

2014•2015  
FACULTEIT GENEESKUNDE EN LEVENSWETENSCHAPPEN  
*master in de revalidatiewetenschappen en de  
kinesitherapie*

## Masterproef

Action prediction in infants is not based on gaze cues: an eye tracking study

Promotor :  
Prof. dr. Marleen VANUCHELEN

Copromotor :  
Mevrouw Lise VAN SCHUERBEECK

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*Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen  
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## **Context of the Research Project**

Autism spectrum disorder (ASD), further referred to as 'autism' is one of the most frequent neurodevelopmental disorders in childhood with prevalence rates ranging between 0.6 and 1.16 percent<sup>1</sup>. Autism is characterized by impairments in social interaction, in communication skills and in behavior, which is restricted and repetitive<sup>1</sup>. Although the onset of the disorder is before three years of age, the average age at first diagnosis is often not prior than school-age<sup>2</sup>. Early identification of autism can lead to earlier entry into intervention programs that can support improved developmental outcome<sup>3</sup>.

The present master thesis is part of the doctoral project of L. Van Schuerbeeck, *Through A Kid's Eyes: Is the association between action observation and imitation altered in young children with autism spectrum disorders?* This project on autism spectrum disorders is realized in REVAL, rehabilitation research center of Hasselt University (Prof. Dr. M. Vanvuchelen) in collaboration with the Leuven Autism Research (LAuRes) Consortium. Previous work of the autism research group of REVAL on imitation problems in autism has advanced the diagnostic process to preschool age<sup>4-13</sup>. Recently, the recurrence risk for later-born siblings of children with autism is estimated to be nearly 20 percent<sup>14</sup>. Therefore, it is important to study precursors of imitation problems in infants and toddlers at risk for autism.

In the explorative work package of the doctoral project the action-observation-action-execution model is studied in a reference group of typically developing children. The model predicts that children detect both the person and the object (detection) during the observation of an adult's action upon an object. Furthermore, the model predicts that children identify critical motor referential cues which indicate the adult's intentions regarding the object (intention identification). As a result of this style of action observation, similar action patterns are activated in the children (simulation) and these action patterns provoke spontaneous imitation. In the clinical work package a group of infants and toddlers with autism and at risk for autism are studied. The newly acquired knowledge is used to investigate whether these children have altered associations of detection and/or intention identification and/or simulation and/or imitation as compared with their typically developing peers. The results of this research project may lead to increased insight in altered functional connectivity within the action observation-action-execution network in children with autism, which may contribute to an earlier identification of autism.

The present study is part of the above mentioned explorative work package. Gaze following and action prediction based on a gaze cue are investigated in typically developing infants between 12 and 24 months of age. This was done with the use of the Tobii T120 eye tracking technology (Tobii T120, Tobii Technology, Stockholm).

This master thesis was written by Janne Bamps and Liese Geerts, two students of the master program in Rehabilitation Science and Physiotherapy, Hasselt University, supervised by Prof. dr. M. Vanvuchelen (promoter) and Dra. L. Van Schuerbeeck (co-promoter). The research protocol and



questions were set in consultation with the promoter and co-promoter. Last year, data were collected by the co-promoter, a thesisstudent whose research was also part of the explorative work package (K.S.), a student Biomedical Sciences (L.V.) who did his internship in REVAL and the students who wrote this thesis (J.B. and L.G.). A part of the data analysis was done by both students separately. Statistical analysis and interpretation of the outcomes were done by both students together, with the assistance and support of the co-promoter. This master thesis was proof read by Prof. dr. M. Vanvuchelen and Dra. Lise Van Schuerbeeck. With the help of their comments and suggestions the students were able to finalize this master thesis.

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## **Abstract**

To investigate whether infants are able to use an adult's gaze shift towards an object to predict his/her upcoming action, an eye tracking study was performed in 39 infants between 12 and 24 months of age. Infants saw a video clip of a model who was sitting at a table with two bowls in front of her. In the beginning of the clip the model's eyes were oriented towards the table and after approximately one second she looked right into the camera (baseline phase). Next, she shifted her gaze towards one out of the two bowls (gaze direction phase). Finally, infants saw the model who was holding a ball right in front of the bowls (test phase). We predicted that infants will follow the adult's gaze shift and will look at the cued bowl in both the gaze direction and test phase. To analyze the eye tracking data, areas of interest (AOI's) were created around the model's face, the two bowls and the ball. Two measures were obtained: the first gaze shift and looking duration towards one of the AOI's. Results show that infants look more often and longer towards the cued bowl in the gaze direction phase. In contrast they did not show this behaviour in the test phase. These findings suggest that, although infants follow the adult's gaze towards an object, they do not use this information to predict the adult's upcoming action. An explanation might be that infants need additional cues to predict observed actions.

