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2013•2014
FACULTEIT GENEESKUNDE EN LEVENSWETENSCHAPPEN
master in de revalidatiewetenschappen en de kinesitherapie

Masterproef

Responding to joint attention at infancy: an eye-tracking study

Promotor :
Prof. dr. Marleen VANVUCHELEN

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Maasmechelen, May 2014 K.S.

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[1]. Autism is characterized by impairments in social interaction, in communication skills and in behavior, which is restricted and repetitive[1]. 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[2]. Early identification of autism can lead to earlier entry into intervention programs that can support improved developmental outcome[3].

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[4-13]. Recently, the recurrence risk for later-born siblings of children with autism is estimated to be nearly 20 percent[14]. 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.

Beside imitation problems, former research on social cognition showed that deficits in joint attention (JA) are another important feature in children with autism. The development of JA skills is both delayed and impaired when compared with typically developing peers[15,16,17]. Investigating JA skills in young children and checking the connection of JA with the action-observation-action-execution network may be promising in accelerating the diagnosis of autism. Anthonis and Sokol (2013)[18] reviewed 26 recent behavioral studies to find an appropriate measurement for assessing JA skills in typically and atypically developing infants and toddlers. Four measurements of JA are traditionally reported, in particular the Early Social Communication Scales (ESCS), a free play situation, a structured interaction and a parental interview[18,19]. For each measurement, the type of JA, the JA task(s) and the coding of the JA task(s) are described in detail[18]. More recently, the non-invasive method of eye-tracking seemed to be a promising tool to assess the observation style and JA skills in very young children.

The present study is part of the above mentioned explorative work package. Looking behaviors and JA skills are investigated in typically developing children between 12 and 24 months of age with the use of eye-tracking technique. In the near future, these results will be used to study the interaction between JA and the action-observation-action-execution network.

This master thesis was written by a student Physiotherapy and Rehabilitation Sciences of Hasselt University (K.S.), supervised by Prof. Dr. M. Vanvuchelen (promoter) and Dra. L. Van Schuerbeeck (co-promoter). The research protocol and research questions were composed in consultation with the promoter and co-promoter. Data was collected by the co-promoter, Dra. L. Van Schuerbeeck, Dr. M. Braeken, the student (K.S.) and a student Biomedical Sciences (L.V.) who did his research internship in our lab. Data-analysis, statistical analysis and interpretation of the results were performed by the student under the guidance of the co-promoter. This master thesis was critically reviewed by Prof. Dr. M. Vanvuchelen (promoter) and Dra. L. Van Schuerbeeck (co-promoter). After their comments and suggestions, the student finalized this master thesis.

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Responding to joint attention at infancy: an eye-tracking study.

Composed according to the guidelines of Developmental Psychology ®

http://www.apa.org/pubs/journals/dev/

Abstract

In order to assess responding to joint attention (RJA) skills and looking behavior in 55 infants (12-23 months old) in an accurate and reliable way, a pre-recorded gaze following task was presented on a monitor and eye movements were recorded by a Tobii eye-tracking device. Children saw a video clip of a female model turning her head with open or closed eyes either to a left or right bowl. Overall, the fixation duration towards the Area of Interest (AOI) of the model's face was significantly higher than towards the AOI of both objects and towards the background, which is consistent with previous findings. A few differences in fixation duration were found in the open-eyes versus closed-eyes condition and in the baseline versus gaze direction phase. Three eye-tracking parameters were used to assess RJA. According to the first parameter no true gaze following behavior or RJA was present. According to the second parameter RJA was present; in addition, RJA was advanced in the closed-eyes condition. According to the last parameter RJA was present, though there was no difference in gaze following behavior between the open and closed-eyes condition. These findings suggest that children of this particular age rather rely on head than on eye movements during a gaze following task. The eye-tracking parameters used in the present study can be implemented in future eye-tracking studies in young children with or at risk for autism to advance research in RJA in this population.

Key words: Responding to Joint Attention, Gaze Following, Eye-tracking Parameters, Infants

Introduction

Social cognition is defined as a set of complex processes that give people the possibility to interact with each other (Adolphs, 1999; Frith, 2008). Cognitive processes involved in social cognition include perception, attention, memory and action planning, which all play an important role in social interaction and in the understanding of the environment in which human being purposefully act (Frith & Frith, 2007; Frith, 2008; Winkielman & Schooler, 2008). By observing other people, children can learn about the world. This phenomenon is referred to as social learning (Frith & Frith, 2007). Verbal (e.g. naming objects) and non-verbal cues (e.g. gaze direction or pointing gestures) are part of a wide set of social cues that people use to express their intentionality towards the surrounding. The same cues are used to detect, understand and even predict where another individual is looking at and what she/he is doing or will do (Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2008; Sebanz, Bekkering, & Knoblich, 2006). Gaze direction is an interesting aspect of this wide repertoire of social cues. A fascination for other's eyes is observed from birth (Farroni, Csibra, Simion, & Johnson, 2002; Frischen, Bayliss, & Tipper, 2007). This responsiveness to other's eyes plays a key-role in the development of social cognition, even in the first months of life (Striano & Reid, 2006). The eyes yield a serious amount of information during social interactions. By following the gaze direction, the object or location a person is attending to is revealed (Frischen et al., 2007). People will automatically follow the gaze of their social partner, because something interesting is expected to be at her/his point of gaze (Frith & Frith, 2007; Frith, 2008). This triadic interaction of coordinating attention towards a social partner and an object or location of mutual interest, is termed coordinated joint attention (JA) (Bakeman & Adamson, 1984; Carpenter, Nagell, & Tomasello, 1998).

In general; two main types of joint attention (JA) are distinguished: parallel JA and coordinated JA (Figure 1). Parallel JA is defined as an interaction in which both social partners are attending to the same object or location, but there is no evidence of awareness of the presence of the social partner (Benigno & Farrar, 2012; Gaffan, Martins, Healy, & Murray, 2010; Osório, Martins, Meins, Martins, & Soares, 2011; Smith, McCarthy, & Benigno, 2009). During episodes of coordinated JA, already defined above, the person is aware of the presence of the social partner, which is shown by gaze shifts between the social partner and the object or location of mutual interest. Coordinated JA can be subdivided in responding to joint attention (RJA) and initiating joint attention (IJA) (Figure 1). RJA implies following the gaze direction and/or the pointing gestures of a social partner towards an object or location. RJA is also referred to as following attention or passive JA. During IJA episodes, the person attempts to direct the attention of the social partner towards an object or location with the intention to share experiences. Therefore, behaviors such as gaze shifts, gestures, verbalizations or vocalizations have to be shown in a coordinated way. The terms directing attention or active JA are often used to describe IJA (Carpenter et al., 1998; Mundy et al., 2007).

