Wilfrid Laurier University

Scholars Commons @ Laurier

Psychology Faculty Publications   Psychology

Gaze, goals and growing up: Effects on imitative grasping

Sonja P. Brubacher
Central Michigan University

Kim P. Roberts
Wilfrid Laurier University, kroberts@wlu.ca

Sukhvinder S. Obhi
Wilfrid Laurier University, sobhi@wlu.ca

Follow this and additional works at: https://scholars.wlu.ca/psyc_faculty

Part of the Psychiatry and Psychology Commons

Recommended Citation

Brubacher, S.P., Roberts, K.P., & Obhi, S. (2013). Gaze, goals and growing up: Effects on imitative grasping. British Journal of Developmental Psychology, 31, 318-333. DOI: 10.1111/bjdp.12009

RUNNING HEAD: Gaze, goals and growing up

British Journal of Developmental Psychology

Gaze, goals and growing up: Effects on imitative grasping

S. P. Brubacher [a]

K. P. Roberts

S. S. Obhi [b]

Wilfrid Laurier University

Abstract

Developmental differences in the use of social-attention cues to imitation were examined among children aged 3- and 6-years old ($n = 58$) and adults ($n = 29$). In each of 20 trials, participants watched a model grasp two objects simultaneously and move them together. On every trial, the model directed her gaze towards only one of the objects. Some object pairs were related and had a clear functional goal outcome (e.g., flower, vase), while others were functionally unrelated (e.g., cardboard square, ladybug). Owing to attentional effects of eye gaze, it was expected that all participants would more faithfully imitate the grasp on the gazed-at object than the object not gazed at. Children were expected to imitate less accurately on trials with functionally-related objects than those without, due to goal-hierarchy effects. Results support effects of eye gaze on motor contagion. Children's grasping accuracy on functionally-related and functionally-unrelated trials was similar but they were more likely to only use one hand on trials where the object pairs were functionally related. Implications for theories of imitation are discussed.

175 words

Imitation is crucial to children's learning and requires social attention (Meltzoff & Decety, 2003), which can be indicated by eye gaze; that is, where a person looks can be indicative of her/his thoughts and future actions (Meltzoff & Brooks, 2007). Some researchers have theorized that the development of gaze-following may in fact be a necessary precursor to certain kinds of imitation (Kumashiro, Ishibashi, Uchiyama, Itakura, Murata & Iriki, 2003).

Meltzoff and Moore (1994) suggest that imitation results from a combination of basic perception-action links and cognition, which sometimes leads to imitation of different components of the action. In this way imitation can be considered as a product of top-down and bottom-up processing. In fact, many researchers have found that young children do not always imitate exactly the process that they see, being motivated instead to emulate[1] the outcome of a goal-directed action (e.g., Gleissner, Meltzoff & Bekkering, 2000; Meltzoff, 1995). None of the research concerning imitation of processes versus outcomes, however, has considered the effect of gaze cues on focusing attention. As both imitation and attention to others' gaze cues are so ubiquitous in young children's everyday social-cognitive learning, it is critical to understand the developmental trends in these processes, and especially how they may interact, which is the focus of the current research.

Eye Gaze and Motor Imitation

Attention to eye movements develops early in life, between 3- to 12-months, depending upon study methodology and definitions (Caron, Caron, Roberts & Brooks, 1997; Hood, Willen & Driver, 1998; Tomasello, 1995). The influence of gaze cues on attention is strong and robust; eye shifts *automatically* attract the attention of an observer,

even when these shifts are uninformative or irrelevant to the task or social situation (Driver, Davis, Ricciardelli, Kidd, Maxwell & Baron-Cohen, 1999; Freisen & Kingstone, 1998; Freisen, Moore & Kingstone, 2005; Ricciardelli, Bricolo, Aglioti and Chelazzi, 2002).

It has been suggested that gaze shifts can also affect the *motor* properties of the gazed-at *object* (Becchio, Bertone & Castiello, 2008). The current research sought to investigate whether children's motor imitation behaviours (i.e., grasping behaviour) could be differentially elicited via gaze cues, such that they would more accurately imitate grasps on gazed-at objects than on objects not gazed at.

Blakemore and Frith (2005) coined the term "motor contagion" to explain the phenomenon that occurs when we read someone else's intention from their eyes, and it affects our own motor behaviour. It has further been proposed that motor contagion is the first step in mentalizing (i.e., attending to, and interpreting, intentional mental states in the self and others) and is very important for young children's social cognitive development (Meltzoff & Brooks, 2007). Effects of motor contagion have been demonstrated in children (Becchio, Pierno, Mari, Lusher & Castiello, 2007) and adults (Castiello, 2003).