**Key words:** Infants, eye tracking, gaze following, action prediction.



## Introduction

Social cognition describes the internal cognitive processes by which individuals understand how people, including both others and the self, behave (Moore, 2010). Perception, attention, memory and action planning are, among others, examples of internal cognitive processes (Frith, 2008). These processes enable individuals to interact with each other (Frith & Frith, 2007). During human interactions many different signals emerge. It is of great importance that we take up these signals as they give us valuable information about others and the environment. For example, we can learn about the feelings and emotions of others by paying attention to their facial expression. Based on body movements we can determine what another individual is going to do. By monitoring someone else's gaze, we receive information about what the other is attending to (Frith & Frith, 2007).

In the development of social cognition it is essential that infants develop a strong relationship with their primary caregivers, this allows them to quickly learn how to interact effectively with other people (Van Hecke et al., 2007; Moore, 2010). Interacting with others plays an important role in the development of social cognitive skills such as the ability to understand, describe and predict people's mental states (Moore, 2010).

An important mechanism that enables infants to interact with others is joint attention. Joint attention occurs when two or more subjects direct their attention towards the same external object (Brooks & Meltzoff, 2014). In early development gaze following, among others, is an important mechanism for perceiving joint attention. "Gaze following refers to the act of following another person's line of regard" (Brooks & Meltzoff, 2014). Following another person's gaze gives us the ability to understand what the other is feeling, thinking or intending to do (Brooks & Meltzoff, 2005). For example, a person is sitting at a bar with an empty glass. When the waiter passes, the person shifts his gaze from the waiter's face towards the empty glass. Due to that gaze shift the waiter is able to make an assumption about the intentions of the other: e.g. that person wants another drink. It is important to notice that gaze following is a complex act in which the relation between the observer and the object of his/her gaze has to be perceived. For example, it is not gaze following when an infant and a parent simultaneously look at a barking dog, because this looking behaviour is provoked by a third component namely the noise the dog produces. Neither is it gaze following if only head movements or body rotations are followed without perceiving the eye movements (Brooks & Meltzoff, 2014).

The significance of gaze finds its origin in a very early stage of life. Infants between two and six months of age tend to look more to the eyes in comparison to other facial features. They are able to notice other individuals' shifts in gaze direction and use in some cases this gaze shift to direct their own attention (Paulus, 2011; Woodward, 2003). From six months on these abilities become more mature (Woodward, 2003). However, at this age it can be that infants respond to the adult's head rotation instead of the adult's eye movements. This behaviour is seen until infants are approximately nine months of age (Brooks & Meltzoff, 2014). From ten months on infants start to see their social partner as a visual perceptive agent, making gaze following possible (Meltzoff & Brooks, 2007; Brooks & Meltzoff, 2014). The brain areas responsible for gaze following are the superior temporal sulcus, the

subcortical pathway, the extended social processing networks and the frontoparietal attention networks (Sheperd, 2010).

Besides gaze following another important social cognitive skill is to predict other people's actions (Moore, 2010). Action prediction can be defined as "predicting another's action before it is actually executed" (Lan, Chen & Savarese, 2014). One method to investigate action prediction is the registration of predictive eye movements (Boria et al., 2009). Predictive eye movements can be defined as "an eye movement which is directed towards a certain location before an event occurs" (Green, 2014). For example: when you are thirsty and want to pick up a glass of water that is located on the bar, you first look at the glass before initiating the pickup action. A similar mechanism is used when observing another person's hand reaching towards an object. The observer's eye movements reach the object before the actor's hand will do. The study of Falck-ytter, Gredebäck and von Hofsten (2006) shows that six-month-old infants are not yet able to perform predictive eye movements when observing a hand-object interaction. In contrast, this study shows that twelve-month-old infants use predictive eye movements in a similar way as adults. The brain area responsible for action prediction is the so called mirror neuron system (MNS) (Ramsey, Cross & Hamilton, 2012). This system consists of the anterior intraparietal sulcus (aIPS) and the premotor cortex. The MNS is recruited when motions from body parts e.g. finger or limb motions, are observed (Van Overwalle & Baetens, 2009).