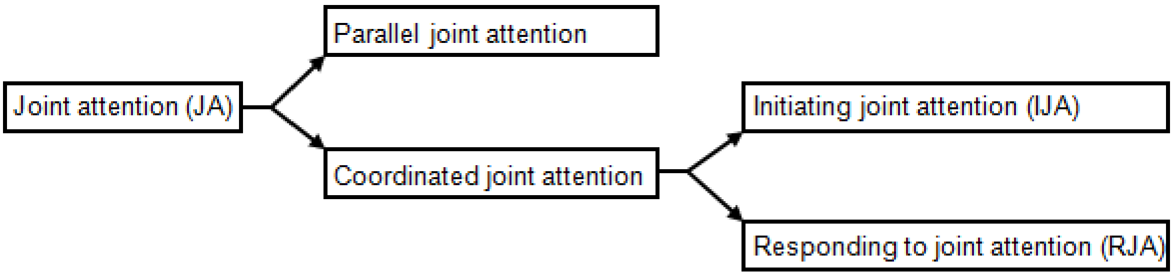


Figure 1 Types of joint attention.

A great number of research has been done about the development of JA skills in young children. The research group of Paparella (2011) provides us with a synthesis of the development of JA skills in typically developing children. The ability to look in a coordinated way, which emerges around the age of 6 months, is the earliest JA skill. Research demonstrates that infants of this age fixate their mother's face attentively while she is turning in a specific direction (Butterworth & Cochran, 1980). When the mother stops moving, infants make a ballistic eye and head movement in the same specific direction. This looking behavior further develops during the first year of life. Between 10 and 14 months of age, children start to use gestures with the purpose of sharing a mutual focus of attention with a social partner. Children show an object around the age of 10 months. By 12 months, infants follow someone's gaze direction. The ability to follow pointing gestures appears around the age of 14 months. From the age of 16 months, infants produce pointing gestures to direct the attention towards a specific object. By reaching the age of 20 months, typically developing children dispose of a large repertoire of JA skills. These include not only responsive skills such as gaze following, used to respond to a person's focus of attention, but also initiating skills such as pointing, used to initiate a JA episode (Paparella, Goods, Freeman, & Kasari, 2011).

The first aim of the present study is to investigate if eye-tracking could be an appropriate measure to assess RJA in young children. Anthonis and Sokol (2013) reviewed 26 recent behavioral studies on measurements for assessing JA skills in typically and atypically developing children between 0 and 6 years of age. Based on their comprehensive search strategy, merely two studies were found which have used an eye-tracking technique (Gredebäck, Fikke, & Melinder, 2010; Navab, Gillespie-Lynch, Johnson, Sigman, & Hutman, 2012). One study used an eye-tracking design and measured the emergence and stability of gaze following behavior in 2 to 8-month-old infants during live interactions with their mother or a stranger (Gredebäck et al., 2010). In the other study, pre-recorded stimuli were presented on a television screen and infant's gaze following behavior was recorded with an eye-tracking device. This study demonstrated a positive correlation between an eye-tracking assessment of RJA and another measurement of RJA, in particular Mundy et al.'s (2003) Early Social Communication Scales (ESCS) (Navab et al., 2012). Despite the fact that only two studies used eye-tracking, it seems a promising technique. It is a non-invasive technique which does not require outstanding motor or language skills of the infants. Furthermore the eye-tracking device provides highly precise and accurate spatial and temporal information. By using pre-recorded video images, the assessment of gaze following behavior is consistent across participants and has the potential to be used as a standardized measurement (Falck-Ytter, Bolte, & Gredebäck, 2013; Navab et al., 2012; Wass, Smith, & Johnson, 2013).

The second aim of the present study is to investigate whether infants rely on head movements or eye movements during episodes of gaze following. The existing literature agrees that infants show gaze following behavior at the age of 12 months (Butterworth & Cochran, 1980; Paparella et al., 2011). Despite efforts of Butterworth and Cochran (1980), Brooks and Meltzoff (2002, 2005), and the research group of Tomasello (2007) to answer the question whether infants use head movements or eye movements to understand where the social partner is looking at and whether infants are already aware of the fact that eyes are essential for seeing, inconsistencies still remain. In previous research of the above mentioned authors, live joint attention episodes between each infant and the experimenter were recorded with a video camera and infant's gaze following behavior was scored based on these video recordings. Butterworth and Cochran (1980) showed that 12-month-old infants fixated the first interesting object along their scanning path. The authors therefore suggest that 12-month-old children rather use the information of the head turn to direct their own attention in the same general direction of their social partner (Butterworth & Cochran, 1980). Infants aged 12 months or younger seem to prefer to follow head movements above eye movements (Butterworth & Cochran, 1980; Johnson, Slaughter, & Carey, 1998). In the Butterworth and Cochran paradigm, infants saw an adult with the eyes oriented in the opposite direction of the head (f.e. a head turn to the right and an eye movement to the left), which causes a conflict between cues and a confusing situation for young children. An alternative gaze-following procedure was developed by Brooks and Meltzoff (2002, 2005). In the Brooks and Meltzoff paradigm, infants were presented with an open-eyes or a closed-eyes condition and with a headband or a blindfold condition. Children of 12, 14 and 18 months looked significantly more at the cued target when the view of the adult was unobstructed (Brooks & Meltzoff, 2002). This result was not confirmed in a sample of 9-month-olds (Brooks & Meltzoff, 2005). The authors therefore conclude that true gaze following develops around 10-11 months of age (Brooks & Meltzoff, 2005). From the age of 12 months, eye movements seem to be the most important factor in gaze following (Brooks & Meltzoff, 2002; Brooks & Meltzoff, 2005; Tomasello, Hare, Lehmann, & Call, 2007).

To conclude, this study was realized to investigate the potential of an eye-tracking measurement to assess RJA in young children with high temporal and spatial accuracy. Three eye-tracking parameters will be evaluated. Consistent with previous studies on RJA, the present study analyzes the fixation duration towards the cued target compared with the uncued target in the gaze direction phase; and a manual score to indicate the location of the child's first fixation (Brooks & Meltzoff, 2002; Brooks & Meltzoff, 2005; Butler, Caron, & Brooks, 2000; Navab et al., 2012; Theuring, Gredebäck, & Hauf, 2007). In addition, we will include a novel eye-tracking parameter: the fixation duration towards the cued and uncued target in the gaze direction phase compared with the baseline phase. If the fixation duration towards the cued target is higher in the gaze direction phase when compared with the baseline phase, we assume that infants are following the adult's cue. However if the fixation duration towards both the cued and uncued target is higher in the gaze direction phase when compared with the baseline phase, we assume that infants just react on the moving adult, regardless of the cue that is given. To evaluate whether children rely on head movements or eye movements during episodes of gaze following, the open-eyes and closed-eyes condition of Brooks and Meltzoff (2002, 2005) is adopted. The present study is the first to use a pre-recorded gaze following task and an eye-tracking technique to answer this question in infants. This technique allows for more precise and accurate gaze following recordings, which is a surplus value.

Methods

Participants

Fifty-five children between 12 and 23 months of age (31 female and 24 male) were recruited from daycare center 'De Ukkies' at Hasselt. One inclusion criterion was applied: at least one of the parents had to speak Dutch. Exclusion criteria were diagnosis of a developmental disorder and abnormalities of the visual system that could interfere with the eye-tracking technique (f.e. strabismus). Parents received a newsletter with information about the study and gave informed consent for their infants prior to their participation.