Pierno, Becchio, Wall, Smith, Turella, and Castiello (2006) found that the same brain areas are recruited in humans when watching a model gaze at an object and when watching a model actually grasp the object. A group of cells in superior temporal sulcus of the macaque monkey has been observed which are active when the monkey observes reaching actions *but only when the model looked* in the direction of his reach (Jellema,

Baker, Wicker & Perrett, 2000). Despite these findings, there exists no research to date demonstrating that gaze direction affects human motor imitation behavior.

Imitation and the Goal-Directed Theory

The theory of goal directed imitation (GOADI; Bekkering, Wohlschläger & Gattis, 2000) states that people will prioritize copying the outcome of an action over copying the actual body movements the model uses to achieve the goal. Children, for example, will recognize that putting the puzzle shape in the correct slot is more important than using the same hand or grip as the adult whose action they are imitating. By the age of two years, children often imitate intended actions (e.g., pulling apart two halves of a dumbbell) rather than "failed" actions (e.g., failing to pull the dumbbell apart) because they understand intentions and goals of others (Meltzoff, 1995).

Gleissner and colleagues (2000) asked 3-year olds to imitate a series of motor behaviours. The experimenter moved her hand near to, or in contact with, a part of her own body. Children made significantly more errors on trials where the experimenter made contact with a body part than when she simply placed her hand near to it. These errors occurred primarily on contralateral trials, suggesting that when contact was made with the body part, the overarching goal of touching the body part superseded the motor action to do so, very much as in Bekkering and colleagues (2000) who also demonstrated greater errors on contralateral trials. In their experiment, the 4- to 6- year old children viewed 'touching the correct ear' as the dominant goal, rather than copying the process to do so. In their second experiment, the model always touched the same ear and so the goal of touching the correct ear was removed. Children were 100% accurate on ipsilateral trials and contralateral accuracy was not significantly lower. In the third

experiment, the model touched locations on a table either marked by dots or unmarked. Children made significantly more contralateral-to-ipsilateral errors in the dots condition (i.e., when there was a 'goal' to touch the dot) than when the location was unmarked.

In a variation of Bekkering and colleagues (2000) task, 12- and 18-month old toddlers observed a model moving a stuffed mouse via either a 'hopping' or 'sliding' motion to a location on a mat which either contained a house or not (Carpenter, Call and Tomasello, 2005). It was predicted that when there was a house on the mat (like the dot on the table), children would be less likely to copy the *style* of moving the mouse than when there was no house. Indeed, children of both age groups were more accurate at imitating style when there was no mouse-house; the magnitude of this effect being larger for the 18-month old children.

In the current research, we compared the accuracy of children's and adults' grasping behaviours when objects were functionally related so as to produce a goal outcome, and when they were not. In line with previous research we predicted that, when imitating a model who brought two objects into contact, children would be more accurate in their grasping of these objects when they were *not* functionally related than when they were, while adults would not be significantly affected by this manipulation.

We also hypothesized that gazed-at objects would be grasped more accurately than objects that were not gazed-at. In light of the salience of eye gaze, we further predicted that this would be the case regardless of goal-status, across all age groups. Experiments using eye gaze as a cue have not yet investigated whether gaze towards a target can improve the accuracy of imitative grasping with that target by children (or whether lack of gaze may impair it). This question applies to many existing publications

concerning children (and adults') imitation. For example, in previous research (e.g., Bekkering et al., 2000; Gleissner et al., 2000) we do not know whether the findings could be altered by whether the model explicitly looked at her *hand* (i.e., effector) before making a movement toward body part or table location. These questions are theoretically important to all types of imitation studies and are practically important to situations in which children's learning takes place. For example, it is already known that even very young children's word-learning can be improved when gaze cues are involved (e.g., Golinkoff, Hirsh-Pasek & Hollich, 1999).

We chose to use 3-year olds as our younger age group because, although research has shown that infants demonstrate gaze tracking (e.g., Hood et al., 1998), the ability to determine exactly where an adult is looking may not be fully developed until the age of 3 years (Doherty & Anderson, 1999). We then included 6-year olds in our design because they are developmentally more able to recognize the connection between gaze and intention/desires (e.g., Pellicano & Rhodes, 2003). This age range has also been used in studies of children's goal-directed imitation (e.g., Bekkering et al., 2000; Gleissner et al., 2000). **Method**

Participants

Originally, 61 children and 30 adults were recruited; three 6-year old children and one adult were excluded due to technical problems with video cameras. The final sample consisted of 31 3-year old children (14 males, *M* age months = 41.59, *SD* = 3.25, range 36 – 47), 27 6-year-old children (16 males, *M* age months = 76.67, *SD* = 3.58, range 72 – 83), and 29 adults (11 males). Adults were recruited through the undergraduate pool and

were not asked for their ages (estimated range 18 – 21 years). Children gave assent and adults signed informed consent statements.

