KATHOLIEKE UNIVERSITEIT LEUVEN

GROEP BIOMEDISCHE WETENSCHAPPEN

FACULTEIT BEWEGINGS- EN REVALIDATIEWETENSCHAPPEN

UNDERSTANDING OF ACTIONS WITH AN INFERABLE FUNCTIONAL OUTCOME LEVEL IN YOUNG TYPICALLY DEVELOPING CHILDREN: AN EYE-TRACKING STUDY

door Goele KUIPERS
en Lise VAN SCHUERBEECK

masterproef aangeboden
tot het behalen van de
graad van master in de
revalidatiewetenschappen
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o.l.v.
Prof. Dr. M. Vanvuchelen, promotor
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Opgesteld volgens de richtlijnen van de *Experimental Brain Research*

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Bilzen and Leuven, 22 mei 2012 G.K. and L.V.S.

CONTEXT OF THE RESEARCH PROJECT

This master thesis is embedded in a project of autism spectrum disorders in collaboration with REVAL (rehabilitation research center of the University of Hasselt), LAuRes (Leuven autism research), IMOB (institute for mobility of the University of Hasselt) and the Centre of Expertise in Autism.

Autism spectrum disorder, further referred to as 'autism', have prevalence rates ranging between 0.6 and 1.16 percent, making autism one of the most frequent childhood neurodevelopmental disorders. The most defining features of this lifelong condition are impairments in social interaction, in communication skills and in behavior, which is restricted and repetitive[1]. The onset of the impairment is before three years of age. Autism shows etiologic heterogeneity, and there is no definitive medical test for this condition[2-3]. The average age at first diagnosis is often not prior than school-age[2]. However, early identification of autism can lead to earlier entry into intervention programs that can support improved developmental outcome[4]. The long delay between parents' initial concerns and eventual diagnosis postpones appropriate intervention, which leaves parents with the sense that precious time has been lost[4].

Autism may be understood at levels of analysis from the genetic and molecular to the behavioral systems, but the neural systems level may be particularly critical for identification of endophenotypes that provide advances in early detection, diagnosis and therapeutic intervention[3]. Previous work of our group on imitation problems in autism has advanced the diagnostic process at preschool age[5-14]. Recently, the recurrence risk for later-born siblings of children with autism is estimated to be nearly 20 percent[15]. Close monitoring of infants at genetic risk for autism has led to a sharp increase in the number of children under the age of three years presenting in the Reference Centres Autism and Centres for Developmental Disorders for differential diagnosis. Therefore, it is important to study precursors of imitation problems in infants and toddlers at risk for autism.

In *the explorative work package* of this research project an action observation-execution model is studied in *a reference group of typically developing children*. This model predicts that when children look at an adult's action upon an object they detect both the adult and the object (detection) and identify critical motor referential cues which characterize the adult's intentionality regarding the object (intention identification). As a result of this style of action observation, similar action patterns are provoked in the children (simulation) and these action patterns provoke spontaneous copying behavior (imitation). In *the clinical work package* this newly acquired knowledge is used to investigate whether *infants and toddlers with autism and at risk for autism* have altered associations of detection, identification, simulation with imitation as compared with chronological and mental age matched typically developing peers. These results may lead to increased insight in altered functional connectivity within the action-observation network, including the mirror neuron system, which may be a promising early biomarker for autism.

Non-invasive methods are used, in particular eye-tracking techniques for assessing the observation style; EMG registrations with surface electrodes for assessing simulation; and comparison of the children's spontaneous actions with the objects before and after observation of the adults' actions for assessing imitation.

The present study entitled "Understanding of actions with an inferable functional outcome level in young typically developing children: an eye-tracking study" is part of the explorative work package. It sought to examine the action observation-execution model in a reference group of typically developing children. This study specifically aims to give an answer to the question if young children are able to identify critical motor referential cues, in particular an adult's grip selection, which characterize the adult's intentionality regarding a familiar object without that they had got the opportunity to execute this action? Therefore, eye movements of participants were recorded using a corneal reflection eye and head tracking technique of the Seeing Machines (FaceLAB eye tracking system, version 5.0).

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UNDERSTANDING OF ACTIONS WITH AN INFERABLE FUNCTIONAL OUTCOME LEVEL IN YOUNG TYPICALLY DEVELOPING CHILDREN: AN EYE-TRACKING STUDY

ABSTRACT

The understanding of actions with an inferable functional outcome level is critical in social interaction. It is unclear whether young children understand these actions without exercising them. The current eye-tracking study sought to investigate gaze behavior in young children when they observe familiar and less familiar human actions with an inferable functional outcome level compared to non-human actions. The following questions were addressed: Do young children use more frequently proactive eye movements when observing familiar actions compared to unfamiliar and non-human actions? Do these proactive eye movements gradually increase by repeated observations of the less familiar actions? We examined 27 typically developing children (13 boys and 14 girls) between 23 and 41 months of age (mean chronological age 31.8 months, SD 4.8 months). Video clips of 4 conditions, respectively drinking, cleaning-up, ball and triangle, were shown. Children's eye movements were recorded with the use of a corneal reflection eye and head tracking technique of the Seeing Machines (FaceLAB eye tracking system, version 5.0). The gaze behavior score was significantly higher in the familiar condition as compared to the less familiar condition and non-human conditions. Analysis of repeated observations revealed a difference score between trial 1 and trial 3 in the less familiar action indicating a significant improvement of gaze behavior. These results suggest that young children may learn to understand and predict less familiar actions solely by observation.

Keywords: Action understanding, Children, Eye-tracking, Mirror Neuron System, Proactive eye movements

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Introduction

Everyday life often requires the understanding of social interaction by predicting actions of others. For example seeing someone put on his coat creates the expectation that this person is going to leave. If we are able to predict this upcoming action and to recognize this person's intention, we can say goodbye and even open the door.