This study was approved by the medical ethics committee of Hasselt University and the Catholic University of Leuven (B322201215699).

Measurements

All participants completed the eye-tracking task. Furthermore the Dutch version of the Bayley Scales of Infant and Toddler Development, third edition (Bayley-III-NL) (Bayley, 2013) and the Preschool Imitation and Praxis Scale (PIPS) (Vanvuchelen, 2009; Vanvuchelen, Roeyers, & De Weerdt, 2011a, 2011b, 2011c) were administered by a professional researcher (M.B.). Three additional questionnaires were completed by the parents of the included children.

Eye-tracking task.

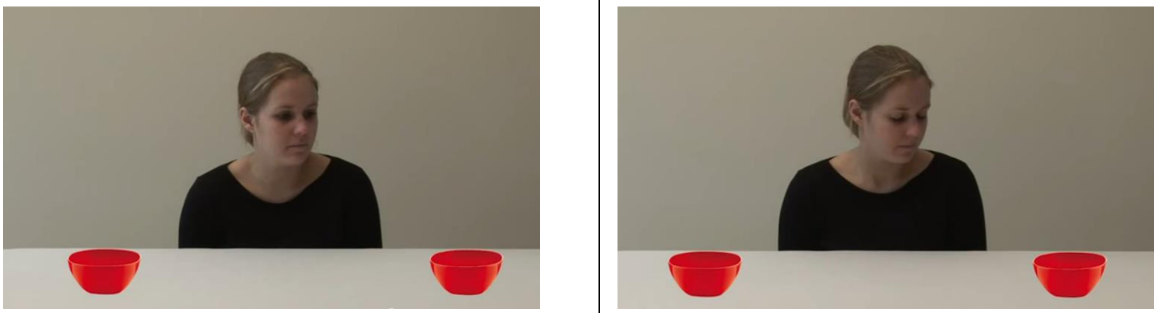
Devices. A Tobii T120 Eye Tracker (Tobii Technology, Stockholm, Sweden) was used to record looking behavior. The eye tracking technology, user camera and speakers are all integrated into the 17 inch monitor (1280 x 1024 pixels). The cameras beneath the monitor record reflections from infrared light at a frequency of 120 Hz to assess the distance between the cornea and the pupil of both eyes. The accuracy and precision of the recordings approximates respectively 0.16° and 0.4° of visual angle in ideal conditions (Accuracy and precision test report: Tobii T120 Eye tracker, 2012). The tolerance of large head movements (30 x 22 x 30 cm) and the ease of use and simple setup are benefits of this device. Another integrated camera records a frontal view of the child's face and upper body.

***Test environment*.** The infants were tested individually in a separate quiet room of the daycare center (Figure 2). The Tobii T120 monitor was placed against a distraction-free wall. A car seat was placed in front of the monitor on a distance of approximately 65 centimeters. Software programs on computers in the left corner of the room recorded the eye tracking data. The computers and the researchers were invisible for the child. A little seat for the caregiver was provided next to the car seat.

Figure 2 Test environment at daycare center ‘De Ukkies’: Tobii T120 monitor and car seat (left), Tobii T120 monitor, car seat and little seat for the accompanying caregiver (middle), and hidden computers for data registration (right).

Stimuli and procedure. The following procedure was followed. When the infant arrived in the room, the accompanying caregiver placed the child in the car seat and took place beside the infant. The caregiver was present during the whole session. A popular movie of ‘Bumba’ was displayed to draw the infant’s attention to the screen and make her/him feel comfortable. Safety seatbelts could be used to prevent the infant from leaning forward or from crawling away. After a while, the movie of ‘Bumba’ was discontinued and a 5-point calibration was made. After a successful calibration (looking at 4 out of 5 cued locations), video clips were shown on the screen.

The following stimuli were presented. In the video clip, a female model sat in front of a table against a neutral background. The model was wearing a black shirt and her hair was tied back. Two red bowls were placed on equal distance left and right in front of the model. Two conditions were shown: an open-eyes and closed-eyes condition (Figure 3). Each condition included two trials, one trial with the model looking at the right bowl and one trial with the model looking at the left bowl. At the beginning of each condition, the eyes of the female model were fixated on the table in front of her (1s). In one condition, the model looked into the camera (1s) and turned her head and eyes to the right or left bowl (3s). In the other condition, the model looked into the camera (1s) and immediately closed her eyes. She then turned her head in the direction of the right or left bowl (3s). The infants were shown all four trials (two trials of each condition) in a randomized order with attention-getting animations between each trial. These four trials were embedded in a larger video clip which included two other conditions that will not be described and analyzed in the present study. The duration of all video clips was approximately 90 seconds. The duration of the video fragments used in the present study approximates 45 seconds.



Condition 1: Open-eyes condition | Condition 2: Closed-eyes condition

Figure 3 Snapshots of a video stimulus showing the two conditions with the model looking to the right bowl.

The models face measured 5.32° and 3.52° of vertical and horizontal angle. Each bowl measured 2.22° and 3.38° of vertical and horizontal angle. The rectangular area of interest (AOI) around the face measured 7.38° and 5.76° of vertical and horizontal angles. The rectangular AOIs around the left and the right bowl measured 5.76° and 7.38° of vertical and horizontal angles (Figure 4).

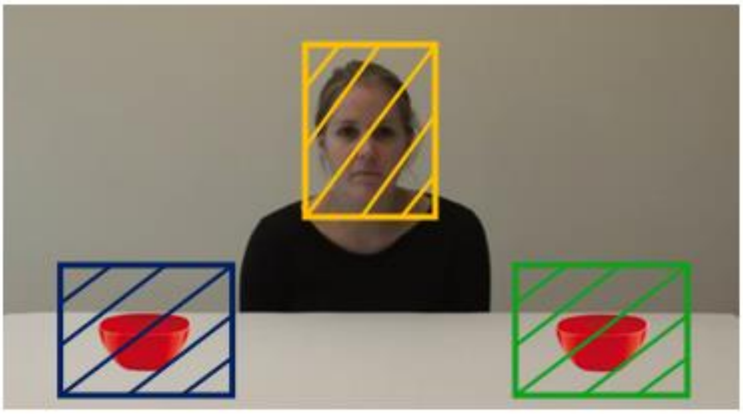


Figure 4 Snapshot of a video stimulus showing the rectangular AOIs of the model's face and both objects.

Bayley-III-NL (Bayley, 2013). The Bayley Scales of Infant and Toddler Development (Dutch version, third edition) is a screening instrument used to identify young children between 2 weeks and 42 months of age with a developmental delay. The Bayley assesses 5 domains: cognition, language, motor skills, social-emotional skills and adaptive behavior. Each domain consists of several items. A subscore can be calculated for each domain and compared with norm scores to determine a child's performance. Only the domains cognition and motor skills were administered in the present study. The guidelines and procedures described in the manual were strictly applied (Steenis, Verhoeven, & Van Baar, 2013).