The sample was predominantly middle-income, Caucasian. Children were recruited through a local daycare and through a database of local parents who expressed interest in developmental research. Parents of children recruited through the database were compensated $5 and the children received a small toy. The daycare received a donation of $5 for each child that participated. Adults received 0.5 participation credits.

Materials and counterbalancing

Forty simple objects that could be comfortably grasped in *at least* two ways by children as young as 3-years old were collected. Of these, 20 objects were functionally related (e.g., flower and vase, beads and hook, toy pot and lid, dartboard and fuzzy-ball), while the other 20 had no stereotypical functional relationship (e.g., frog and car, bee and letter cube, shovel and flag, wristwatch and snail) and were used for the ten functionally-unrelated trials. Objects were roughly 3.5 in^3 in size.

For counterbalancing, a trial list was first created containing each of the 20 pairs. We then determined two specific grasps for each of the 40 objects; a fine precision grasp (e.g., pick up flower stem with thumb and index finger) and a gross grasp (e.g., whole hand grasp on flower head). All objects afforded multiple comfortable grasps; that is, we did not ask participants to imitate grasps that were very awkward or unusual, or which would be incompatible with obtaining the goal end-state, on functional goal trials[2]. Although we acknowledge that some types of grasps may be more common with particular objects (e.g., picking up the pot lid by its handle rather than its edge), it is

important to note that type of grasp as well as gaze status was counterbalanced across versions.

Each object was presented on the left or right side of space, and each object was gazed at or not gazed at. We created five partially counterbalanced trial lists by selecting five possible versions of each trial, without replacement. The following constraints were placed on the trial selection: approximately equal numbers of objects looked-at on the left and right side of space, approximately equal numbers of fine and gross grasps on both sides of space as well as approximately equal numbers of fine and gross grasps for looked-at and non-looked at objects. After the lists were created, the order of the 20 trials was randomized with the constraint that there were no more than three consecutive trials of any of the following: Functionally-related/unrelated trials, fine/gross grasp on the same side of space, eye gazes to the same side of space (left or right). All participants were assigned randomly to the five counterbalanced versions under the constraint that age and gender be equated as much as possible.

Trials were filmed using a SONY digital camcorder. A female research assistant (RA) sat at a plain grey table in front of a white wall. Each trial began with the RA having hands in her lap, and each object placed directly in front of her left and right shoulders. At the onset of the trial, the RA was looking directly into the camera and then shifted her gaze to one of the objects, simultaneously making a small head movement (approximately 15° from centre) towards the same object. She contacted the objects with her hands simultaneously, brought them to her midline and into contact with each other, either to complete a functional goal, or simply to bring them into proximity with each other. Her eyes remained on the gazed-at object until the end of the trial, when they

again looked straight ahead (i.e., when the objects were in the centre). Each trial lasted approximately six seconds.

Participants were presented the DVDs on a Dell XPS laptop computer (screen size 19 in.) using the Windows Media Player program in full-screen mode. The RA's head was 41% of actual size.

Two digital cameras were used to record all participants. One was placed behind and to the side of the participant. These videos were checked to ensure accurate placement of objects by the RA conducing the sessions. The other camera was placed in front of the participant, beside the laptop screen, and captured the participants' hands, arms, upper torso, and face.

Procedure

Children were invited by a RA (different from the RA in the videos) to help play some games. Adults participated for partial course credit. Participants were tested individually, seated at a table 40 cm from the ground and approximately 53 cm from the center of the laptop screen. The RA told the child "we are going to watch my friend do some things with toys, and then when she is done, I want you to do exactly what my friend did, ok?" Adult participants were simply told that they were a comparison sample for a group of 3- and 6-year olds in a study looking at children's imitative behaviours. They were told to "do what the model on the screen did."

When the participant was ready, the trial was initiated. When it ended, a black screen appeared. The RA then placed the objects seen in the video simultaneously on the table directly in front of the participant's left and right shoulders. We elected to use this procedure instead of a fixed angle from centre to control for differences in participant

size. All trials were mirrored, such that an object contacted by the right hand of the RA in the video (which was on the left side from the participant's perspective) was placed on the participant's left side. It has been demonstrated that children generally imitate in a mirror-like fashion automatically (Bekkering et al, 2000; Schofield, 1976). If a child did nothing on the first trial, the RA showed the trial again and encouraged the child to "do what [RA name] did." Only four 3-year olds actually needed this procedure; their first trial was excluded from data analysis.

