they intervene proactively before a mistaken action has happened. Finally, in contrast to previous studies (Southgate et al., 2007, 2010; Buttelmann et al., 2009), infants in the current paradigm were not familiarized or trained on the response measure beforehand. Thus, although our study shows that not all infants were equally motivated to point spontaneously on the very first trial, and that there was some indication of individual differences across Experiments 1 and 2, it is still a remarkable demonstration of spontaneous communication in a staged laboratory setting.

With regard to the cognitive underpinnings of infants' success on recent theory-of-mind tasks, the current debate centers around the question as to whether the obtained results best fit a mentalistic interpretation or a behavioral rule interpretation. Do infants understand that the mind mediates between perception and action or do they instead follow behavioral rules that link one behavior to another? Preschool children have a mentalistic ("representational") theory-of-mind since they can engage in, and verbalize their mentalistic reasoning even in the absence of behavioral situations that would provoke a reaction (Perner, 2010). In contrast, there is no such evidence for prelinguistic infants, and so Perner (2010) has argued that theory-of-mind tests in infancy are most parsimoniously explained by the use of behavioral rules. One problem with the latter account is that it is somewhat unclear what these behavioral rules are, especially since they are often based on post hoc interpretations of specific task performances (e.g., Perner & Ruffman, 2005). Some of the previously formulated rules (e.g., "three-way-association", Perner & Ruffmann, 2005; "Doesn't know- gets it wrong", Ruffmann, 1996) have also been empirically refuted (Träuble, Marinović & Pauen, 2010; Scott & Baillargeon, 2009; Scott et al., 2010). In Perner's (2010) more recent and general formulation, behavioral rules "capture the workings of the mind without mentioning the mind" (Perner, 2010, p.257). In this case, mentalistic and behavioral rule accounts make the same predictions about theory-of-mind performance. Before being able to mention the mind, infants may thus have an implicit or practical 'theory-of-mind'. However, it is currently debatable how postulating two systems may be more parsimonious than assuming one, and what the developmental antecedents and consequences for each system could be (e.g., Apperly & Butterfield, 2009).

The current study demonstrates that infants have the skills of anticipating another's belief-specific action mistake before it is apparent in the overt behavior, and that infants are motivated to intervene prospectively through communication. The study is in line with recently accumulating evidence from other infant 'theory-of-mind' studies (for recent reviews see Baillargeon, Scott & He, 2010; Caron, 2009), and cannot easily be interpreted in terms of the specific behavioral rule that adults who lack information will commit a specific action mistake (Ruffman, 1996). Thus, already before they have acquired language in earnest, infants actively use their theory-of-mind skills to communicate prospectively. It will be important to unravel whether the underlying cognitive format remains the same over development, whether it is supplanted or complemented by another system, and what the underlying nature of prelinguistic and linguistic social-cognitive representations are.

# Chapter 5

## Epilogue

# 5. Epilogue

In everyday life, we commonly conceive others' behaviour as being driven by mental states such as beliefs – an ability referred to as theory of mind, or more generally, mindreading. The common finding in the last 30 years of research was that this ability developed around four years of age (Wellman et al., 2001). The debate, however, was recently revived by looking-based studies (e.g. Kovács, Téglás & Endress, 2010; Onishi & Baillargeon, 2005; Southgate, Senju, Csibra, 2007; Surian, Caldi & Sperber, 2007), which suggested that theory of mind skills were already present in the second year of life. These studies revealed that even infants use others' informational states, rather than their own, when watching others' actions. However, existing studies focussed primarily on infants' information processing capacities in which infants were merely passive onlookers of others' actions, as opposed to active participants. The present thesis took a second-person approach to mind reading and investigated whether infants in their second year also actively use their sensitivity to others' beliefs when interacting with other people. In particular, I asked whether infants would anticipate others' belief-based actions and spontaneously communicate relevant information through pointing. Infant pointing was introduced as an advantageous method of testing mindreading abilities since it involves an overt response and hence, also involves a choice between relevant locations on behalf of the infants. This method allows us to differentiate between self and other perspective in false belief paradigms. The results of the studies reported in this thesis (Chapters 2-4) revealed that infants indeed not only recognize others' beliefs, but also actively use their appreciation of others' beliefs in contextualized second person interactions. In particular, infants' spontaneous pointing behavior was shown to be dependent on the particular knowledge state of the adults with whom they were interacting.