The ability to predict another person's upcoming action based on his/her gaze shift is already extensively investigated in adults using functional magnetic resonance imaging (fMRI). Studies showed that observing another person's gaze enables the observer to determine the goals of the model. Pierno, Mari, Glover, Georgiou, and Castiello (2006) conducted a fMRI study in which participants saw video clips with three different conditions. In the first condition, the model gazed towards an object and grasped it. In the second condition, the model only gazed towards an object, no grasp action was performed. In the third condition, the model did not gaze towards the object and no grasping action was present. They found that observing another person's gaze towards an object (second condition), activates parts of the same network as when an individual observes a grasping action (first condition). These findings were confirmed by Ramsey et al. (2012), who also performed a fMRI study. In this study, participants saw short videos consisting of two phases: a gaze and a grasp phase. In the first phase, the model gazed towards an object on an empty table. In the second phase, the model either reached to grasp the object or reached towards the empty table. They found that in adults, perceiving someone else's gaze activates a part of the MNS, namely the left anterior inferior parietal lobule (aIPL) and the parietal operculum. This suggests that in adults the MNS not only enables action prediction based on a hand-object interaction but also enables action prediction based on a gaze cue. However, it is unclear if these results can be generalized to children. A few studies regarding gaze behaviour and action prediction in children have been performed. In the above mentioned fMRI study, children between ten and thirteen years of age also use the gaze direction of an adult to determine the goal of this adult (Pierno et al., 2006). Paulus (2011) did an eye tracking study in fourteen-month-old infants to determine if infants, like adults, are able to predict the goal of a model based on the looking behaviour of that model. In this experiment, 32 fourteen-month-old infants were divided into two groups. The first group saw a video clip in which a model gazed four times

towards one out of two objects. The second group saw a video clip in which a model grasped one out of two objects. Afterwards both groups saw a picture of the model and both objects. Predictive eye movements of the infants towards the object which the model previously gazed at/grasped were measured. The result of the study was that fourteen-month-old infants are able to make predictive eye movements towards an object after seeing the goal-directed action of the model. In contrast, they did not make predictive eye movements towards an object after seeing the model gazing at the object. This implies that fourteen-month-old infants are not able to predict an action based on a gaze cue. We wanted to investigate action prediction based on an adult's gaze cue in a broader age range, namely between the age of 12 to 24 months of age. This was done by measuring eye movements of 39 typically developing infants.

## **Method**

### *Participants*

The final sample consisted of 39 typically developing infants between 12 and 24 months of age (mean age: 17.0 months, SD 2.9) and were recruited from and tested in a day care center (Hasselt, Belgium). Inclusion criteria were: (1) at least one Dutch speaking parent (2) no diagnosis of a developmental disorder (3) no visual abnormalities (e.g. strabismus). An additional infant was excluded from the data analyses because of technical difficulties during the eye tracking procedure. Parents of the infants received information and signed an informed written consent prior to their participation. The study was approved by the medical ethics committee of the Catholic University of Leuven and University Hasselt. (B322201215699)

### *Developmental scale*

The Bayley Scales of Infant and Toddler Development- Dutch version third edition (Bayley-III-NL) was administered. The Bayley-III-NL is a valid scale to determine the mental and motor developmental level of infants between 16 days and 42 months of age (Steenis, Verhoeven, & Van Baar; 2013).

### *Experimental setup and eye-tracking procedure*

The experiment was conducted in a stimulus-free room at the day care center. In the center of the room, a car seat was placed. In front of the car seat at a distance of approximately 65 centimeter, an eye tracker Tobii T120 (Tobii T120, Tobii Technology, Stockholm) was installed (figure 1). The Tobii T120 eye tracker is integrated in a 17" inch TFT monitor. The x and y coordinates of the eye position are determined by the corneal reflection of an infrared signal. These signals are recorded at 120 Hz. In optimal circumstances, the accuracy and precision are 0.16° and 0.4° of visual angle. Tolerance of large head movements allows subjects to move freely and naturally in front of the screen. The computers needed for the registration and processing of the eye tracking results were set up left of the car seat and were concealed from the infant's view by a white sheet.





**Figure 1** *Test environment at the day care center.*

The infants entered the room with their caregiver and were placed in the car seat. The caregiver took place on the little chair next to the infant. To attract the attention of the infant to the screen, a fragment of a children's program called 'Bumba' was displayed. When the infant was looking towards the screen, the fragment of 'Bumba' was closed and a five-point calibration was performed. The calibration consisted of five sound making, colorful and spinning figures that were shown in each of the corners and in the center of the screen. The calibration was considered successful if the infant looked at four out of five figures.