Preschool Imitation and Praxis Scale (PIPS) (Vanvuchelen, 2009; Vanvuchelen et al., 2011a, 2011b, 2011c). The Preschool Imitation and Praxis Scale (PIPS) is developed to assess imitation skills of actions with and without objects. Different types of actions are included and several imitation tasks for each type of action are investigated (Vanvuchelen, 2006). PIPS-scores of 654 typically developing young children between 12 and 59 months of age were obtained to determine age equivalents.

Questionnaires. Three additional questionnaires were completed by the children's parents.

The Ages and Stages questionnaires 2nd edition (Bricker & Squires, 1999) is a questionnaire designed to identify young children with developmental delays. The questionnaire incorporates 30 items in five developmental areas namely communication, gross motor, fine motor, problem solving and personal-social. After completing the questionnaire, a total score for each developmental domain can be calculated and compared to cut-off scores.

The Modified Checklist for Autism in Toddles (M-Chat) (Robins, Fein, Barton, & Green, 1999) is a questionnaire to identify toddlers between 16 and 30 months of age who are at risk for an eventual diagnosis of an autism spectrum disorder or a developmental delay. Twenty-three behaviors are assessed and compared to established cut-off criteria to identify the level of risk for autism.

The Vineland Screener (Scholte, van Duijn, Dijkxhoorn, Noens, & van Berckelaes-Onnes, 2008) contains 72 items divided into 4 subscales: communication skills, social skills, motor skills and daily skills. A total score can be calculated and compared with norm scores to determine the developmental age of children between 0 and 6 years.

In addition, the parents provided some general information about the family situation, including the educational level of the parents which is an indication of the socio-economic status of their child.

Scoring and Statistical Analysis

Baseline and gaze direction phase. Each of the four stimuli could be divided into two phases: the baseline and gaze direction phase (Figure 5). The baseline phase starts from the beginning of the trial and ends just before the model turns her head (Figure 5a-5b). The gaze direction phase starts when the baseline phase ends and lasts until the end of the trial. During the gaze direction phase, the model turns her head towards one of the bowls on the table (Figure 5c-5d). This subdivision in two phases is important for both the analysis of looking behavior as for the assessment of RJA.

Baseline phase	 Start (a)	 End (b)
Gaze direction phase	 Start (c)	 End (d)

Figure 5 Snapshots of a video stimulus showing the baseline (5a-5b) and gaze direction phase (5c-5d).

Eye-tracking assessment: Looking behavior. To have an indication of the time that the child actually looked at the screen and eye-tracking data could be administered, the average looking time to the screen was analyzed. Therefore, the fixation duration, a variable provided by the eye-tracking analysis software (Tobii Studio, Sweden), was analyzed for the total video fragment and for the open-eyes and closed-eyes condition separately. As the total fixation duration varied between infants, a proportional fixation duration was used.

To know which locations on the screen especially attracted the child's attention, the fixation duration towards respectively the Area of Interest (AOI) of the model's face, the AOI of the objects and the background (i.e. the child does not look at any AOI) was calculated (Figure 4). This was done for both the baseline and the gaze direction phase in the total video fragment and for both conditions separately. For this purpose 4 variables were used. The following equations describe the 4 variables:

$$\text{Proportional total fixation duration} = \frac{\text{Total fixation duration towards the screen}}{\text{Total duration towards the video fragment}}$$

$$\text{Proportional fixation duration towards the model's face} = \frac{\text{Fixation duration towards the model's face}}{\text{Total fixation duration towards the screen}}$$

$$\text{Proportional fixation duration towards the objects} = \frac{\text{Fixation duration towards the objects}}{\text{Total fixation duration towards the screen}}$$

$$\text{Proportional fixation duration towards the background} = \frac{\text{Fixation duration towards the background}}{\text{Total fixation duration towards the screen}}$$

Eye-tracking assessment: RJA. To evaluate if eye-tracking is an appropriate measure to assess RJA, 3 different RJA parameters will be explored.

For the first parameter a comparison between the children's gaze behavior to both targets in the gaze direction phase (i.e. a cue is given) versus the baseline phase (i.e. the cue is not yet given) will be made. If infants looked more to the cued target in the gaze direction phase compared to the baseline phase, we initially assume that they followed the cue the adult was attending to; and by consequence that RJA is present. However, if infants also looked more to the uncued target in the gaze direction phase compared to the baseline phase, we assume that they just reacted on the moving adult, regardless of the cue that was given. In that case, there is no true RJA.

For the second parameter a comparison of the fixation duration towards the cued and uncued target in the gaze direction phase is made (Navab et al., 2012; Theuring et al., 2007). If children looked more to the cued target than to the uncued target in the gaze direction phase (i.e. after the cue was given), we assume that infants observed the cue and responded to it and thus, that they show RJA behavior.

For the third parameter the recorded eye-tracking data will be re-played on the eye-tracking device and a manual scoring procedure will be used to assess the location of the first fixation of each infant in the gaze direction phase (i.e. after the cue was given). This variable provides us an indication of the capacity of young children to follow the cue of an adult towards an object. One of the options of the eye-tracking device is to show the scanning patterns on the screen. This means that during re-playing the recordings on the eye-tracker, the exact scanning patterns of the infants are shown so we know exactly where they are looking at (Figure 6). Therefore, RJA behavior can be assessed more accurate. This manual scoring procedure is adopted from previous studies (Brooks & Meltzoff, 2002; Brooks & Meltzoff, 2005; Butler et al., 2000). Different options are possible. The first fixation could be either correct or incorrect or it could be that the infant did not look at all. A score of +1, termed correct look, was achieved if the child looked correctly, meaning that the first gaze shift of the child was between the model's face and the cued object (i.e. the bowl matching the model's head and/or eye turn). An incorrect look was awarded with a score of -1, indicating that the first gaze shift of the child was between the model's face and the uncued object. If the infants fixated the model or looked at the background and did not look at either object, they received a score of 0. This score was termed nonlook. To calculate a total score, the sum of the correct looks, incorrect looks and nonlooks was made. Scores could vary between -4 and +4. All trials were scored by two independent raters (K.S and L.V.S.). If the median manual score differs significantly from zero, we reject the null hypothesis and conclude that RJA behavior is present.

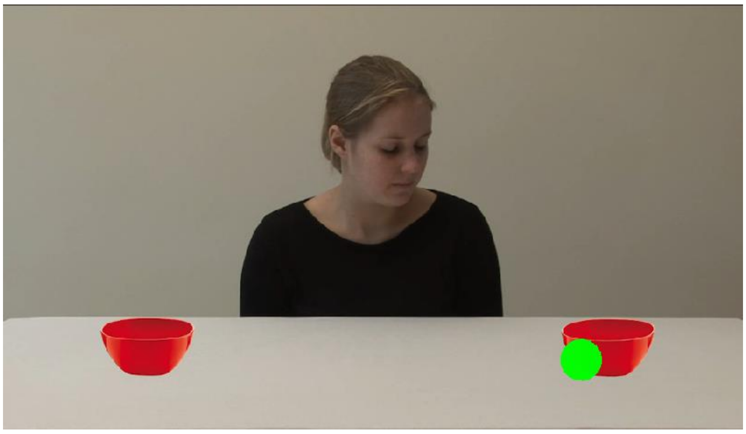


Figure 6 Snapshot of a video overlay showing the green dot indicating exactly where the infant is looking at.