Anticipating the actions of others involves processes of recognition, understanding and prediction of observed behavior, which is linked to the functional properties of the mirror neuron system (MNS) (Gallese et al. 2009). The MNS was first discovered in 1992 by single cell neuron recordings in the premotor cortex (F5) of monkeys. Mirror neurons were not only activated when the animal performed a motor action but also when the animal observed the same action performed by another individual. Because of the properties of this particular class of visuomotor neurons, which almost suggest that the monkey is observing its own action reflected by a mirror, these cells were called mirror neurons (di Pellegrino et al. 1992; Gallese et al. 1996). Indirect evidence for the existence of MNS in humans is based on other techniques, including functional magnetic resonance imaging (fMRI) (Rizzolatti and Craighero 2004). A recent meta-analysis based on more than 200 fMRI studies in healthy adults indicates that the MNS mediates action understanding and is located in the anterior intraparietal sulcus (aIPS) and the premotor cortex (PMC). The aIPS is activated during the observation and execution of goal oriented movements, while the PMC identifies the goals of actions by matching them with own stored representations for these actions (Van Overwalle and Baetens 2009). Thus, mirror neurons create internal representations of motor actions and mediate a direct matching process with observed actions. This is why mirror neurons are so important in recognizing and understanding motor actions (Van Overwalle and Baetens 2009).

There are two important theories about the ontogeny of action understanding and the MNS. The adaptation hypothesis of Rizzolati and Craighero (2004) claims that humans are born with the MNS and that sensorimotor experience is not so important for the development of action understanding. The authors suggest that mirror neurons are an adaptation for action understanding and that they were favoured by natural selection because they helped individuals to understand what others are doing. In this case, it is plausible that infants predict observed actions in adults which they cannot yet perform themselves. However studies in adults show that sensory (Ferrari et al. 2005) and motor experiences (Calvo-Merino et al. 2006) of the observed actions influence the neural activity of the MNS. In line with these findings, the associative hypothesis of Heyes (2001) states that the MNS is exclusively the product of associative learning or conditioning. Each mirror neuron is forged by sensorimotor experiences. In this case, it is plausible that young children can only predict observed actions in adults if they are able to perform these actions themselves.

Eye movements ensure crucial information in visually guided actions. The movements are not only responding to stimuli but are also proactive and therefore important for the planning and control of actions (Land and Furneaux 1997). A proactive eye movement during an action with an object is defined as a gaze shift to the area of interest, which is the landing place of the object, and this before the object arrives in this area (Gredebäck et al. 2010). The coordination between eyes and body movements are similar whether executing or observing the same motor actions (Flanagan and Johansson 2003; Rotman et al. 2006). This finding suggests a link between proactive eye movements and direct matching processes of the MNS. Therefore, recording of eye-movements during action observation can be used as an indirect but non-invasive measure of MNS functioning (Flanagan and Johansson 2003). Recent eye-tracking studies demonstrated evidence for the MNS. Through the evaluation of eye movements of six- and twelve-months old infants and these of adults during video presentations showing toys that were moved by an actor's hand into a bucket, the research group of Falck-Ytter (2006) showed that adults and twelve-month olds directed their gaze towards the goal area before arrival. This anticipatory response was only present if there was an interaction between the toy and the agent performing the displacement (Falck-Ytter et al. 2006). In contrast, six-months old infants failed to predict this action (Falck-Ytter et al. 2006). However a recent study showed that infants were able to anticipate more familiar actions such as feeding with a spoon (Kochukhova and Gredebäck 2010). These findings may indicate the necessity of the infants' sensorimotor experiences with the observed action for perceiving and anticipating the goal of other people's actions. However, there may be an alternative explanation for this finding. Infants are exposed to feeding from a very early age and feeding is a biologically rooted action. The understanding of feeding might be phylogenetic primed. Infants place objects inside their mouths even outside the feeding context and develop their own hand–mouth coordination from a very early age. It is thus possible that the infants' anticipatory responses in the feeding context did not indicate action understanding (Kochukhova and Gredebäck 2010). To date the ontogeny of action understanding is not yet fully understood and clearly needs more research to clarify the importance of sensorimotor experiences.

The present eye-tracking study sought to investigate proactive eye movements in young children when they observe adults' actions with a familiar object (i.e. a glass) and a different functional outcome. The understanding and prediction of actions with an object may be supported by either the contextual information from the standard use of the object or by the ability to identify and integrate relevant information from the adult's grip selection when grasping the object. The children will see an adult picking up a filled glass with either a lateral grip suggesting that she/he is willing to drink (i.e. familiar action which is congruent with the contextual information) or with an overhand grip suggesting that she/he is willing to clean-up (i.e. less familiar action which is incongruent with the contextual information), contrasted to non-human actions represented by geometric figures. Before interpreting the gaze behavior recordings we also aimed to verify the inter-rater reliability of the manual coding system we developed.

The novel aspect of our approach lies in the contrast between the familiar, less familiar human and non-human actions. This particular contrast enables us to determine the importance of sensorimotor experience as well as human nature of observed actions on action understanding. We expect that proactive eye movements will appear significantly more when children observe familiar congruent actions than when they observe unfamiliar incongruent and non-human actions. In addition, we expect that repeated observation of less familiar human actions will result in a gradually increase of proactive eye movements even without the child has got the opportunity to execute these actions. Finally, we determine possible effects of different variables of development on the gaze behavior.

Method

Participants

In this study, 29 typically developing children (14 boys and 15 girls) between 23 and 41 months of age (mean chronological age 32.1 months, SD 4.9 months) were involved. The following inclusion criteria were used: (1) maximum one failure on a developmental domain assessed by the Ages and Stages Questionnaires (ASQ) (Bricker & Squires 1999); (2) no form of strabismus because of the used eye-tracking technology; (3) sufficient eye-tracking data and (4) signed informed consent. Two children (1 boy of 40 months, 1 girl of 31 months) were excluded because of insufficient eye-tracking data due to poor calibration.

Participants were recruited from kindergarten in the region Diepenbeek-Hasselt and through acquaintances and friends.

Procedure

Parents received a newsletter with information about the study. Parents were asked to bring their child to the research lab in REVAL (Building A at the University of Hasselt, Diepenbeek). Prior to this appointment, they were asked to sign an informed consent and to fill in four questionnaires: (1) the Ages and Stages Questionnaires (ASQ); (2) the Dutch version of the MacArthur-Bates Communicative Development Inventories (N-CDI) (Zink and Lejaegere 2002); (3) a questionnaire on medical history and early movement skills (Chambers and Sugden 2002) and (4) a questionnaire about the family situation.

Clinical Assessment

The Ages and Stages Questionnaires (ASQ) is a parent completed developmental screening questionnaire including five domains of child development: communication, gross motor, fine motor, problem solving, and personal–social skills. The ASQ demonstrates reasonable test characteristics with a high specificity (86%) and an average sensitivity (72%) (Bricker and Squires 1999). Further the Dutch version of the MacArthur-Bates Communicative Development Inventories (N-CDI) (Zink and Lejaegere 2002) was administrated which measures the children's language comprehension and language production level. Finally, the parents filled in a questionnaire on medical history and Early Movement Skills (EMS) (Chambers and Sugden 2002) and a questionnaire about the family situation.