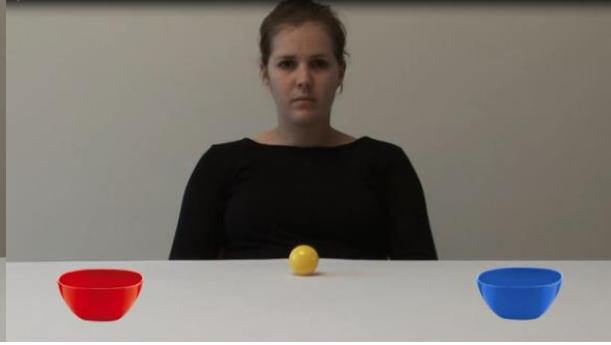
### *Stimuli*

After a successful calibration, eight video clips with each a duration of approximately nine seconds were shown in a randomized order. In these clips, a female model with a black shirt and her hair tied back was shown. The model was sitting in front of a white wall and behind a white table. Two bowls of the same size but with a different color (red and blue) were placed left and right on the table. A yellow ball was placed on the table right in front of the model. Each of the eight trials consisted of three different phases: the baseline phase, the gaze direction phase and the test phase.

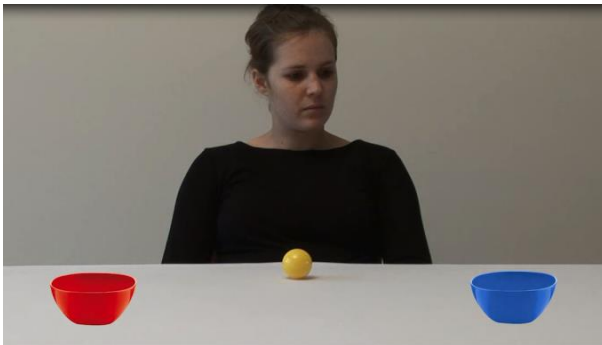
In the baseline phase, the model's eyes were directed towards the table for approximately one second (figure 2a). Subsequently the model looked right into the camera for approximately one second (figure 2b). In the gaze direction phase, the model turned her head left or right towards one of the two bowls (termed as the cued bowl) and looked at it for approximately three seconds (figure 3). In half of the video clips, the blue bowl was on the right side and in the other half the blue bowl was on the left side of the table. In the test phase, a picture of the model was shown for approximately three seconds. In this picture the model was holding the ball right in front of her body and her eyes were oriented towards the ball, suggesting that she wants to put the ball into one of the bowls. Both bowls were either placed in their initial positions (figure 4a) or placed in the reversed positions (figure 4b). The model always held the ball in the hand that was nearest to the cued bowl.



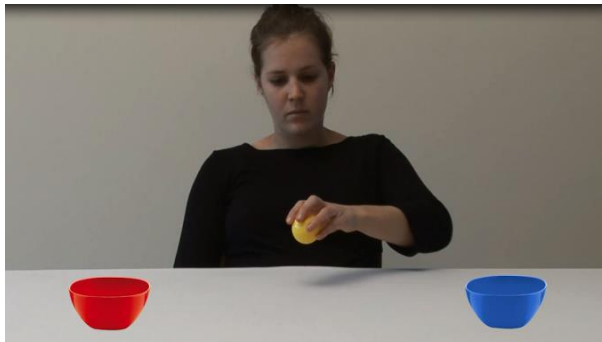
**Figure 2a** *Start of the baseline phase.*



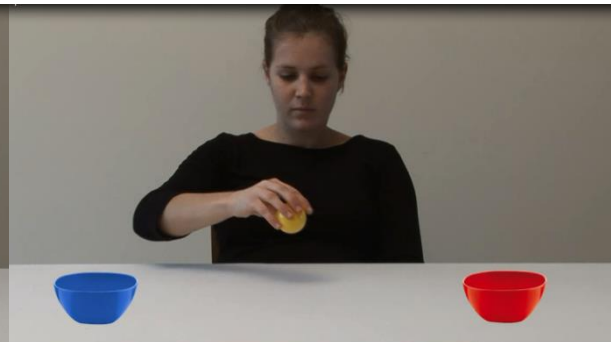
**Figure 2b** *End of the baseline phase.*