Statistical analysis. Eye-tracking in young children presents a great challenge with respect to missing data for several reasons such as excessive motion during the eye-tracking assessment or distraction (Gredebäck et al., 2010; Sasson & Elison, 2012). This problem leads to unreliable results because of insufficient sampling. Sasson and Elison (2012) highlight the importance of establishing a minimum time cut-off value. Their advice is to exclude participants with more missing than recorded data. Therefore, the present study used a cut-off value of 50% in each condition (Sasson & Elison, 2012).

Descriptive statistics were used to describe the most important variables of the participants who were included in the data analysis process.

The inter-rater reliability of the manual scores of first fixation was evaluated by a simple Cohen's Kappa value. The guidelines of Viera and Garrett (2005) were used to interpret the Kappa values. A kappa value of 0 indicates agreement equivalent to chance and a kappa value of 1 indicates perfect agreement. Values between 0.01 and 0.20 were read as slight agreement, between 0.21 and 0.40 as fair agreement, between 0.41 and 0.60 as moderate agreement, between 0.61 and 0.80 as substantial agreement, and between 0.81 and 0.99 as almost perfect agreement.

As the total fixation duration varied between infants, the proportional variables were used in the statistical analysis of the eye-tracking recordings. A Shapiro-Wilk test of normality was applied to check if data were normally distributed (Razali & Wah, 2011). As this was not the case, non-parametric statistics were used: a Wilcoxon Signed Ranks Test (Z) to compare two related samples and the Friedman test (χ^2) to compare more than two related samples. A p-value smaller than .05 was considered significant. When a Friedman test was performed, post-hoc analysis with Wilcoxon Signed Ranks Test was conducted with a Bonferroni correction to account for the problem of multiple comparison (Field, 2009). In this post-hoc analysis, the significance level was set at $p<.05$ divided by the number of conducted statistical tests. For the analysis of the manual scores, a one sample Wilcoxon Signed Rank Test was performed to compare the median of the total score with 0.

Spearman's rank correlation coefficients (r_s) were calculated to investigate the relation between the fixation duration towards the cued object in the gaze direction phase and the manual score of first fixation with several variables. These variables include: chronological age, gender, number of daily hours television-watching, and M-Chat, ASQ, Vineland, Bayley-III-NL and PIPS scores. Spearman correlation coefficients were interpreted according to Hinkle et al. (1998). Values below .30 were interpreted as little or no correlation, values between .30 and .50 as low, between .50 and .70 as moderate and above .70 as high correlation.

Statistical analyses were performed using the statistical software SPSS version 22.0. Graphic figures and tables were made with Microsoft Office Word 2007.

Results

Description of the Study Sample (n=45)

A preliminary analysis of the level of gaze behavior was performed and participants with more missing than recorded data in each condition (i.e. a total fixation duration less than 50%) were excluded for further analysis. After applying this criterion, recordings of 45 out of the 55 participants remained.

Table 1 presents the descriptive characteristics of the 45 participants (25 females and 20 males) that are included for further data analysis. All the infants were between 12 and 23 months old (mean age 16.8 months; SD 3.4 months). Two of the infants, both female, were born preterm, which is defined as 'born alive before 37 weeks of pregnancy' by the World Health Organization (WHO). Furthermore, 3 infants (1 female, 2 male) had a low birth weight (i.e. less than 2500 grams) and 1 female infant had an abnormal birth weight of 4750 grams. None of the children had any medical diseases or visual impairments that could interfere with the eye-tracking technique. By analyzing the questionnaires, completed by the parents or caregivers of the children, some important remarks must be made. Considering the Ages and Stages Questionnaires (ASQ), 14 children scored below the cut-off score on the communication domain. On the domains gross motor, fine motor, problem solving and personal social, respectively 8, 1, 2 and 2 infants scored below the cut-off point. Overall, 18 infants failed on one domain and 3 infants failed on more than one domain. When analyzing the Vineland Screener, two infants failed on the social skills domain and two on the motor skills domain. Furthermore, one infant had a total score below the cut-off point. Overall, one infant scored below cut-off on one domain and two infants failed on more than one domain. As video images are shown on a screen during the eye-tracking assessment, the number of daily hours television-watching could be of importance. Results show that 23 infants watch television less than 1 hour a day, 8 infants 1 to 2 hours a day and 1 infant more than 2 hours a day. The remaining 13 infants watch never or almost never television.

Parents also had to answer some questions about family situation, work, education and origin. These variables give us an indication of the socio-economic status of the children. Of the 45 children, 43 were natural and 2 were donor conceived. Most infants (93.3%) lived with their natural mother and father, of whom 55.5% was married and 37.8% was co-habiting. Three children (6.7%) lived with their natural mother and female partner, who were co-habiting. Regarding the educational level of the parents, 3.3% of the parents only finished lower secondary education, 23.3% of the parents finished upper secondary education, 39% of the parents achieved a higher, non-university grade and 32.2% of the parents achieved a university grade. The educational level of one parent (1.1%) is unknown. The father of 97.8% of the children is of Belgian origin, the origin of one father is unknown (2.2%). Most of the children (93.3%) have a Belgian mother. One mother is of Dutch origin, one of Russian origin and one of Estonian origin (6.7%). The majority of the fathers (89%) works full-time. Furthermore, one father works part-time (2.2%), one temporarily interrupted his work (2.2%) and two are self-employed (4.4%). The work status of one father is unknown (2.2%). 71.2% of the mothers is working full-time and 22.2% is working part-time. Furthermore, one mother is self-employed (2.2%) and two mothers are unemployed but receive a replacement income (4.4%).

Despite the variation in the participant's characteristics and socio-economic status, their total fixation duration was higher than 50% in all conditions. Not any outlier was found.

Table 1 Description of the study sample (n=45).

Age (n=45)	Mean (months)	SD (months)		Range (months)	
	16.8	3.4		12-23	
Gender (n=45)	Male	Female			
	20	25			
Gestational age (n=45)	Term	Preterm			
	43	2			
Birth weight (n=45)	Normal	Abnormal			
	41	4			
ASQ (n=45)	Communication	Gross motor	Fine motor	Problem solving	Personal social
Below cut-off	14	8	1	2	2
Vineland (n=44)	Communication skills	Social skills	Daily skills	Motor skills	Total score
Below cut-off	0	2	0	2	1
Watching TV (n=45)	Almost never	<1h/day	1-2h/day	>2h/day	
	13	23	8	1	

SD: standard deviation; Preterm: Infants born alive before 37 weeks of pregnancy (World Health Organization, WHO) ; Abnormal birth weight: Infants with a birth weight less than 2500 grams or more than 4500 grams (World Health Organization, WHO) ; Below cut-off: number of children with a score below the cut-off score of a particular developmental domain of respectively the Ages and Stages Questionnaire (ASQ) or the Vineland Screener.