Assessment of eye-movements

Test environment

The participants were individually tested in the child research lab of REVAL (See Appendix 1 Fig. A). The left area of the room consisted of a play corner. In the center of the room there was a car seat and a screen of 39 cm by 70 cm. Underneath the screen both cameras of the eye-tracking system were attached in order to register the child's eye movements. On the right side, beyond the purview of the child, eye-tracking data were recorded by software programs on computers.

Pilot trial out

Prior to the experiment, a pilot trial-out was carried out with 4 typical developing children (3 boys and 1 girl) between 28 and 40 months of age. Based on this experience two adjustments were made: (1) the introduction of a standardized pretest familiarization procedure and (2) the addition of an individual fine-tuning after the standard calibration procedure.

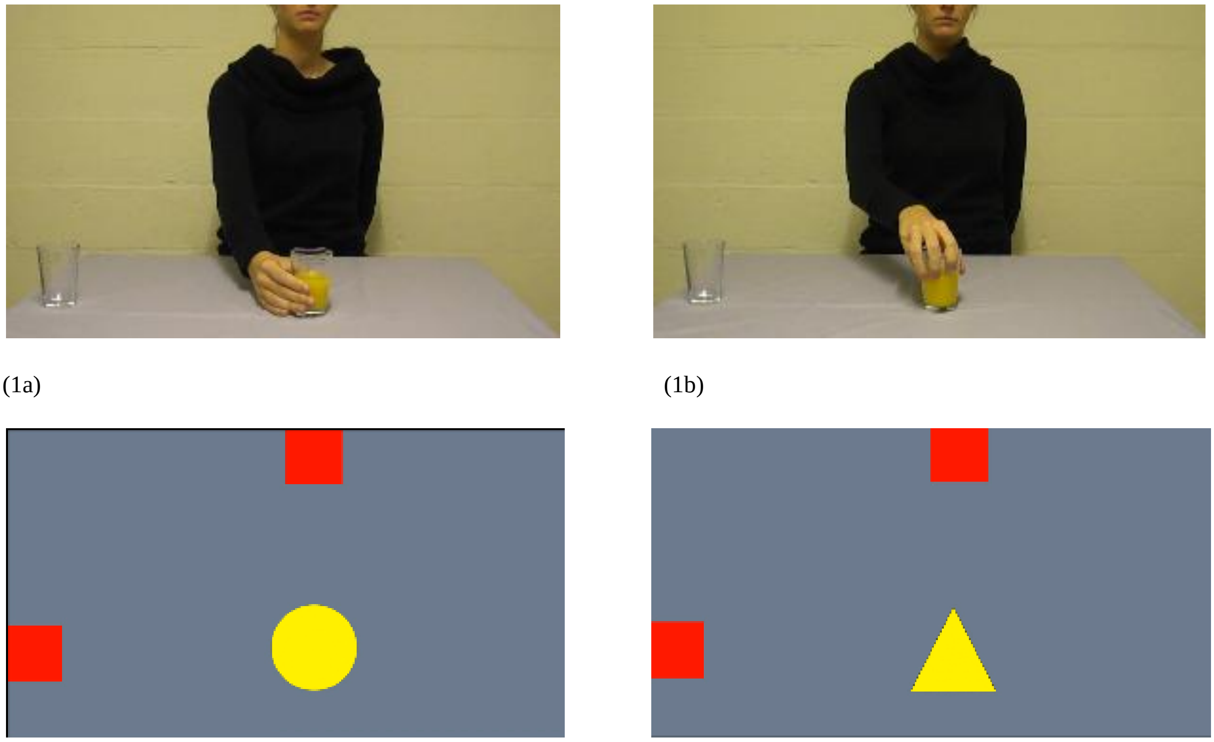
Pretest familiarization

The participants and the accompanying parent were given the opportunity to explore the research lab. First, the child made a puzzle together with one of the investigators (GK or LVS) in order to feel acquainted with the investigator and the environment. Then, the attention of the child was attracted to the screen by displaying a popular animated movie, in particular "Ukki". If the child was interested in the movie, the parent was asked to install the child in the car seat in front of the screen. The parent took place behind or beside the child.

Stimuli of experimental and control conditions

Video clips were shown on the screen. In the target video clip (Fig. 1a and 1b) participants saw an adult picking up a filled glass in two different ways: with a unimanual lateral grip suggesting that she was willing to drink and with a unimanual overhand grip suggesting that she was willing to clean-up. The adult was portrayed to the mouth in order to prevent distraction of the participants' attention by the adult's face. The mouth was located at a distance of 30 cm to the center of the table. A glass (height 9.3 cm, diameter at the top 6.3 cm and 5.1 cm at the bottom) filled with orange juice was placed in the middle of the table. On the right-hand side of the filled glass a similar empty glass was placed. The distance between the two glasses was 30 cm.

Control video tasks (Fig. 1c and 1d) with geometric figures which made similar movements as the hand in the target video clip were used to rule out that logical reasoning instead of the understanding of the specific goal-related hand-glass interaction construed action and intention understanding. In the ball condition children saw a yellow ball enlarging and then moving upwards to the upper red square as simulation of the adult's hand in the drinking condition. In the triangle condition children saw a yellow triangle enlarging and then moving to the right red square as simulation of the adult's hand in the cleaning-up condition.



(1a) (1b)

(1c) (1d)

Fig. 1: Snapshots of both target and both control video stimuli : (1a) a unimanual lateral grip in the drinking condition; (1b) an overhand grip in the cleaning-up condition; (1c) the yellow ball moves forward and then upward (as simulation of the drinking condition) and (1d) the yellow triangle moves forward and to the right (as simulation of the cleaning-up condition).

Children were shown each condition (drinking, cleaning-up, ball and triangle) eight times (4 conditions*8 trials resulting in 32 possible gaze shift events) in a randomised order with 2 seconds of attention-getting animations (sound making spinning figures such as a boat and a car) before each sequence of four stimuli (see Appendix 1 Fig. B). The duration of the whole sequences was 4 minutes and 32 seconds. Four different sequences were assembled and divided over the 27 participants in order to randomize the initial stimuli.