**Figure 3** *Gaze direction phase: the cued bowl is the blue one and the noncued bowl is the red one.*



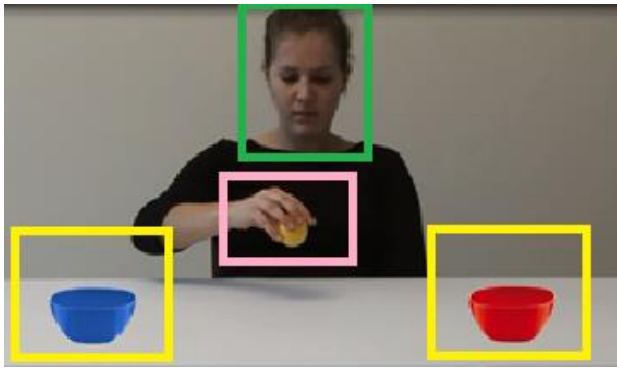
**Figure 4a** *Test phase: bowls in their initial position.*



**Figure 4b** *Test phase: bowls in the reversed position.*

#### *Data and statistical analysis*

Eye-tracking data were analyzed using a Matlab-based routine, developed by researchers at Uppsala University ([www.timestudioprojects.com](http://www.timestudioprojects.com)). For this purpose areas of interest (AOI) were created around the model's face, which measured 5.70° of horizontal visual angle and 7.89° of vertical visual angle and around each of the two bowls, which measured 7.89 of horizontal visual angle and 5.70° of vertical visual angle. During the test phase, an extra AOI was created around the ball which measured 6.52° of horizontal visual angle and 4.35° of vertical visual angle. A visual representation of the AOIs is shown in figure 5.



**Figure 5** *Visual representation of the AOIs of the face, bowls and ball.*

In the baseline phase, preliminary analyses were done by registering looking duration towards AOIs to determine if there was a difference in attention between the face AOI, left and right bowl AOIs and blue and red bowls AOIs. To determine if there was a difference in attention between the face, left bowl and right bowl, blue bowl and red bowl, a Friedman test for several related samples and afterwards a post hoc Wilcoxon Signed Ranks test was done.

In the gaze direction and test phase, the analyses of the first gaze shift of the infants were used. Gaze is defined as “attentive looking at something” (Binder, Hirokawa & Windhorst, 2009). In our study the first gaze shift is defined as the first shift in gaze which is made after looking towards the face AOI (gaze direction phase) respectively ball AOI (test phase). During the gaze direction phase, the first gaze shift was included if the infants fixated the face AOI for at least 200 ms before looking towards the AOI of one of the bowls to make sure that they had seen the gaze shift of the model.

During the test phase, the first gaze shift was included if infants fixated the ball AOI for at least 200 ms before looking towards the AOI of one of the bowls, this was done to make sure that they had seen the ball. Afterwards, difference scores for the amount of first gaze shift (DS “amount”) were calculated. Infants received a score of one if they looked towards the cued bowl, a score of minus one if they looked towards the noncued bowl, a score of zero if they did not look towards one of both bowls (Paulus, 2011). For all eight trials, the maximum DS “amount” infants could accomplish was eight, the minimum DS “amount” infants could accomplish was minus eight. In addition to the first gaze shifts, looking durations towards the cued and noncued bowl were included in the analyses. Similar to the first gaze shift, difference scores for looking duration (DS “looking duration”) were calculated. In each trial the looking duration of the infants was assigned as a positive value if they looked towards the cued bowl, a negative value was assigned if they looked towards the noncued bowl. A positive DS “looking duration” means that in total the infant looked longer towards the cued bowl.

Both in the gaze direction and test phase, five different analyses were done (Table 1). The first analysis was done using the DS “amount” and DS “looking duration” of all eight trials. The DS “amount” and DS “looking duration” were also used in the second and third analysis. In the second analysis the four trials where the bowls stayed in their initial position were analyzed. The third analysis was performed with the data of the four trials where the bowls were placed in the reversed position. The two previously mentioned analyses were executed to determine if the location of the bowls

influenced the gaze behaviour of the infants. In the fourth analysis, only the first trial of each infant was analyzed to prevent that the results were influenced by a possible decrease in attention towards the end of the session. This analysis was done by using the first gaze shift and looking duration towards the cued bowl. These two variables were also used in the fifth analysis, where the first trial of each infant in which they scored one in the gaze direction phase was analyzed. This was done to make sure that the gaze direction of the infants towards the cued bowl in the test phase is the result of gaze following in the gaze direction phase. In the latter analysis, was a drop-out of eight infants because they never looked towards the cued bowl in the gaze direction phase. A schematic overview of all analyses can be found in table 1.