Inter-rater Reliability of the Manual First Fixation Scores

A manual scoring procedure was conducted by two independent researchers (K.S. and L.V.S.) to obtain information about the location of the first fixation of each child. Table 2 provides an overview of the Kappa values of these manual scores. Both the left and the right trial (i.e. the model turns her head towards respectively the left and right bowl) of each condition (i.e. open-eyes and closed-eyes) revealed an almost perfect inter-rater agreement with Cohen's Kappa values ranging from 0.89 to 0.96.

Table 2 Inter-rater reliability of the manual scores for the right and left trial of the 2 conditions.

Condition	**Cohen's Kappa (ASE)**	**Interpretation**
Open-eyes condition, left trial	0.90 (.06)	Almost perfect agreement
Open-eyes condition, right trial	0.93 (.05)	Almost perfect agreement
Closed-eyes condition, left trial	0.96 (.04)	Almost perfect agreement
Closed-eyes condition, right trial	0.89 (.06)	Almost perfect agreement

ASE: Asymptotic Standard Error.

Looking Behavior

Total fixation duration during the video clip. During the whole presentation of the video clip, infants had a median fixation duration of 80.1% (IQR 74.4-87.0%). When comparing the open-eyes condition with the closed-eyes condition, the median fixation duration was slightly higher in the open-eyes condition (84.0%, IQR 68.6-90.6%) than in the closed-eyes condition (81.2%, IQR 68.0-89.6%). However, the Wilcoxon Signed Ranks Test revealed that this difference was not statistically significant ($Z=-.67$, $p=.50$) which demonstrates that the status of the model's eyes has no influence on the median looking time (%).

Fixation duration within the baseline, respectively gaze direction phase. An overview of the fixation duration towards each Area of Interest (AOI) in the baseline, respectively gaze direction phase of each condition is provided in table 3.

In the baseline phase, the Friedman test demonstrated a significant difference between the fixation duration towards each area of interest ($\chi^2=70.1$; $p<.001$). Applying the Bonferroni correction resulted in a significance level of $p<.017$. Infants looked significantly more to the model's face when compared with both the targets ($Z=-5.84$, $p<.001$) and the background ($Z=-5.84$, $p<.001$). In addition, they looked significantly more to the targets compared to the background ($Z=-3.37$, $p<.001$). Wilcoxon Signed Ranks Tests (Z) revealed no significant difference between the fixation duration towards each area of interest in the open-eyes and closed-eyes condition, indicating that infants' fixation duration was not affected by the status of the model's eyes (Table 3).

In the gaze direction phase, the Friedman test demonstrated a significant difference between the fixation duration towards each area of interest ($\chi^2=78.9$; $p<.001$). Applying the Bonferroni correction resulted in a significance level of $p<.017$. Infants looked significantly more to the model's face when compared with both the targets ($Z=-5.82$, $p<.001$) and the background ($Z=-5.84$, $p<.001$). In addition, they looked significantly more to the targets compared to the background ($Z=-5.39$, $p<.001$). When comparing the fixation duration in the open-eyes and closed-eyes condition, Wilcoxon Signed Ranks Tests (Z) revealed a significant difference between the fixation duration towards the model's face and the objects (Table 3). Results indicated that children were more likely to fixate the model's face in the open-eyes condition and they were more likely to fixate the objects in the closed-eyes condition.

Table 3 Fixation duration in the open-eyes and closed-eyes condition in the baseline, respectively the gaze direction phase.

AOI		Open-eyes condition	Closed-eyes condition	Z	P-Value
Baseline phase					
Model's face	Median (%)	93.7	88.9	-.03	.98
	IQR (%)	81.7-97.3	78.9-99.5		
	Range (%)	50-100	63-100		
Objects	Median (%)	1.4	6.8	-.75	.46
	IQR (%)	0-15.1	0-15.5		
	Range (%)	0-49	0-36		
Background	Median (%)	2.6	1.9	-.97	.33
	IQR (%)	1.0-4.6	0-5.4		
	Range (%)	0-13	0-15		
Gaze direction phase					
Model's face	Median (%)	79.0	71.1	-3.23	<.001
	IQR (%)	68.6-93.9	60.3-83.2		
	Range (%)	50-100	24-100		
Objects	Median (%)	14.6	20.6	-2.49	.01
	IQR (%)	4.2-21.8	12.9-30.2		
	Range (%)	0-51	0-72		
Background	Median (%)	2.7	2.8	-.68	.50
	IQR (%)	0-6.9	0-9.0		
	Range (%)	0-23	0-43		

AOI: Area of interest; IQR: Interquartile range; significance level was set on p<.05.

Fixation duration towards each area of interest in the gaze direction phase compared to the baseline phase. An overview of the fixation duration towards each Area of Interest (AOI) in the baseline and gaze direction phase is provided in table 4.

When comparing the fixation duration towards each area of interest between the baseline and the gaze direction phase, Wilcoxon Signed Ranks Tests (Z) revealed significant differences between the fixation duration towards each area of interest in the total video fragment. Infants looked significantly less to the model's face in the gaze direction phase compared to the baseline phase. Furthermore they were more likely to fixate the objects and the background in the gaze direction phase compared to the baseline phase. Subanalysis of the open-eyes condition only, revealed also a significant difference between the fixation duration towards the model's face (Z=-3.88, p<.001) and both objects (Z=-3.18, p<.001), in contrast with the fixation duration towards the background (Z=-.04, p=.97). Subanalysis of the closed-eyes condition only, revealed also a significant difference between the fixation duration towards the model's face (Z=-5.15, p<.001) and both objects (Z=-5.13, p<.001). In addition, a significant difference between the fixation duration towards the background was found (Z=-2.68, p=.01), indicating that children also looked more to the background in the gaze direction phase compared to the baseline phase.

Table 4 Fixation duration in the gaze direction phase compared to the baseline phase.

AOI		Baseline phase	Gaze direction phase	Z	P-value
Model's face	Median (%)	88.9	73.7	-5.39	<.001
	IQR (%)	83.4-96.4	64.2-83.4		
	Range (%)	60-100	36-99		
Objects	Median (%)	6.7	20.6	-5.21	<.001
	IQR (%)	0-13.2	12.0-30.4		
	Range (%)	0-36	0-47		
Background	Median (%)	2.8	3.9	-2.81	.01
	IQR (%)	0.6-4.8	1.4-6.7		
	Range (%)	0-10	0-25		

AOI: Area of Interest; IQR: Interquartile range; significance level was set on p<.05.

Responding to Joint Attention (RJA)

Parameter 1: Comparison of fixation duration towards the cued target in the gaze direction phase compared to the baseline phase. Infants looked significantly more to the cued target in the gaze direction phase compared to the baseline phase (Z=-4.32, p<.001). However, the same was true for the uncued target (Z=-3.8, p<.001). We therefore conclude that children only reacted to the model's head movement resulting in enhanced attention to both targets. Regarding this parameter, no true gaze following behavior or RJA was present.

Parameter 2: Comparison of fixation duration towards both targets in the gaze direction phase. Infants were more likely to look at the cued target than at the uncued target (Z=-1.97, p=.04), suggesting that they were following the adult's gaze as a meaningful cue and that RJA was present. In order to know if RJA behavior is influenced by the status of the model's eyes, the fixation duration towards the cued target was compared with this towards the uncued target in the gaze direction phase for both conditions separately. Wilcoxon Signed Ranks Tests revealed that the fixation duration towards the cued target (Z=-2.54, p=.01) was significantly higher in the closed-eyes condition when compared with the fixation duration towards the uncued target. This was not true in the open-eyes condition (Z=-1.56, p=.12). Based on this parameter, we conclude that RJA was present and even advanced in the closed-eyes condition.