Devices

The eye movements of the participants were recorded using a corneal reflection eye and head tracking technique of the Seeing Machines (FaceLAB eye tracking system, version 5.0). This head-free table-mounted system uses two small cameras to track head and eye movements. The infrared lights directed toward the cornea are invisible to the children. The head rotations can be detected up to + /- 90 ° about the y-axis and + /- 45 ° around the x-axis. The accuracy of the head movement is around 1 mm translational error and rotational error around 1 °. Eye rotations can be detected up to + /- 45 ° about the y-axis and + /- 22 ° around the x-axis. The accuracy of the gaze direction is between 0.5 and 1 ° rotational error (Seeing Machines 2006, FaceLAB specifications).

Calibration

A child-friendly 9-point calibration procedure was applied. The participants were asked to follow nine figures with a matching sound. The accuracy was verified with a puzzle piece (diameter 4.5 cm) holding to the screen. Special attention was paid to the accuracy of measurement within the three areas of interest (AOI) which were defined on the screen for the analysis of gaze: respectively the central AOI, the correct goal AOI and the incorrect goal AOI (Fig. 2). The AOI's were invisible to the children. The measurement error was accepted if the fixation of the child's eye fell within 2 cm of the AOI's. If this was not the case, the above mentioned procedure was repeated. EyeWorks™ overlaid the participants gaze position on the target material and made analysis of the data possible.

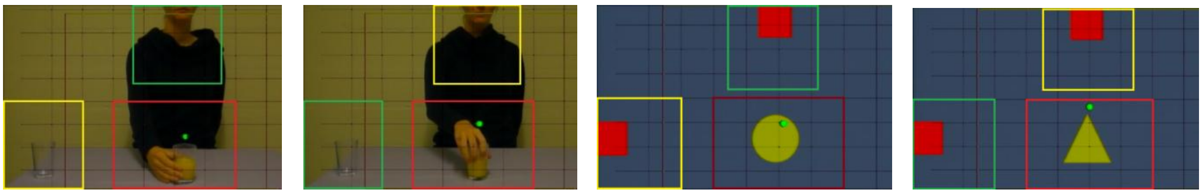


Fig. 2 Areas of interest (AOI). The central AOI are delimited in red, the correct goal AOI in green and the incorrect goal AOI in yellow. Note that the AOI's were invisible to the children.

Scoring of gaze behavior

According to the Seeing Machines (2006), gaze responses can described as a fixation (i.e. the eye focuses for more than a short period), a saccade (i.e. a fast eye movement between two points) or a smooth pursuit (i.e. a slow eye movement that follows the movement of an object). These gaze responses could occur in the first and second phase of the observed action, i.e. when the hand reached to the glass and grasped it, respectively when the hand moved the glass to the goal. A similar distinction was made in the control conditions. The geometric figures enlarged in phase 1 and started to move to the goal in phase 2.

The level of gaze behavior of the 27 participants in each of the 32 possible gaze shift events (resulting in 864 possible data points) was scored on a five point ordinal scale (see below). Two independent raters (GK and LVS) scored the gaze behavior by using the decision tree described in Figure 3.

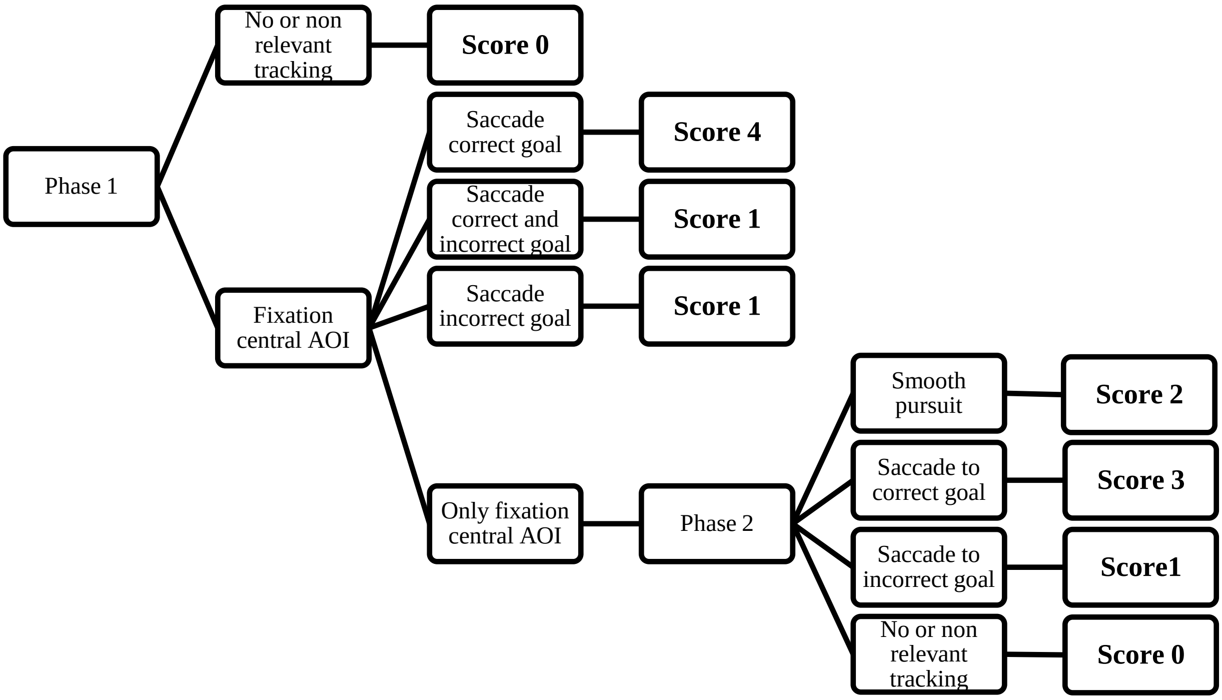


Fig. 3 Decision tree for scoring five different gaze responses in 864 possible data points

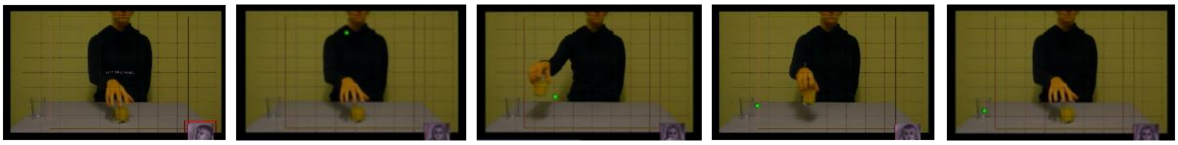
Score 0 was given to an *inadequate gaze shift*, when no eye-tracking data were available (e.g. when the child did not look to the screen) or when the child did not look to the central AOI (Fig. 4a). Inadequate gaze shift was interpreted as 'the child *does not see* what the adult *is doing*'.