**Table 1** Schematic overview of the five different analyses

<b>Analysis</b>	<b>Analyzed trials</b>	<b>Used variables</b>
<b>1</b>	All 8 trials taken together	DS “amount”, DS “looking duration”
<b>2</b>	4 trials with the bowls in their initial position	DS “amount”, DS “looking duration”
<b>3</b>	4 trials with the bowls in the reversed position	DS “amount”, DS “looking duration”
<b>4</b>	The first trial of each infant	First gaze shift and looking duration towards the cued bowl
<b>5</b>	The first trial in which each infant scored one in the gaze direction phase (drop out of 8 infants)	First gaze shift and looking duration towards the cued bowl

The five previously mentioned analyses were done using a one sample Wilcoxon Signed Rank test. In the gaze direction phase, this was done to measure gaze following. In the test phase, this was done to measure gaze following towards the previously cued bowl.

To investigate the correlation between overall development (age in months, Bayley-III-NL raw scores) and gaze behaviour (DS “amount” of the gaze direction phase, DS “looking duration” of gaze direction phase, DS “amount” of the test phase, DS “looking duration” of the test phase) a Spearman’s Rho correlation coefficient was calculated. These coefficients were interpreted according to Hinkle, Wiersma & Jurs (2003). Values below .30 were interpreted as little if any correlation, values between .30 and .50 as low correlation, between .50 and .70 as moderate correlation, above .70 as high correlation and above .90 as very high correlation.

## **Results**

### *Baseline phase*

During the baseline phase, the Friedman test revealed a significant difference ( $\chi^2= 59.279$ ,  $p < .001$ ) in looking duration between the face, the left and right bowl. The post hoc Wilcoxon Signed Rank test showed that the infants looked longer at the model's face in comparison with the left ( $Z = -5.373$ ,  $p < .001$ ) and right bowl ( $Z = -5.373$ ,  $p < .001$ ). Looking duration between the left and right bowl ( $Z = -.277$ ,  $p = .782$ ) and between the blue and the red bowl was not significantly different ( $Z = -1.468$ ,  $p = .142$ ), indicating neither a left/right preference, nor a color preference.

#### *Gaze direction phase*

In the first analysis, in which all eight trials were analyzed, a one sample Wilcoxon Signed Rank test revealed a DS "amount" ( $p = .001$ ) and a DS "looking duration" above zero ( $p = .001$ ) towards the AOI of the cued bowl, indicating general appearance of gaze following behaviour towards the cued bowl over the eight trials. In the second analysis in which the four trials with the bowls in their initial position were analyzed, a one sample Wilcoxon Signed Rank test revealed a DS "amount" ( $p = .004$ ) and a DS "looking duration" ( $p = .006$ ) towards the AOI of the cued bowl above zero, indicating general appearance of gaze following behaviour towards the cued bowl over the four trials. In the third analysis in which the four trials with the bowls in the reversed position were analyzed, a one sample Wilcoxon Signed Rank test revealed a DS "amount" ( $p = .029$ ) and a DS "looking duration" ( $p = .011$ ) towards the AOI of the cued bowl above zero, indicating general appearance of gaze following behaviour towards the cued bowl over the four trials. The fourth analysis in which the first trial of each infant was analyzed shows a trend towards a positive amount in first gaze shifts ( $p = .052$ ) towards the AOI of the cued bowl which suggests that the infants tend to follow the adult's gaze towards the cued bowl. In the fifth analysis only infants who looked towards the AOI of the cued bowl in the gaze direction phase were analyzed, therefore gaze following in the gaze direction phase of this analysis was 100%.

#### *Test phase*

In the first analysis in which all eight trials were analyzed, a one sample Wilcoxon Signed Rank test revealed a DS "amount" ( $p = .263$ ) and a DS "looking duration" ( $p = .881$ ) towards the AOI of the cued bowl not significantly above zero, indicating that in general infants did not tend to look towards the cued bowl. The same was true for the second analysis in which the four trials with the bowls in their initial position were analyzed (DS "amount",  $p = .209$  and a DS "looking duration",  $p = .273$ ), and the third analysis in which the four trials with the bowls in the reversed position were analyzed (DS "amount",  $p = .873$  and a DS "looking duration",  $p = .732$ ). In the fourth analysis in which the first trial of each infant was analyzed, the amount of first gaze shift ( $p = .180$ ) and looking duration ( $p = .500$ ) towards the AOI of the cued bowl showed also no significant  $p$ -value. The same was true for the fifth analysis, where the amount of first gaze shift ( $p = .763$ ) and looking duration ( $p = .541$ ) towards the AOI of the cued bowl, indicate that in general infants did not tend to look towards the cued bowl in the test phase despite that they followed the model's gaze in the gaze direction phase.