Parameter 3: Manual score of location of first fixation. A one sample Wilcoxon Signed Rank Test was applied to compare the median of the total manual score with 0. With a significant p-value less than .001, we rejected the null hypothesis and conclude that children followed the cue of the adult, which is shown by their first location of fixation. Further analysis revealed that children followed the cue in the closed-eyes condition (p=.01). This was not the case in the open-eyes condition, however the p-value of .07 suggested a trend towards significance. To investigate whether the difference between the manual score in both conditions was significant, a Wilcoxon Signed Ranks Tests was performed. Results revealed no significant difference between RJA in the open-eyes condition when compared with the closed-eyes condition (Z=-1.21, p=.23).

Correlations

Table 5 summarizes the relation between the fixation duration towards the cued object in the gaze direction phase and the manual score of first fixation with several variables. A significant positive but low correlation between the fixation duration towards the cued object in the gaze direction phase and the Vineland daily skills score was found (r_s = .33, p=.03). In addition a significant positive moderate correlation was found between the fixation duration towards the cued object in the gaze direction phase and the manual score of first fixation (r_s=.55, p<.001).

Table 5 Spearman Rho correlation coefficients (r_s) and p-values between the manual score of first fixation during the gaze direction phase and the fixation duration towards the cued object in the gaze direction phase with chronological age, gender, ASQ, Vineland, M-Chat, Bayley and PIPS scores.

	Fixation duration		**Manual score**	
	r_s	**p-value**	**r_s**	**p-value**
Chronological age	.22	.16	.15	.31
Gender	-.16	.28	-.20	.18
TV-watching (hours/day)	.04	.81	.27	.07
M-Chat	.03	.89	-.16	.43
ASQ				
Communication	.15	.32	.13	.39
Gross motor	-.23	.13	-.16	.29
Fine motor	.03	.85	-.12	.43
Problem solving	.07	.67	-.07	.67
Personal social	.02	.92	.17	.27
Vineland				
Communication skills	.15	.33	.08	.63
Social skills	-.02	.90	-.24	.12
Daily skills	.33	.03	.01	.99
Motor skills	.18	.24	-.09	.57
Total score	.17	.27	-.08	.60
Bayley-III-NL				
Gross motor	.06	.70	.01	.94
Fine motor	.21	.18	.01	.95
Total motor	.14	.39	.04	.80
Cognition	.14	.37	.03	.86
PIPS				
Bodily imitation	.01	.93	.11	.48
Procedural imitation	.17	.28	.14	.38
Total imitation	.11	.49	.10	.51
Manual score	.55	<.001	1	-
Fixation duration	1	-	.55	<.001

Significance level was set on p<.05.

Discussion

As reported in previous research, we assumed that the children in our study sample, who were all aged between 12 and 23 months, were gifted with RJA skills. The study of Navab et al. (2012) already demonstrated a positive correlation between the ESCS (only the distal task) and two eye-tracking RJA parameters. In the present study, three parameters were used to check if eye-tracking is an appropriate measurement for the assessment of RJA skills. For the first parameter, the fixation duration towards the cued target in the baseline phase was compared with the fixation duration towards the cued target in the gaze direction phase. We hypothesized that children will show RJA, and thus will look more to the cued target after the model has given a cue by looking at that particular target (i.e. in the gaze direction phase). Results revealed that children looked more to both the cued and uncued target in the gaze direction phase when compared with the baseline phase, suggesting that they were reacting on the movement of the adult's head which may have distracted their attention from the adult's face and enhanced their attention to the targets. According to this parameter there was no true gaze following behavior or RJA. For the second parameter, we expected in the gaze direction phase itself a longer fixation duration towards the cued target than towards the uncued target. Results revealed that this was true, which is consistent with previous eye-tracking studies (Theuring et al., 2007; Navab et al., 2012). Theuring and colleagues (2007) investigated infant's object processing during a pre-recorded gaze following task. Navab et al. (2012) investigated the relation between eye-tracking recordings of RJA during a pre-recorded gaze following task and Mundy et al.'s (2003) Early Social Communication Scales (ESCS) for the assessment of RJA. We therefore concluded that in the gaze direction phase children between 12 and 23 months of age have shown RJA behavior. However, the fixation duration does not indicate whether or not the infant's first gaze shift was from the model's face to the cued target. This parameter does not allow to rule out parallel JA. Therefore, we have used the first fixation as third parameter. This parameter assessed whether the infants were aware of the presence of the social partner. For this parameter, a manual scoring procedure, adopted from previous studies, was used (Brooks & Meltzoff, 2002; Brooks & Meltzoff, 2005; Butler et al., 2000). This scoring procedure was applied on the eye-tracking recordings of each infant, which allowed a more accurate scoring of the infant's gaze behavior as the exact scanning patterns could be shown. Data analysis demonstrated that the first gaze shift of the infants was significantly more from the model's face to the cued target compared with the uncued target, indicating that coordinated JA behavior, in particular RJA behavior, was present. In sum, two eye-tracking parameters were successful in demonstrating RJA behavior and can be implemented in future research.

The present study did not find any proof that children rely on the adult's eye-movements during JA episodes. Results rather suggest that children rely on the adult's head movements as they showed more RJA in the closed-eyes condition according to parameter 2 or as there was no difference between the two open- and closed-eyes conditions according to parameter 3. This is in contrast with previous research of Brooks and Meltzoff (2002, 2005), who concluded that children rely on eye-movements rather than head movements during RJA episodes. It is important to note however, that there are several differences between our study and Brook and Meltzoff's studies (2002, 2005). The present study presented a pre-recorded video fragment on a screen, whereas Meltzoff and Brooks (2002, 2005) investigated a live interaction. Furthermore, no greeting was used in the present study, what could have decreased the feeling of a real interaction. However, previous research showed that monitor-based studies reveal the same results as studies in a natural setting (Falkmer, Bjällmark, Larsson, & Falkmer, 2011; Noris, Nadel, Barker, Hadjikhani, & Billard, 2012). Another important difference between the studies of Brooks and Meltzoff (2002, 2005) and the present study should be highlighted. Brooks and Meltzoff (2002, 2005) assigned half of the study sample at random to the open-eyes condition and the other half to the closed-eyes condition. They conducted 4 trials with a total duration of 6.5 seconds and a break of 2 minutes between them. In contrast, the present study presented two trials of each condition to all infants. Each trial had a total duration of 7.5 seconds. Attention-getting animations were shown on the screen for a few seconds between the trials. The fact that we studied the two conditions in one sample could have led to more reliable results. Though it is also possible that children were confused by the variation of the status of the model's eyes. It could be that in the closed-eyes condition children were waiting until the adult would open her eyes. In that case, we could expect that they looked more at the adult's face in this condition. However, results revealed that this was not the case. A final remark should be made. The present study adopted the manual scoring procedure from previous studies of Brooks and Metlzoff (2002, 2005) and Butler et al. (2000), who scored infant's gaze following behavior based on videotapes. In contrast, the present study used the same manual scoring procedure, but scored their gaze following behavior based on eye-tracking recordings. The scanning patterns of the infants were shown during the scoring procedure. Therefore, we were able to detect even the most subtle eye movements and to know exactly where the infants were looking at, which allowed a more accurate score for RJA behavior.