Score 1 was given to an *exploratory gaze shift*, which is a gaze shift from the central AOI to the incorrect goal AOI or both goal AOI's (Fig. 4b). Exploratory gaze shift was interpreted as 'the child *wonders* what the adult *is doing*'.

Score 2 referred to a *reactive gaze shift.* This is a gaze shift from the central AOI to the correct goal AOI which is initiated *after* the displacement of the object (filled glass, respectively geometric figures) and which arrived *after* the object arrival (Fig. 4c).We assume that the child has tracked the direction of the moving object *to understand* the end-goal. Reactive gaze shift was interpreted as 'the child *sees* what the adult *is doing*'.

Score 3 was given for an *active gaze shift.* This is a gaze shift from the central AOI to the correct goal AOI which is initiated *after* the displacement of the object (filled glass, respectively geometric figures) and which arrived *before* the object arrival (Fig. 4d). We assume that the child has tracked the direction of the moving object *to predict* the end-goal. Active gaze shift was interpreted as 'the child *sees* what the adult *is willing to do*'.

Score 4 referred to a *proactive gaze shift*. This is a gaze shift from the central AOI to the correct goal AOI which is initiated *before* the displacement of the object (filled glass, respectively geometric figures) and which arrived *before* the object arrival (Fig. 4e).We assume that if in the participant's gaze reaches the correct goal AOI (mouth, respectively empty glass) before the actor's hand reaches the central AOI of the filled glass, the child had tracked the type of grip *to predict* the correct goal. Proactive gaze shift was interpreted as 'the child *foresees* what the adult *is willing to do*'. In addition, we assume that if in the participant's gaze reaches the correct goal AOI before the geometric figure starts to move, the child had tracked the shape of the geometric figure *to predict* the correct goal.



(4a) (4b) (4c) (4d) (4e)

Fig. 4 Snapshots of video overlay of the target video clip in the cleaning-up condition. The green dot represents the gaze direction of a typically developing girl of 2years 2months of age. Example of scores: (4a) score 0 for an inadequate gaze shift; (4b) score 1 for an exploratory gaze shift; (4c) score 2 for a reactive gaze shift; (4d) score 3 for an active gaze shift; and (4e) score 4 for a proactive gaze shift.

Data analysis

Descriptive statistics were performed to define the characteristics of the participants.

Eye-tracking in young children presents unique challenges, in particular with respect to the missing data points (Gredeback et al. 2010). Gaze behavior could not be analyzed when no eye-tracking data were available or when the child did not look to the central AOI (score 0). Therefore a preliminary analysis of the level of gaze behavior was performed and trials (4 conditions*27 participants) showing more than 25% inadequate gaze behavior (score 0) were excluded for further analyses. On the basis of this analysis five trials were included.

The inter-rater reliability of the scoring system (level of gaze behavior) was calculated by means of a Cohen's Kappa weighted value and percentages of agreement. Kappa values were interpreted according to Fleiss (1981) whereby values were read as agreement by coincidence below .40, as moderate between .40 and .60, as good between .61 and .75 and as excellent agreement above .75. Percentages of agreement were also determined for all items and considered as acceptable with a percentage higher than or equal to 75 %.

Also sum scores of gaze behavior in the included trials for each condition were calculated (range: 0-4*5 included trials = 0-20). Prior to the analysis of gaze behavior, possible group differences in the sum scores of gaze behavior according to gender and stimulus sequence order were verified with the Mann-Whitney U test, respectively Kruskall-Wallis test. Participants were considered as one sample if no significant group differences were found.

To examine the gaze behavior, possible differences in the level of gaze behavior between the four conditions for each trial as well as changes in the level of gaze behavior over the included trials for each of the four conditions were analyzed, using Friedman's nonparametric repeated measures test and the Wilcoxon Signed Rank test as a post hoc test. In the Friedman's analysis, the significance level was set at p<.05. In the post hoc analysis, the significance level was set at p<.05 divided to the number of included trials, respectively p.<05/5 = p<.01, to account for the problem of multiple comparison.

To investigate the relationship between the sum scores of gaze behavior in the included trials of all conditions and several developmental parameters, in particular chronological age, ASQ, NCDI and EMS scores, Spearman's rank correlation coefficients were calculated. Correlation coefficients were interpreted according to Hinkle et al. (1998), with values below .30 as little or no, between .30 and .50 as low, between .50 and .70 as moderate and above .70 as high association.

The level of significance was set at p<.05 unless otherwise indicated. All analyses were performed with the statistical software SPSS (version 20.0).

Results

Descriptive statistics of the participants

Table 1 presents the descriptive characteristics of the 27 included participants.

Table I Characteristics of the participants (N=27)

Age (n=27)	Mean (months)		SD (months)		Range (months)
	31.8		4.8		23-41
Gender (n=27)	Male		Female		
	13		14		
ASQ (n=27)	Communication	Gross motor	Fine motor	Problem solving	Personal Social
Mean (max. 60)	54.8	53.3	47.2	52.4	53.8
SD	7.6	8.0	13.6	9.3	7.3
Range	30-60	30-60	40-60	25-60	35-60
Below cut off	n=0	n=1	n=2	n=2	n=0
NCDI (n=26)	Language Comprehension		Language Production		
Mean (max. 702)	604.2		488.4		
SD	90.4		153.9		
Range	429 – 702		55-702		
EMS (n=27)	Self Help Skills	Desk Skills	Classroom Skills	Recreational Skills	Total
Mean Raw Score	13.5	8.8	5.7	10.7	39.1
SD	4.0	2.8	0.9	3.1	8.5
Range	5 – 19	5 – 15	4 – 8	7 – 17	22 – 60

SD, Standard deviation; Below cut off, number of children with a score below the cut off score of a particular developmental domain of Ages and Stages Questionnaires (ASQ); NCDI, Dutch version of the MacArthur-Bates Communicative Development Inventories; EMS, Early Movement Skills.

Preliminary analysis of the level of gaze behavior

Figure 5 visualizes the level of gaze behavior according to the five point scale within each trial. The last three trials (trial 6, 7 and 8) were excluded because inadequate gaze behavior was observed in more than 25% of the stimuli. The remaining five trials (trial 1 until 5) were included for further analysis.