Once a participant had executed the actions, the objects were removed and the next trial was initiated when the participant was ready. Children were reminded to "to what [RA name] did" every two or three trials.

Scoring and Coding

Both halves of each of the 20 trials were scored independently (i.e., 40 grasps) because we expected that the gazed-at object would be grasped more accurately than the one not gazed at. Grasps were coded as 'Accurate' if they were the same as the grasp by the model, within reason; that is, the object had to be contacted in the same location, with the same type of grasp (fine/precision or gross/whole-hand). In situations where the former criteria was met, but the participant used four fingers instead of all five (for example), the grasp was still coded as accurate. Grasps were coded as 'Inaccurate' if the object was contacted in a different location, and/or the participant executed a gross-motor grasp on a fine-motor trial, or vice versa. When children and adults were inaccurate, they most often simply picked up the object in the most natural way based on its size and orientation (typically an overhand grasp on the center of the object). Grasps were automatically coded as inaccurate if the participant used the wrong hand. This occurred

infrequently with 3- and 6-year olds only, and only on trials where the child used one hand with an object to bring it into proximity with the other object.

This particular type of inaccuracy; using only one hand, was given its own code: "No-grasp" (i.e., for the grasp not performed; the behaviour of the other hand was coded). This code was applied to adults as well, but only occurred three times across all grasps for adult participants. As such, proportion accurate and inaccurate grasps are not the direct inverse of each other for children's data.

Two independent coders trained together on five participants and then independently scored 10% of the participants of each age group. Overall reliability (Cohen's Kappa) averaged .91 and ranged from .82 to .97. The primary coder, who was blind to the hypotheses of the study, then scored the rest of the data. One participant from each Age Group (not previously used in training or reliability coding) was randomly selected for analysis of reliability over time, and was coded by the second coder. Kappa remained high, averaging .93 (range: .88 to 1.00). Disagreements were resolved by watching the trial again and coming to a consensus.

Because each grasp within a trial was coded independently to reflect the potential effects of eye gaze, and for ease of interpretation, the data were analyzed with 3 (Age Group: 3-year olds, 6-year olds, Adults) x 4 (Grasp-type: Gazed-at/Functionally-related [GF], Not Gazed-at/Functionally-related [ngF], Gazed-at/Functionally-unrelated [Gfu], Not Gazed-at/Functionally-unrelated [ngfu]) mixed analyses of variance (ANOVAs), the latter factor within-subjects. Note that the data were also examined via a more traditional 3(Age Group) x 2(Goal-trial Gaze Status: Gazed-at, Not gazed-at) x 2(Non-goal trial

Gaze Status: Gazed-at, Not gazed-at) mixed ANOVA, the first factor between-subjects, and the results yielded the same interpretations.

Results

Descriptive Statistics

The data were examined for means, ranges and outliers. No data points were identified as outliers for any Age Group or Grasp-type, thus no data were removed. Excluded trials (e.g., if participant looked away for more than one second, or did not watch trial onset) made up 1% of grasps, or 44 of 3480 (87 participants x 20 trials x 2 grasps per trial). Two adult participants each had one excluded trial (i.e., 2 grasps out of 40) and 16 children had one or two excluded trials.

Proportion accurate was at least .10 for all Grasp-types except for Non-goal/Not Gazed-at, for children only (2 children were 100% inaccurate for this type). Adults reached 100% accuracy (1.00) on all trial types, whereas 3-year olds only achieved a maximum accuracy rate of .70 (on Gazed-at/Functionally-unrelated [*Gfu*] trials) and 6-year olds achieved a maximum accuracy rate of .90 on the same trial type.

Five participants failed to complete one of the ten goals (three 3-year olds, two 6-year olds) and one child failed to complete three goals (a 3-year old). These failed goals represented six different object pairs (i.e., children did not consistently fail the same object-pair combination). For example, two children did not put the flower in the vase (they instead brought them into contact). Results reported below were not affected by the removal of these children from analyses. On functionally-unrelated trials, participants largely complied in moving the objects towards each other and did not attempt to create unusual relationships between the object pairs. Children only did so in rare cases when

the object pairs were not immediately removed by the RA after the trial (i.e., children then began to play with the toys).

Gender was tested in all analyses reported below, and was not significant as a main effect or in any interactions, $Fs \leq 2.74$, $ps = ns$, $\eta_p^2s \leq .063$. Gender is thus collapsed in all analyses that follow.