Analysis of the looking behavior of the infants demonstrates that they looked most of the time to the model's face. This was the case in both the baseline and gaze direction phase, which is consistent with previous findings of Theuring et al. (2007). It seems logical that typically developing children are attracted by social stimuli such as an unfamiliar adult's face. Furthermore they were also attracted more by the objects than by the background, which was reflected in a higher fixation duration towards the objects. When comparing the open-eyes condition with the closed-eyes condition, two important differences were revealed. First of all, infants looked significantly more to the model's face in the open-eyes condition, and secondly they looked significantly more to the objects in the closed-eyes condition. Two possible explanations could be considered. One possible explanation is that children were more attracted by the perfectly visible white sclera of the eyes in the open-eyes condition (Tomasello et al., 2007). In the closed-eyes condition, the white sclera were not visible and the colorful objects may have attracted the children's attention. However, in the baseline phase, no difference was found between the open-eyes and closed-eyes condition, which contradicts this explanation. A second possibility is that children understood that the model was giving a cue during the gaze direction phase. It could be that they expected the model to give a second cue in the open-eyes condition, but not in the closed-eyes condition because the model had her eyes closed as if she was asleep and not interested in interacting with the child. In order to see a possible second cue, the infants would check the model's face more in the open-eyes condition. When comparing the baseline with the gaze direction phase, a difference was found. Infants looked more to the model's face in the baseline phase, in contrast, they looked more to the objects and the background in the gaze direction phase. This could be explained by the cue that is given in the gaze direction phase: children will react on the movement of the model's head and/or eyes by scanning the entire screen, which is reflected by a longer fixation duration towards the background. In addition, they are more likely to detect and fixate the objects.

A significant, but low correlation was found between the fixation duration towards the cued object in the gaze direction phase and the Vineland daily skills score. No correlation was found between RJA and number of daily hours television-watching and between RJA and gender, which is consistent with previous research (Carpenter et al., 1998; Mundy et al., 2007). Previous findings report a positive correlation between RJA and chronological age (Carpenter et al., 1998; Mundy et al., 2007) and between RJA and imitation skills in both typically and atypically developing children (Carpenter et al., 1998; Charman et al., 2000; Colombi et al., 2009; Hobson & Hobson, 2007). However, these findings could not be confirmed in the present study. No correlation was found between RJA and the M-Chat score, which is consistent with Navab et al. (2012), but in contrast with Naber et al. (2007) who reported a negative correlation between RJA and autistic symptoms. No correlations were found between RJA and ASQ, Vineland and Bayley-III-NL scores, with the exception of the Vineland daily skills score. It should be noted that several authors report that JA skills predict future communicative and cognitive development (Brooks & Meltzoff, 2005; Carpenter et al., 1998; Mundy et al., 2007; Poon, Watson, Baranek, & Poe, 2012; Tomasello & Farrar, 1986). Therefore, it could be interesting to follow up the participants of the present study and to administer the ASQ, Vineland and Bayley-III-NL questionnaires on regular time moments in the future. It is possible that correlations between their future scores and their RJA skills at present can be found.

As with all research, results of the present study must be considered within the strengths and limitations of its design. This study presented a pre-recorded structured interaction on a screen. Gaze following behavior of young typically developing children (12-23 months) was recorded with an eye-tracking device. Such a structured interaction, measured with an eye-tracking device, has several advantages. First of all, specific tasks are presented to elicit the desired JA behaviors. Furthermore, this measure can be standardized which enhances the reliability and the repeatability of the measurements. On the other hand, it is no natural interaction and the infant is rather forced to show specific JA skills, which can influence their behavior. In addition, working with pre-recorded video images implies that there is no live interaction, which can also lead to different gaze following behavior. However, as mentioned before, previous research of Falkmer (2010) and Noris (2012) demonstrated that monitor-based studies reveal the same results as studies in a natural setting, and thus may be generalized. Besides a structured interaction as used in eye-tracking studies, one non-structured and two other structured JA measurements for young kids are reported in the literature (Anthonis & Sokol, 2013): the Early Social Communication Scales (ESCS), a free play situation and a parental interview. A major advantage of the ESCS is that a manual is available with information about the tasks and coding, which makes the ESCS a standardized measurement to assess both RJA and

IJA skills. The reliability of the ESCS is extensively investigated. However, administering the ESCS takes 15 to 25 minutes which is a long time period for young infants. The free play situation is a more natural interaction in a familiar environment, which improves the possibility to generalize results. A major disadvantage is the lack of standardization and the lack of control over the behavior of the child. Furthermore, the social partner and his or her behavior can also influence the child's behavior. As the ESCS and the free play situation are just snapshots of JA behavior at that particular moment, a parental interview provides a more general view of the child's behavior. However, it is a very subjective measurement and parents have to rely on their memory when answering the questions. When comparing the advantages and disadvantages of each measurement, the structured interaction during eye-tracking seems a founded choice. It allows for highly precise and accurate spatial and temporal gaze following recordings, in contrast with traditional JA measurements. However, it also contains the risk of making incorrect conclusions based on unreliable results because of extensive data loss. This problem is especially present in the study of young children. They are not capable to concentrate for long periods of time and to sit quietly in a car seat without making large motions. To avoid the problem of extensive data loss, the total duration of the video fragment was limited and the most optimal test moments were chosen in consultation with the caregivers. Nevertheless, 18% of the infants looked less than 50% of the time to the screen in at least one condition. According to the guidelines of Sasson and Elison (2012), they were excluded for further analysis. The median total fixation duration of the included children was 80% with no significant difference between the open-eyes and closed-eyes condition. Another strength of the present study is that two identical bowls were used and that the accompanying caregiver sat randomly on the right or on the left side of the infant, thereby excluding a preference gaze direction. Furthermore, a combination of three eye-tracking parameters was investigated, including one novel eye-tracking parameter. A limitation of the present study is that the four trials were part of a larger video fragment. The other images could have influenced the infant's gaze behavior.

In sum, the present study presents two usable eye-tracking parameters to assess RJA on a reliable and accurate way. Consistent with previous research, this study demonstrated the presence of RJA skills in a study sample of typically developing infants between 12 and 23 months of age. Results suggest that infants of this age rather rely on head movements and are not influenced by the status of the model's eyes during RJA episodes. This is in contrast with previous findings of Brooks and Meltzoff (2002, 2005). In the future, the two usable eye-tracking parameters should be implemented in studies assessing RJA skills not only in typically developing children, but also in atypically developing children. Children with autism or at risk for autism especially seem an interesting target group because they display impairments in RJA skills. Early detection of these impairments can contribute to the advancement of the diagnostic process.

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