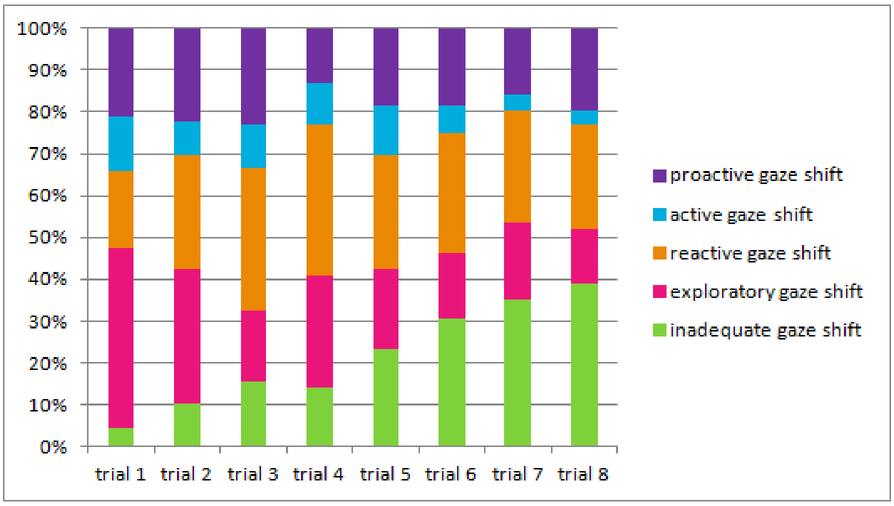


Fig. 5 Level of gaze behavior expressed as percentage of each score within each trial.

Inter-rater reliability

The inter-rater reliability of the gaze behavior scores of the five trials in each condition is presented in table 2. Among the 20 gaze shift events, 19 revealed an excellent inter-rater agreement and 1 had good agreement. All percentages of agreement were above 75%.

Table 2 Inter-rater reliability of gaze behavior scores (five point scale) in 4 conditions for the 5 trials

Condition	Trial	Weighted Cohen's Kappa (ASE)	Percentage of agreement
Drinking	1	.77 (.09)	77.7%
Drinking	2	.98 (.02)	96.3%
Drinking	3	.97 (.03)	96.3%
Drinking	4	.95 (.04)	92.6%
Drinking	5	.87 (.09)	88.8%
Cleaning-up	1	.92 (.07)	96.3%
Cleaning-up	2	.94 (.05)	96.3%
Cleaning-up	3	.94 (.06)	96.3%
Cleaning-up	4	1.00 (.00)	100%
Cleaning-up	5	.85 (.10)	92.6%
Ball	1	.97 (.02)	96.3%
Ball	2	.84 (.08)	85.1%
Ball	3	.92 (.06)	92.6%
Ball	4	.90 (.07)	92.6%
Ball	5	.73 (.13)	85.1%
Triangle	1	.86 (.07)	85.1%
Triangle	2	.93 (.05)	92.6%
Triangle	3	.87 (.07)	88.8%
Triangle	4	.79 (.08)	77.7%
Triangle	5	.90 (.06)	88.8%

ASE, Asymptotic standard error

Preliminary group differences in gaze behavior

No significant gender differences were found for the sum scores of the drinking (*U*=83.0; p=.69), the cleaning-up (*U*=73.5; p=.38), the ball (*U*=78.5; p=.54) and the triangle (*U*=152.5; p=.15) condition. Also, the stimulus sequence order was not statistically significant in the drinking (*H*=2.29; p=.52), the cleaning-up (*H*=.77; p=.86), the ball (*H*=7.77; p=.05) and the triangle (*H*=.43; p=.93) condition. Therefore, participants were considered as one sample in the following analyses.

Differences in gaze behavior between the four conditions

The median and interquartile range of the gaze scores for the five trials, as well as for the sum scores of gaze behavior in each of the four conditions and the statistical comparison between the conditions are shown in table 3.

The Friedman test revealed a statistically significant difference between the sum scores of gaze behavior in the four conditions (Friedman's χ^2=17.23; p=.001). The sum score of gaze behavior in the drinking condition was significantly higher compared to the sum score of gaze behavior in the cleaning-up (Z=-3.88; p=.00), the ball (Z=-3.75; p=.00) and the triangle (Z=-2.87; p=.004) condition.

The Friedman test revealed a statistically significant difference in trial 1 (Friedman's χ^2=7.98; p=.046), trial 3 (Friedman's χ^2=17.68; p=.001) and trial 4 (Friedman's χ^2=10.76; p=.013). In trial 1, the gaze behavior scores were significantly higher in the drinking condition as compared to the cleaning-up condition (Z=-3.24; p=.001). In trial 3, the gaze behavior scores were significantly higher in the drinking condition as compared to the ball condition (Z=-3.40; p=.001) and the triangle condition (Z=-3.12; p=.002). In trial 4, the gaze behavior scores were significantly higher in the drinking condition as compared to the cleaning-up condition (Z=-2.81; p=.005) and the ball condition (Z=-2.68; p=.007).

Table 3 Median and Interquartile range of the gaze behavior scores for the four conditions during the 5 trials

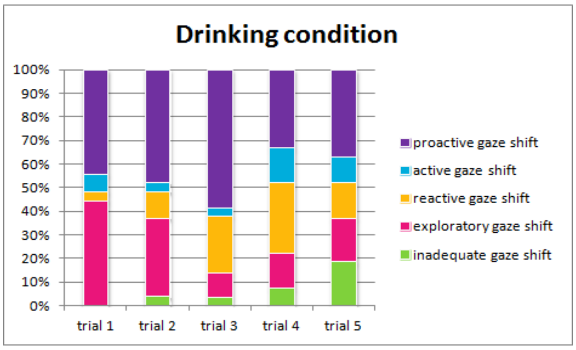
	Drinking		Cleaning-up		Ball		Triangle		χ^2
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	p
Trial 1	3.0	1.0-4.0	1.0	1.0-2.0	2.0	1.0-4.0	3.0	1.0-3.0	.046*
Trial 2	3.0	1.0-4.0	2.0	1.0-2.0	2.0	1.0-2.0	1.0	1.0-3.0	.123
Trial 3	4.0	2.0-4.0	2.0	2.0-3.0	2.0	0.0-2.0	2.0	1.0-3.0	.001*
Trial 4	2.0	2.0-4.0	2.0	1.0-2.0	2.0	1.0-2.0	1.0	1.0-3.0	.013*
Trial 5	2.0	1.0-4.0	1.0	1.0-2.0	1.0	0.0-2.0	2.0	1.0-3.0	.083
Sum scores	13.0	10.0-16.0	8.0	7.0-10.0	9.0	5.0-11.0	8.0	7.0-12.0	.001*