To determine whether there were any differences in accuracy of grasping across Age Groups as a function of hand used (left or right), proportions of Accurate grasps with the left and right hand were subjected to a set of twelve paired-samples t-tests (four Grasp-types x three Age Groups). Alpha was set at .004 to correct for multiple comparisons. No comparisons were significant, $ts \leq 2.71$, $ps = ns,$ Cohen's ds $\leq .60$, thus we collapsed across hand.

Inferential Analysis

The main focus of this research was whether children and adults would imitate more accurately the grasp of the object that was gazed-at, than not gazed-at, and whether there would be developmental differences in the accuracy of grasping behaviours when objects were functionally-related versus functionally unrelated. Analyses were 3 (Age Group) x 4(grasp type) mixed-measures ANOVAs, Grasp-type being within-subjects, on proportion Accurate, proportion Inaccurate, and proportion No-grasp. Alpha is evaluated at .05. All post hoc tests are *Bonferroni* corrected for multiple comparisons.

For the analysis on proportion Accurate, there were main effects of Age Group $F(2, 84) = 126.80$, $p < .001$, $\eta_p^2 = .751$, and Grasp-type, $F(3, 252) = 16.80$, $p < .001$, $\eta_p^2 = .167$, but they did not interact, $F(6, 252) < 1$, $p = ns$, $\eta_p^2 = .021$. Adults ($M = .73$, $SD = .10$) were more accurate overall than were 6-year olds ($M = .44$, $SD = .11$), who were

more accurate than 3-year olds ($M = .32$, $SD = .09$). Post hoc tests confirmed that all means differed significantly.

When an object was Gazed-at, whether it was part of a Functionally-related ($M = .54$, $SD = .22$), or Functionally-unrelated ($M = .55$, $SD = .23$) trial, it was grasped significantly more accurately than when the object was not gazed-at (Functionally-related: $M = .42$, $SD = .24$; Functionally-unrelated, $M = .47$, $SD = .25$), neither the former nor the latter means differing significantly.

For the analysis on proportion Inaccurate, there were again main effects of Age Group, $F(2, 84) = 56.73$, $p < .001$, $\eta_p^2 = .575$, and Grasp-type, $F(3, 252) = 21.87$, $p < .001$, $\eta_p^2 = .207$. Three- ($M = .52$, $SD = .09$) and 6-year olds ($M = .48$, $SD = .10$) were more inaccurate than were adults ($M = .27$, $SD = .13$), the means of the children not differing. See Table 1 for means and significant comparisons among Grasp-types.

These main effects were superseded by an interaction between the two variables, $F(6, 252) = 3.90$, $p = .001$, $\eta_p^2 = .085$, which was explored through a set of three 4(Grasp-type) repeated-measures ANOVAs (one per Age Group; corrected alpha = .017). The analyses were significant only for the children, $Fs \geq 9.42$, $ps < .001$, $\eta_p^2s \geq .266$, and not for the adults, $F(3, 84) = 2.33$, $p = ns$, $\eta_p^2 = .077$. For 3-year olds, Gazed-at/Functionally-related [GF] grasps were imitated significantly less inaccurately than all other grasp types and Not Gazed-at/Functionally-related [ngF] grasps were imitated less inaccurately than Not Gazed-at/Functionally-unrelated [ngfu] grasps. The pattern of the six-year olds was similar (see Table 2 for means and significant comparisons) except that the not gazed-at grasps were not significantly different from each other.

Supplementary Analyses

As previously noted, proportions Accurate and Inaccurate do not total to 1.00 for children because all participants were assigned a code of "No Grasp" if they failed to contact an object with one of their hands. Adults did this very rarely; in fact on only 3 grasps (by three different adult participants) out of a total of 1160 grasps (29 participants x 40 grasps each) was the "No Grasp" code employed. As such, we report analyses for 3- and 6-year olds only, concerning the "No Grasp" data. The analysis was a 2(Age Group) x 4(Grasp-type) mixed ANOVA on proportion "No Grasp." There was a main effect of Age Group, $F(1, 56) = 24.01$, $p < .001$, $\eta_p^2 = .30$, Grasp-type, $F(1.99, 111.32) = 41.24$, $p < .001$, $\eta_p^2 = .424$, and an interaction between them, $F(1.99, 111.32) = 4.31$, $p = .016$, $\eta_p^2 = .071$. The assumption of sphericity was violated in this analysis, and the Greenhouse-Geisser correction was applied.