The first study (Chapter 2) investigated if 18- and 24-month-old infants correct an adult who is mistaken about the location of an object in anticipation of her searching in the wrong location. Results revealed that both age groups corrected the adult when she was mistaken about the object's location by pointing to the object's new location. In contrast, they did so significantly less when the adult knew about the object's new location and when it was not her intention to find the object (Different action condition, 18-month-olds only). This study provides evidence that, by 18 months, infants take others' intentions and knowledge states into account when responding to their actions.

The second study (Chapter 3) asked whether 12- and 18-month-old infants inform an adult about the reappearance of an aversive object in anticipation of her encountering it again. Results revealed that the majority of infants in both age groups informed the adult when she was mistaken about the object's location. In contrast, they informed her significantly less when she either knew about the object's reappearance, or when she had introduced the object as positive as opposed to aversive. These results suggest that already by 12 month of age, infants tailor their responses to what others' know or do not know. In addition, infants were shown to take into account the adult's emotional attitude (positive or negative) towards the object in their responses. This is therefore the first study to show that preverbal infants can also use the pointing gesture to draw people's attention to things that should be avoided (as is typical in the case of warning) as opposed to things that should be approached.

Finally, the third study (Chapter 4) aimed at directly investigating false belief. Since the results of the studies presented in Chapter 2 and 3 might also be alternatively explained by an ignorance interpretation, the logic of the third study was designed such that a single testing situation was able to differentiate between false belief and ignorance interpretations. This study examined whether 18-month-old infants inform an adult differently about two contaminated locations depending on her holding a false belief or her being ignorant about the location of her toy. Results showed that infants informed an adult specifically about the contaminated location which she falsely believed to hold her toy. In contrast, they informed an adult about both contaminated locations equally when she was ignorant about the location of her toy. These results suggest that by 18 months, infants are capable of differentiating between a person who is ignorant versus a person who holds a false belief, and further that they intervene accordingly. Together, these studies consistently show that infants use their theory of mind abilities and tailor their communicative acts accordingly.

The majority of researchers investigating theory of mind development in infancy adhere to information processing accounts, which propose that infants come to grips with others' inner motives for action through an inborn psychological reasoning system, association, or the application of rules (e.g. Scott et al., Perner, 2010, Perner & Ruffman, 2005). However, these interpretations are based on experimental results which are stripped to the level of looking times. In contrast, the results of the interactive studies presented in this thesis (Chapters 2-4) demonstrate that information processing accounts fail to completely capture the full range of infants' mindreading abilities.

The recurrent finding that infants are able to communicate their sensitivity to others' beliefs spontaneously and appropriately across different contexts, provides evidence that social processes as practised in second person engagements play a crucial role in the development of mindreading.

Whereas information processing accounts to mindreading (as well as looking based methods) are primarily concerned with infants' comprehension of others' minds, a second person approach incorporates infants' responsiveness to others' minds. This is not to say that associations or rules are not at all involved in infants' productive mindreading abilities. For example, associations such as actor-object-location associations might very well contribute to infants' success on various false belief tasks, including interactive tasks. However, by themselves, these associations are not enough to explain why infants are motivated to initiate communicative responses such as pointing. This becomes particularly clear, when one considers the fact that, in the current thesis, infants processed a whole range of object-actor-location associations throughout the experimental procedures which did not lead to pointing (see, for example, the Procedure section in Chapter 4), which made them point significantly less (Correct action condition, Chapter 2; No problem condition, Chapter 3), or which made them point at random (Ignorance condition, Chapter 4). Associations alone are unable to explain the pattern of infant pointing across conditions. It is more likely that infants learnt both when to point and what to point at through participation and engagement with others. Moreover, the first study (Chapter 2, Different action condition) showed that intention understanding is able to trump actor-object-location associations (see also Luo & Baillargeon, 2007; Song & Baillargeon, 2008; Surian et al., 2007 and Senju, Southgate, Snape, Leonard & Gergely Csibra, 2011 for evidence against association explanations; for evidence against rule-based explanations, see Träuble et al., 2010; Song, Onishi, Baillargoen & Fisher, 2008; Friedman & Petrashek, 2008). Thus, the evidence collected in this thesis goes beyond information processing capacities and demonstrates that, from the beginning of their second year, infants sensitivity to others' beliefs is manifested in their own actions. According to a second person approach, infants experience from the very beginning, that that they are the object of others' attention. It is through embodied interactions that they learn to act according to their sensitivity to others' beliefs. Such an approach is beneficial since it avoids the alleged distinction between mental understanding and behaviour (see Chapter 1). The distinction can be eliminated if one adheres to the notion that perceiving others' actions entails mentality. This differs greatly from information processing accounts which view action perception as involving merely the processing of abstract features. That is, infants' processing of others' actions is understood as being as much affective and mentalistic as it is cognitive. These assumptions further provide the opportunity to (a) describe and understand theory of mind development in a continuous manner, ranging from a minimal understanding (e.g. sensitivity to others' attentional states) to a more complex understanding (e.g. justifying false beliefs) and (b) to avoid the division between first person experience and second person ascription.