*IQR, Interquartile range; χ^2, Friedman's nonparametric repeated measures test;*p < .05*

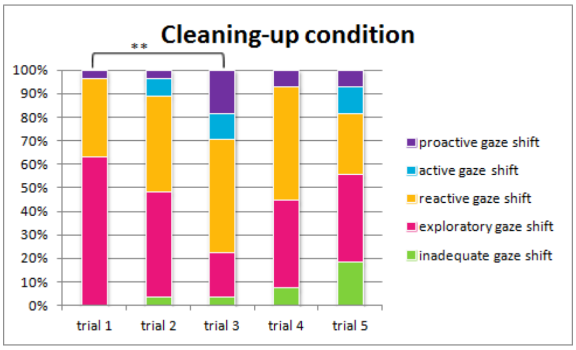
Changes in level of gaze behavior within the four different conditions

Figure 6 visualizes the participants' level of gaze behavior when viewing the four different conditions during the five consecutive trials. The visual inspection of the level of gaze behavior in the drinking and cleaning-up conditions shows a shift from a rather exploratory to a more reactive, active and even proactive gaze shift. However this change is not obvious in the non-human conditions.

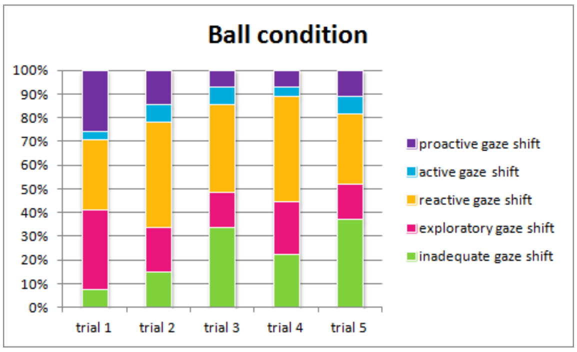
The Friedman test revealed only a statistically significant difference in the cleaning-up condition (Friedman's χ^2=10.60; p=.031). The difference score between trial 1 and trial 3 in the cleaning-up condition was significantly different (Z=-2.71; p=.007) indicating a significant improvement of gaze behavior scores.



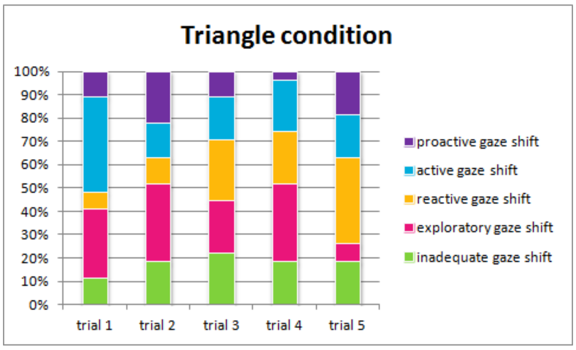
(6a)



(6b)



(6c)



(6d)

Fig. 6 Frequencies of gaze behavior in the four different conditions during the 5 trials: (6a) the drinking condition; (6b) the cleaning-up condition; (6c) the ball condition and (6d) the triangle condition. **p < .01

Correlations

Table 4 summarizes the correlation coefficients between the sum score of gaze behavior of all conditions and several developmental parameters. Only the sum score of the cleaning-up condition showed a significantly negative but low correlation with the ASQ problem solving score (r_s=-.46; p=.016).

Table IV Spearman Rho correlation coefficients between the sum score of gaze behavior in the drinking, cleaning-up, ball and triangle condition with chronological age, ASQ, NCDI and EMS scores

	Drinking	Cleaning-up	Ball	Triangle
Chronological age	.11	-.05	.13	.29
ASQ				
Communication	.14	-.08	.11	.12
Gross motor	-.04	-.16	.11	.07
Fine motor	.35	.09	.11	.08
Problem solving	.28	-.46*	-.12	.12
Personal Social	-.18	-.37	.06	-.05
NCDI				
Language comprehension	.23	-.06	.08	.28
Language production	.22	-.08	.12	.24
EMS	.17	.12	-.08	-.33

*ASQ, Ages and Stages Questionnaires; NCDI, Dutch version of the MacArthur-Bates Communicative Development Inventories; EMS, Early Movement Skills; *p < .05.*

Discussion

The present study recorded eye movements in young children when they observed human as well as non-human actions. In the first case the children observed adults' picking up a glass in order to drink (familiar congruent action) or to clean-up (less familiar incongruent action). These actions are actions with an inferable outcome level because the goal of the action can be deduced from the adult's grip. In the latter case children observed non-human incongruent actions, represented by geometric figures, shifting in a similar movement pattern as the human actions.

The expectation that proactive eye movements will appear more when children observe the familiar action of drinking than the less familiar action of cleaning-up was confirmed. Comparisons between trials revealed significant differences in two out of the five trials, respectively trial 1 and trial 4, for the median gaze score in favour of the drinking condition. Also the sum score of gaze behavior was higher in the drinking condition compared to the cleaning-up condition. Furthermore visual inspection of the data (see figure 6) showed a much higher percentage of proactive eye movements in the drinking condition (44.44% in trial 1; 33.33% in trial 4) as compared to the cleaning-up condition (3.70% in trial 1; 7.41% in trial

4). The children probably expected from the contextual information of the filled glass that the adult was willing to drink in the cleaning up condition. They seem not to recognize the overhand grasp to clean-up the glass. This may be due to a lack of motor experience with the observed action. In order to be able to predict the intention of both human actions it seems from these results important to observe and recognize the differences in grip. These findings are consistent with previous studies of Falck-Ytter et al. (2006) and Flanagan and Johansson (2003) in which the need of sensorimotor experiences with the observed action for action understanding was reported.