"No Grasp" was coded proportionally twice as often for 3-year olds ($M = .16$, $SD = .06$) than for 6-year olds ($M = .08$, $SD = .06$). The code was used about five times more often on Functionally-related trials regardless of whether the object was Gazed-at (GF: $M = .21$, $SD = .16$) or Not Gazed-at (ngF: $M = .19$, $SD = .15$) (means not differing), than on Functionally-unrelated trials, which again did not differ as a function of whether they were Gazed-at (Gfu: $M = .03$, $SD = .06$) or Not Gazed-at (ngfu: $M = .05$, $SD = .08$).

The interaction appeared to be driven by age differences in the Functionally-related trials (see Figure 1, upper two lines) and so independent samples t-tests were conducted for each Grasp-type (alpha = .013). The tests revealed that 3-year olds were more likely to use only one hand for Gazed-at/Functionally-related and Not Gazed-at Functionally-related grasps than were 6-year olds, ts ≥ 3.33, ps $\leq .002$, Cohen's ds $\geq .88$

but the Age Groups did not differ on Functionally-unrelated trials, Fs $\leq$ 1.73, ps = ns, Cohen's ds $\leq$ .53.

Discussion

We examined the effect that a model's gaze would have on the imitative grasping behaviours of 3- and 6-year olds, as well as adults, and whether the nature of the trial (functionally-related versus functionally-unrelated) would interact with gaze cues. We hypothesized that accuracy would increase with age, and that gazed-at objects would be grasped more accurately than their non-gazed at counterparts. It was further hypothesized that trials in which the objects were functionally-related in ways that would afford a traditional goal would heighten grasp inaccuracies in children more than in adults, in line with predictions of the goal directed theory of imitation (GOADI).

Age effects were robust; as expected, adults were more accurate for any grasp-type than were 6-year olds who, in turn, were more accurate than 3-year olds. Adults were also less inaccurate than children. Three- and 6-year olds did not differ on proportion inaccurate grasps, but this finding resulted from younger children being more likely than older children to only use one hand on a trial, which was given a separate code.

Effects of gaze were strong; all participants were proportionally more accurate in grasping gazed-at objects than non-gazed at objects, as predicted. The same pattern was observed across all age groups, in line with research demonstrating that automatic attentional responses to gaze develop early (Caron, Caron, Roberts & Brooks, 1997; Hood et al., 1998; Tomasello, 1995). These effects of gaze were prevalent regardless of whether or not the objects were functionally-related.

In a recent study by Itakura, Ishida, Kanda, Shimada, Ishiguro and Lee (2008), young children's imitation of goal-directed actions was also influenced by gaze, but in a notably different paradigm to that used in the current study. Children 2- to 3-years old watched a robot with humanoid features (e.g., eyes, hands) complete or fail to complete a goal (e.g., hanging beads on a peg). When the robot first made eye contact with a human confederate before performing an action, children completed the intended goal regardless of the robot's success. When the robot did *not* make eye contact with the confederate, children were significantly more likely to complete the goal when the robot also did than if it failed. Taken together with the eye gaze findings of the current study, research strongly suggests that whether, and what, children imitate, is influenced by the language of the eyes.

We predicted that we could further manipulate what children imitated by altering the functional relationships between the objects being grasped. That is, some objects yielded traditional goals when brought into contact, while others did not. We expected that children's grasping accuracy would be lower on trials where objects were functionally related. This hypothesis was not supported by statistical analyses, and in fact children were generally *less* inaccurate on the functionally-related trials. Both 3- and 6-year olds were significantly less inaccurate when a grasp was gazed-at than when it was not gazed-at, for functionally-related trials. These data suggest that on trials where the objects afforded traditional goals, children seemed to have been *more* influenced by gaze cues than when the objects did not share a clear relationship. In fact, children's lowest proportion accurate score was for grasps of the object Not Gazed-at on Functionally-related trials. At first glance, this idea seems contrary to our hypothesis, however, it may

be that on trials with functionally related objects, since the goal was so obvious (e.g., puzzle and puzzle piece), children did not need to attend to what the model was doing and so had resources free to follow her gaze. Additionally, researchers who have previously demonstrated hierarchical goal-directed imitation effects have used more complicated paradigms, where there are several steps in a sequence (some of which are not actually required and which children may leave out) before a goal-outcome is achieved (e.g., Carpenter, Call & Tomasello, 2002; Whiten, Flynn, Brown & Lee, 2006).

The strongest evidence found in the current research for the influence of goal-status on imitative grasping comes from the No-Grasp analyses, in that children were more likely to only use one hand on Functionally-related than Functionally-unrelated trials (i.e. to achieve the goal), regardless of which object the model gazed at. This effect was stronger for 3-year olds than 6-year olds, whereas they did not differ on Functionally-unrelated trials. Overall, 6-year olds were far less likely to use only one hand, indicating that, despite the presence of a traditional goal, there were developmental improvements in imitating the model's style.