#### *Correlations*

Both in the gaze direction and test phase the Spearman's Rho correlation coefficient revealed low correlations, between overall development (age, Bayley-III-NL scores) and gaze behaviour (DS "amount" of the gaze direction phase, DS "looking duration" of gaze direction phase, DS "amount" of the test phase, DS "looking duration" of the test phase). In contrast, there are strong and statistical significant correlations between the different developmental variables. An overview of the correlation coefficients can be found in table 2.

**Table 2** Correlation matrix of overall development and gaze behavior

	Age	AGP	LDGP	ATP	LDTP	GM	FM	TM	COG
Age	-								
AGP	.221	-							
LDGP	.193	.786**	-						
ATP	-.151	.002	.181	-					
LDTP	-.164	.023	-.025	.772**	-				
GM	.751**	.111	-.009	-.001	-.100	-			
FM	.810**	.154	.119	.083	.015	.663**	-		
TM	.868**	.137	.051	.005	-.103	.958**	.810**	-	
COG	.877**	.072	.090	-.095	-.128	.740**	.838**	.851**	-

AGP: DS "amount" gaze direction phase, LDGP: DS "looking duration" gaze direction phase, ATP: DS "amount" test phase, LDTP: DS "looking duration" test phase, GM: Gross motor raw score (Bayley-III-NL), FM: fine motor raw score (Bayley-III-NL), TM: total motor raw score (Bayley-III-NL), COG: cognition raw score (Bayley-III-NL). \*\* correlation is significant at the level of .01 (two-tailed).

## Discussion

The prediction of an observed goal-directed action with an object, for instance drinking from a filled glass, based on the actor's gaze shift towards that particular object is an important social cognitive skill that adults use daily to understand and foresee what other people are doing. Action prediction helps us to make sense of other people's behaviour, which is important during social interaction (Moore, 2010). The present study was set up to investigate, on the base of eye tracking data, whether or not infants between 12 and 24 months already master this skill. The results of the present study show that although the infants followed the model's gaze shift towards the objects, they did not use this information to predict the model's upcoming action. Our findings regarding gaze following behaviour are consistent with Meltzoff and Brooks' study (2007) that reported that infants from the age of ten months onwards are able to follow an adult's gaze. Surprisingly, our findings regarding action prediction are inconsistent with previous studies (Falck-Ytter et al. 2006; Meltzoff, 1995) which have reported that infants from the age of twelve months onwards are able to predict the outcome of an upcoming action based on a hand-object interaction. On the other hand, the results of Paulus' study (2011) support our findings by indicating that fourteen-month-old infants are not able to use gaze as a cue to predict an upcoming action. In their study fourteen-month-old infants are able to perform predictive eye movements towards an object after seeing a model grasping the object, but not

after seeing a model gazing repeatedly at the object. This result is consistent with our result despite the fact that in Paulus' study (2011) infants saw the model gaze four times towards the object. This might suggest that frequency of gaze cues does not have an influence on the ability to predict an action based on a gaze cue.

The inconsistency in results might be attributed to differences between our paradigm and the paradigms used in the previously mentioned studies of Falck-Ytter et al. (2006) and Meltzoff (1995). A remarkable difference in paradigm can be found when comparing our study with the study of Falck-Ytter et al. (2006) and Meltzoff (1995). They used a hand-object interaction to investigate action prediction in infants. In the eye tracking study of Falck-Ytter et al. (2006) six and twelve-month-old infants were presented with a video presentation in which a model's hand moved three toys into a bucket. Twelve-month-old infants, but not six-month-old infants, were able to predict the model's action. In the behavioural study of Meltzoff (1995) eighteen-month-old infants watched demonstrations of an act with five different objects. One group of infants saw the complete act with the objects, the second group saw a failed attempt to complete the act. Afterwards, they investigated whether the infants were able to reproduce and complete the object related action. This study indicates that eighteen-month-old infants are able to predict the outcome of an adult's action based on his/her underlying intention. In our study and in the eye tracking study of Paulus (2011) a gaze cue instead of a hand-object interaction was used to investigate action prediction in infants. It is possible that for infants a gaze cue is not sufficient enough to predict an adult's upcoming action. Johnson, Ok and Luo (2007) and Paulus (2011) support this explanation. Johnson et al. (2007) stated that it is more difficult for infants to make a mental representation of a gaze shift in comparison to a hand-object action. On one hand, this might be related to the fact that a hand-object action always has a direct consequence and a gaze action does not, as people do not always perform an action with the object of their gaze, sometimes they just let their eyes drift absent mindedly. On the other hand, this difference might be related to the brain areas involved when observing a hand-object interaction and a gaze shift. It is supposed that when observing a hand-object interaction brain areas including the MNS are activated. In contrast, when observing a gaze shift the posterior part of the superior temporal sulcus is activated. It might be that infants between 12 and 24 months are not yet able to use this part of their brain adequately and therefore are not able to predict an action based on a gaze cue.