Appropriately characterizing the exact level and nature of infants' mindreading abilities still needs to be addressed in future research. The majority of researchers studying theory of mind currently agree that infants' mindreading skills do not amount to adults' full-blown mindreading in the standard sense of representing and ascribing (*intentional*) mental states with propositional (*intensional*) content. Instead, many believe that infants' mindreading abilities can be accounted for based on more simplistic explanations, for example by asserting that a infants track belief-like states (Apperly & Butterfill, 2009; Spaulding, 2011), only have perceptual access reasoning (Hedger & Fabricius, 2011; Fabricius & Imbens-Bailey, 2000), or are sensitive to others' action affordances (Bruin, Strijbos & Slors, 2011). Thus, the question that will likely take centre stage in future research is whether and to what extent infants' sensitivity to others' beliefs involves full-blown mindreading or is achieved by other means (Hutto, Herschbach & Southgate, 2011).

**5. 1. Conclusion**

In summary, the present thesis provides evidence that second person engagements and social interactions play a leading role in the development of mindreading. The results showed that infants in their second year are not only sensitive to others' beliefs when passively watching others, but also actively and appropriately respond to others' beliefs in contextualized interactions. This suggests that pure information processing accounts are insufficient in explaining mindreading abilities in infancy. Such accounts might be better informed by embracing the assumption that behaviour cannot be separated from its psychological meaning, hence, behaviour-reading and mindreading develop concurrently along a continuum which begins with a simple understanding, and develops towards a more complex understanding through experience in second person engagements.

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## Samenvatting

Als volwassenen interpreteren we het gedrag van anderen doorgaans door het toeschrijven van mentale toestanden, bijvoorbeeld geloofsovertuigingen. Deze eigenschap wordt ook wel 'theory of mind' genoemd of meer algemeen 'mindreading'. Uit onderzoek van de laatse 30 jaar blijkt dat deze vaardigheid rond het vierde levensjaar aanwezig is (Wellman et al., 2001). Echter, recente studies die kijkgedrag hebben gemeten, suggereren dat theory of mind-vaardigheden al veel vroeger aanwezig zijn (e.g. Kovács, Téglás & Endress, 2010; Onishi & Baillargeon, 2005; Southgate, Senju, Csibra, 2007; Surian, Caldi & Sperber, 2007). Deze studies hebben aangetoond dat kinderen al in hun tweede levensjaar gevoelig zijn voor verschillende mentale toestanden van anderen zoals bijvoorbeeld juiste aannames (true beliefs), onjuiste aanames (false beliefs) en onwetendheid (ignorance). Een beperking van deze studies (en hun interpretaties) is echter dat ze uitsluitend gericht zijn op het cognitieve vermogen van het kind om informatie te verwerken. De kinderen in deze studies hebben alleen passief naar anderen gekeken, maar hebben zelf niet actief meegedaan. Het doel van dit proefschrift is te onderzoeken of kinderen in hun tweede levensjaar hun gevoeligheid voor de mentale toestanden van anderen ook actief kunnen gebruiken als ze met iemand anders interacteren, namelijk in sociale interacties. De vraag is in het bijzonder of kinderen in staat zijn om hun sensitiviteit voor wat anderen weten of niet weten (de mentale toestand) expliciet te maken door wel of niet te wijzen naar dingen die binnen de interactie relevant waren, zoals speelgoed.

In de eerste studie is onderzocht of kinderen van 18 en 24 maanden oud de onderzoekster informeren over de verplaatsing van een stuk speelgoed, afhankelijk van haar mentale toestand (dat wil zeggen, de onderzoekster weet dat het speelgoed verplaatst is versus ze weet het niet) en haar intentie (de onderzoekster wilde spelen met het speelgoed of ze wilde schoonmaken). Uit de resultaten blijkt dat kinderen in beide leeftijdsgroepen de onderzoekster informeren over de verplaatsing van het speelgoed door te wijzen naar de nieuwe plek – maar alleen als de onderzoekster niet weet dat het verplaatst is. Ook als het niet de intentie van de onderzoekster is om met het speelgoed te gaan spelen (maar in plaats daarvan schoon te maken), informeren de kinderen haar niet over de verplaatsing. Dit toont aan dat kinderen van 18 maanden in hun communicatie rekenig houden met de intenties van de ander en met wat de ander wel of niet weet (de mentale toestand).