Limitations

Because we examined the role of eye gaze on grasping behaviour of objects contacted simultaneously, we kept the actions as simple as possible. Completion of "goal" trials required only one step. Children may have perceived all trials as having goals; namely, to change the state of affairs. To make all trials as similar as possible, all objects were grasped and moved from directly in front of the shoulders to in front of the midline of the body, regardless of goal-status. Where objects were functionally related, an outcome was achieved at this point (e.g., putting the puzzle piece into the empty

location). It could be said, however, that children perceived a similar outcome being achieved on Functionally-unrelated trials (i.e., two objects that were separate were brought together). This issue underscores the importance for future work to disambiguate between different levels of goal representation.

The present work nicely demonstrates the important role of eye gaze on imitative behaviour. Goals may indeed be very important in the imitative hierarchy as suggested by GOADI. However, the current results demonstrate that gaze cues play an important role; the processing of goals may in some cases be subordinate to the processing of gaze cues, which has implications for theories such as GOADI which state that goals form the top of the imitation hierarchy.

Implications

The current experiment is the first to examine the interaction of eye gaze and goal-status on imitative grasping behaviours. We found that gaze cues affected children equally as much as adults. We infer that children and adults automatically followed the gaze of the model, even though it was not a requirement of the task, in line with research on automaticity of gaze-following (Driver et al., 1999; Friesen et al., 2005; Ricciardelli et al., 2002). And, as suggested by Becchio and colleagues (2008), these gaze shifts did in fact affect the level of motoric imitation when grasping the gazed-at object such that there was an increased chance of grasping the object identically to the model. These 'motor contagion' (Blakemore & Frith, 2005) effects were prevalent in the youngest children in the sample, which supports notions that motor contagion plays an important role in children's learning about their social world (Meltzoff & Brooks, 2007).

Contrary to expectations, trial goal-status did not result in significant decreases in accuracy in children's imitative grasping. However, 3-year olds, and to a lesser degree 6-year olds, were more likely to only employ one hand on trials with functionally-related object pairs than on trials where objects were not functionally related in traditional ways, suggesting that they did favour outcome over process on "goal" trials. Finally, to reiterate, this study confirms the critical role of gaze cues in affecting how and what actions are imitated, and future work in this area would do well to consider the effects of gaze direction on imitative behaviour.

References

Ames, C.S., & Jarrold, C. (2007). The problem with using eye-gaze to infer desire: A

    deficit of cue interference? *Journal of Autism and Developmental Disorders, 37,*

    1761 – 1775. doi: 10.1007/s10803-009-0808-2

Baron-Cohen, S. (1995). The eye direction detector (EDD) and the shared attention

    mechanism (SAM): Two cases for evolutionary psychology. In C. Moore & P.J.

Dunham (Eds.) *Joint attention: Its origins and role in development.* (pp. 41 – 59). Hillsdale, NJ: Erlbaum.

Becchio, C., Bertone, C., & Castiello, U. (2008). How the gaze of others influences object processing. *Trends in cognitive sciences, 12,* 254-258. doi: 10.1016/j.tics.2008.04.005

Becchio, C., Pierno, A., Mari, M., Lusher, D., & Castiello, U. (2007). Motor contagion from gaze: The case of autism. *Brain, 130,* 2401-2411. doi: 10.1093/brain/awm171

Bekkering, H., Wohlschläger, A., & Gattis, M. (2000). Imitation of gestures in children is goal-directed. *The Quarterly Journal of Experimental Psychology, 53A,* 153 – 164. doi: 10.1080/027249800390718

Bird, G., Brindley, R., Leighton, J. & Heyes, C. (2007). General processes, rather than "goals" explain imitation errors. *Journal of Experimental Psychology: Human Perception and Performance, 33,* 1158-1169. doi: 10.1037/0096-1523.33.5.1158

Bird, G., & Heyes, C.M. (2007). Imitation: thoughts about theories. In K. Dautenhahn & C. Nehaniv (Eds.) Models and mechanisms of imitation and social learning in robots, humans and animals. Cambridge University Press.