Previous research has shown that infants are able to adapt their own grip to the shape and orientation of an object from the age of 9 months (Keen 2011). Between 6 and 12 months of age they pick-up small objects with an unimanual grip and large objects with a bimanual grip (Fagard and Pezeacute 1997). Children will switch from a bimanual to an unimanual grip when they pick-up a glass around the age of 30 months (Haley 1992; Wassenberg-Severijnen and Custers 2005). In the present study, participants were between 23 and 41 months of age. So we may assume that not all children were able to pick up a glass with one hand. Unfortunately we were not able to determine which participants use a unimanual grip to pick-up a glass. However, it may be important because the study of Kanakogi and Itakura (2010) found a link between proactive eye movements and the own grasp capacity of children between 4 and 10 months of age.

The results showed also a significant difference in median gaze scores between the drinking condition and the non-human conditions (ball and triangle) in trial 3, as well as the ball condition in trial 4 in favour of the drinking condition. The visual inspection (figure 6) showed a low percentage of proactive eye movements for these trials in the ball (7.41% in trial 3; 7.41% in trial 4) and triangle condition (11.11% in trial 3) compared to the drinking condition (62.96% in trial 3; 33.33% in trial 4). Overall we observed low percentages of proactive eye movements in the ball (7.41-25.93%) and the triangle (3.70-22.22%) condition. These findings confirmed the expectation that proactive eye movements will appear more when children observe the familiar action of drinking than the non-human actions. This is also in line with the findings of a previous study of Falck-Ytter et al. (2006) that only found proactive eye movements if object displacement was caused by human action.

Another study objective was to examine if repeated observations of less familiar actions result in a gradually increase of proactive eye movements even without the children have got the opportunity to execute these actions. Our results showed that some children did learn to predict the less familiar action of grasping a glass to clean it up. This was expressed in the higher median gaze behavior scores in the third trial as compared to the initial trial of the cleaning-up condition. Visual inspection (figure 6) also showed more proactive and less exploratory eye movements in trial 3. This finding suggests that visual exposure to a certain action alone provides young children the ability to predict human actions. In contrast, the children were not able to improve their gaze behavior during the observation of non-human actions. This finding suggests that young children do not learn from repeated trials when there is no human action involved. Our results are in line with previous research of Falck-Ytter et al. (2006) and support the view that action understanding is linked to the MNS. Therefore we assume that the participants created an internal representation of human motor actions but not of non-human ones.

Solely one significant correlation was found between the sum scores of gaze behavior of all conditions and several developmental parameters. The ASQ problem solving score showed a low but significant negative relationship with the cleaning-up condition. We could not explain this result on the basis of literature. Because we found no other correlations with the developmental parameters, we assume that development in our age range had no influence on our results.

A strength of the present study is found in the focus that is laid on functional tasks, such as drinking and cleaning-up a glass. This is in contrast with previous similar studies that also used tasks with an object but however had no functional outcome. Another strength of this study is the differentiation between familiar and less familiar actions and human and non-human actions. The present study also warrants some critical considerations. The sample of participants was rather small. This may have induced a lack of statistical power. Also participants with quite a wide age range were included. We assumed that older children would be better in understanding and predicting human actions due to their longer sensorimotor experiences as compared to younger children. However no significant correlations between the sum score of gaze behavior in the included trials of all conditions and chronological age was found. Further, we did not succeed to determine which grip the participants spontaneously and predominately use to pick-up a glass. Most of the children refused our glass of orange juice which we offered before and after the experiment. The last three out of eight trials were excluded because no appropriate gaze behavior could be recorded due to a lack of interest of the participants. This finding may raise the question about the relationship between the duration of the movie and the attention of the participants. We were rather surprised that the attention span of healthy preschool children was less than 4 minutes. Further, it is also important to mention that gaze behavior was judged with a manual coding system and not with continuous data. Therefore it was difficult to record small learning effects.

The study showed proactive eye movements in the drinking condition, ranging from 33.33% till 62.96% but showed less proactive eye movements in the other three conditions. It will be informative in further studies to expand our age range in order to verify of older children and even adults are able to predict less familiar and non-human actions. In addition, it will be a value to include children with a disability like autism spectrum disorders. Several studies (Dapretto et al. 2006; Williams et al. 2006; Martineau et al. 2008; Oberman et al. 2008; Greimel et al. 2010) showed indirect evidence for an otherwise acting MNS in children with autism spectrum disorders. Therefore it is justifiable to hypothesize that this population has more difficulties to predict even familiar actions.

In summary, proactive eye movements seem to require a familiar human action such as drinking at the age range of 23 till 41 months. Still children in this age group are already able to learn to predict more complex human actions without having the opportunity to execute the observed action. However children of this age group are not able to learn and to predict non-human actions.

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APPENDIX 1

(a) (b) (c)

Fig. A Child research lab of REVAL (Campus UHasselt): (a) play corner; (b) car seat, screen and eye-tracking cameras; (c) computers for data-registration.

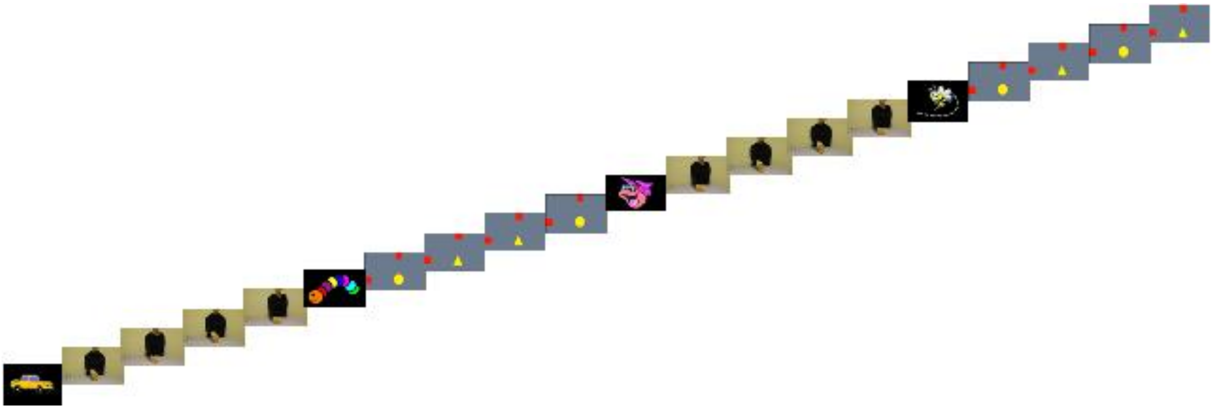

Fig. B Example of stimulus sequence of 16 out of 32 possible gaze shift events.

APPENDIX 2: Guidelines of Experimental Brain Research for authors