In de tweede studie is onderzocht of 12 en 18 maanden oude kinderen de onderzoekster waarschuwen over de verplaatsing van een aversief voorwerp. Tijdens het onderzoek speelde de onderzoekster met een knikkerbaan, vond daarbij een vies voorwerp en ruimde het op. Vervolgens werd het voorwerp door een tweede onderzoekster weer teruggelegd, toevallig op dezelfde plaats als voorheen. Dan keert de eerste onderzoeker weer terug en wil doorgaan met spelen. De resultaten laten zien dat beide leeftijdsgroepen naar het vieze voorwerp wijzen indien de onderzoekster niet weet dat het voorwerp weer terug werd gelegd. Echter, de kinderen wijzen significant minder naar het voorwerp als de onderzoekster weet dat het aversieve voorwerp terug werd gelegd of als de onderzoekster het voorwerp niet vies vond maar juist positief waardeerde: ze vond het mooi of zacht. Deze resultaten laten zien dat kinderen niet alleen hun reacties aanpassen aan wat hun interactiepartner wel of niet weet, maar dat ze daarnaast ook rekening houden met de emotionele houding (positieve of negatieve waardering) van hun interactiepartner.

In de derde en laatste studie werd specifiek gekeken naar de mentale toestand ’onjuiste aanname’ (false belief) in vergelijking met ’onwetendheid’ (ignorance). Het onderzoek begint met een onderzoekster die met een speelgoed speelt in twee dozen die naast de tafel staan. Voordat ze even weggaat, ruimt ze een vies voorwerp op en laat ze haar speelgoed op één van twee dozen achter. Tijdens haar afwezigheid komt een tweede onderzoekster, neemt het speelgoed mee en plaatst tijdens het schoonmaken in beide dozen een vies voorwerp en gaat weer weg. Als de tweede onderzoekster weg is komt de eerste onderzoekster weer binnen en wil doorgaan met spelen. De vraag is of 18 maanden oude kinderen de onderzoekster informeren over het vies voorwerp in de doos waarin ze haar speelgoed verwacht. Het blijkt dat kinderen bij terugkomst van de onderzoekster inderdaad vooral naar het vies voorwerp in de doos wijzen waarop de onderzoekster denkt haar speelgoed weer te kunnen pakken. Echter, wanneer de onderzoekster vlak voor ze weggaat het speelgoed aan de tweede onderzoekster overhandigt (en dus onwetend is over waar het speelgoed precies geplaatst gaat worden), wijzen de kinderen bij terugkomst naar de viese voorwerpen in beide dosen even vaak. Dit laat zien dat kinderen een verschil maken tussen onjuiste aannames (false belief) en onwetendheid (ignorance) en dat ze dienovereenkomstig reageren.

Samenvattend laat dit proefschrift zien dat kinderen onderscheid maken tussen een interactiepartner die een 'false belief' of een 'true belief' heeft of 'ignorant' is en bovendien dat ze hiermee gepast om kunnen gaan door behulpzame informatie te verstrekken. Deze resultaten zijn echter niet goed te verklaren vanuit cognitieve informatieverwerkingstheorieën. De bevinding dat kinderen hun gevoeligheid voor mentale toestanden van anderen ook spontaan kunnen gebruiken in verschillende communikatieve situaties, zoals alledrie de studies uitwijzen, bewijst dat sociale processen een cruciale rol spelen in de ontwikkeling van theory of mind vaardigheden.

## Curriculum Vitae

Birgit Knudsen was born in Heide (Germany), on 1st of October 1975. She studied art therapy (B.A.) at the Hogeschool van Arnhem en Nijmegen, psychology (B.A.), Cognitive Neuroscience (MSc.) and philosophy (B.A.) at the Radboud University Nijmegen and participated in the Honours program (Honours bul) at the Radboud University Nijmegen throughout the years 1997 to 2008. In 2008 she started a Phd project on social cognition in the Communication Before Language Group of the Max Planck Institute for Psycholinguistics. Currently, she is a post-doc at the Universität des Saarlandes, Philosophische Fakultät III, Empirische Humanwissenschaften.

## Publications

Knudsen, B. & Liszkowski, U. (in press). 18- and 24-month-old infants correct others in anticipation of action mistakes. *Developmental Science*.

Knudsen, B. & Liszkowski, U. (under revision). One-year-olds warn others about negative action outcomes.

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