In our study information about the upcoming action could only be extracted from one cue, namely gaze towards one out of two bowls. It might be that a gaze cue alone does not provide the infants with enough information to perceive the adult's goal to perform an action with the object. Eshuis, Coventry and Vulchanova (2009) did a study in adults. In this study, adults were shown hand-object interactions with and without end effects, examples of end effects were a sound or a positive emotion. The study showed that the additional cues help the adults to discover the model's goal to perform an action with the object. It might be that this is also the case in infants.

As expected, baseline measures in our study showed that infants had more attention for the model's face in comparison with the two bowls that were placed on the table. As demonstrated by Sanefuji and colleagues (2011) infants from a very early age on are more interested in human faces than in objects. In their study, three different stimuli were used. The first was a human face, the

second was a doll face and the third was a backpack with a drawing of a face on it (object). Infants show preferential interest towards a human face in comparison to an object. Taking this into account, it is important to notice that in the video clip of Falck-Ytter et al.'s (2006) studies the model's face was not visible. This was done to prevent that the infants would solely focus on the model's face and to attract the infant's attention towards the executed action. In our study the model's face was visible, this potential distractor might have prevented the infants from predicting the upcoming action.

When interpreting the results, one has to take account of some strengths and limitations of the study. In this study, infants between 12 and 24 months were included, which is a relatively wide age range. This was done with the aim of getting an impression of the possible development of action prediction based on a gaze cue between one and two years of age. However, this prevents us from making a statement about the occurrence of action prediction based on a gaze cue at a specific age. Infants saw eight trials in which gaze direction and placement of the bowls were alternated. The long duration of the test could have possibly caused a decrease in the attention of the infants. The alternated placing of the bowls could have possibly caused the infants to be confused. Therefore, three additional analyses were done. First, the first trial of each infant was analyzed separately to counteract a possible influence of the long test duration on the test results. Next, the four trials with the bowls in their initial position and the four trials with the bowls in the reversed position were analyzed separately to counteract the possibility that the infants were confused by the alternating placement of the bowls. However, these analyses did not reveal any differences in results. Moreover, the gaze behaviour of the infants was measured with an eye tracker. The use of an eye tracker in a standardized environment allows for reproducibility of the measurements and reliable results. On the other hand, it is possible that this unnatural setting has an influence on the infant's gaze behaviour. In our study the infants were presented with a video clip of an adult model who was performing a gaze action. We chose to use a video clip to collect data in the most accurate way. However this might have implications when the infants tried to establish an interaction. If infants looked at the cued bowl in the test phase they might have tried to initiate an interaction with the model although this was impossible. This could have led to a decrease in interest of the infants because their demand for interaction stayed unanswered.

We advise future researchers to investigate which cue, additional to gaze, enables infants to predict an actor's action. Furthermore, it would be interesting to investigate the development of action prediction based on solely a gaze cue using a longitudinal study design. Later on, action prediction based on a gaze cue can be investigated in children with problems in their social development, more specifically in children with autism spectrum disorders (ASD). These children are known to have problems with the development of social cognition (Senju, 2013). Action prediction based on a gaze cue is an important social cognitive skill which is critical in our daily social interaction. It would be interesting to investigate whether or not this particular skill is impaired in children with ASD and in which way it influences their social interaction. It would also be interesting to find out if action prediction based on a gaze cue in children with ASD emerges at the same age as in typical developing infants, or at a later age or not at all. The possible new insights into the looking behaviour



of infants with ASD can be used to expand and in this manner improve the diagnostic procedures for ASD.

In summary, the findings of our study show that although infants between 12 and 24 months of age follow an adult's gaze towards an object, they do not use this information to predict the adult's upcoming action. An explanation can be that infants need additional cues other than gaze shifts, such as emotions, noises or grip selection to predict an upcoming action.

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Richting: **master in de revalidatiewetenschappen en de kinesitherapie-revalidatiewetenschappen en kinesitherapie bij kinderen**

Jaar: **2015**

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