Blakemore, S.J., & Frith, C. (2005). The role of motor contagion in the prediction of action. *Neuropsychologia, 43,* 260 – 267. doi: 10.1016/ j.neuropsychologia.2004.11.012

Caron, A.J., Caron, R., Roberts, J., & Brooks, R. (1997). Infant sensitivity to deviations in dynamic facial-vocal displays: The role of eye regard. *Developmental Psychology, 33,* 802 – 813. doi: 10.1037/0012-1649.33.5.802

Carpenter, M., Call, J. & Tomasello, M. (2002). Understanding "prior intentions" enables two-year olds to imitatively learn a complex task. *Child Development, 73,* 1431 – 1441. doi: 10.1111/1467-8624.00481

Carpenter, M., Call, J. & Tomasello, M. (2005). Twelve- and 18-month olds copy actions in terms of goals. *Developmental Science, 8,* 13 – 20. doi: 10.1111/j.1467-7687.2004.00385.x

Castiello, U. (2003). Understanding other people's actions: intention and attention. *Journal of Experimental Psychology, 29,* 416-430. doi: 10.1037/0096-1523.29.2.416

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition, 6,* 509 – 540. doi: 10.1080/135062899394920

Doherty, M.J., & Anderson, J.R. (1999). A new look at gaze: Preschool children's understanding of eye-direction. *Cognitive Development*, 14, 549 - 571. doi: 10.1016/S0885-2014(99)00019-2

Friesen, C.K. & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review, 5,* 490 – 495. Retrieved from http://www. pbr.psychonomic-journals.org/

Friesen, C.K., Moore, C., & Kingstone, A. (2005). Does gaze direction really trigger a reflexive shift of spatial attention? *Brain and Cognition, 57,* 66 – 69. doi: 10.1016/j.bandc.2004.08.025

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain, 119,* 593 – 609. doi: 10.1093/brain/119.2.593

Gallese, V., Keysers, C., & Rizzolatti, G. (2004). A unifying view of the basis of social cognition. *Trends in Cognitive Sciences, 8,* 396 – 403. doi: 10.1016/ j.tics.2004.07.002

Gleissner, B., Meltzoff, A.N., & Bekkering, H. (2000). Children's coding of human action: cognitive factors influencing imitation in 3-year olds. *Developmental Science, 3,* 405-414. doi: 10.1111/1467-7687.00135

Golinkoff, R.M., Hirsh-Pasek, K., & Hollich, G. (1999). Emergent cues for early word learning. In B. MacWhinney (Ed.) *The emergence of language* (pp. 305 – 330). Mahwah, NJ: Erlbaum.

Hood, B.M., Willen, J.D., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science, 9,* 131 – 134. doi: 10.1111/1467-9280.00024

Itakura, S., Ishida, H., Kanda, T., Shimada, Y., Ishiguro, H., & Lee, K. (2008). How to build and intentional android: Infants' imitation of a robot's goal-directed actions. *Infancy, 13,* 519 – 532. doi; 10.1080/15250000802329503

Kumashiro, M., Ishibashi, H., Uchiyama, Y., Itakura, S., Murata, A., Iriki, A. (2003). Natural imitation induced by joint attention in Japanese monkeys. *International Journal of Psychophysiology, 50,* 81 – 99. doi: 10.1016/S0167-8760(03)00126-0

Meltzoff, A.N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month old children. *Developmental Psychology, 31,* 838-850. doi: 10.1037/0012-1649.31.5.838

Meltzoff, A.N., & Brooks, R. (2007). Eyes wide shut: The importance of eyes in infant gaze following and understanding of other minds. In R. Flom, K. Lee, & D. Muir (Eds.) *Gaze following: Its development and significance* (pp. 217-241). Mahwah, NJ: Erlbaum.

Meltzoff, A.N., & Decety, J. (2003). What imitation tells us about social cognition: A rapprochement between developmental psychology and cognitive neuroscience. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 358,* 491 – 500. doi: 10.1098/rstb.2002.1261

Meltzoff, A.N., & Moore, M.K. (1994). Imitation, memory and the representation of persons. *Infant Behavior and Development, 17,* 83-99. doi: 10.1016/0163-6383(94)90024-8

Nuku, P., & Bekkering, H. (2008). Joint attention: Inferring what others perceive (and don't perceive). *Consciousness & Cognition, 17,* 339-349. doi: 10.1016/j.concog.2007.06.014

Pellicano, E., & Rhodes, G. (2003). The role of eye-gaze in understanding other minds. *British Journal of Developmental Psychology, 21,* 33 – 43. doi: 10.1348/026151003321164609

Pierno, A.C., Becchio, C., Wall, M.B., Smith, A.T., Turella, L., Castiello, U. (2006). When gaze turns into grasp. *Journal of Cognitive Neuroscience, 18,* 2130 – 2137. doi: 10.1162/jocn.2006.18.12.2130

Ricciardelli, P., Bricolo, E., Aglioti, S.M. & Chelazzi, L. (2002). My eyes want to look where your eyes are looking: Exploring the tendency to imitate another individual's gaze. *Neuroreport, 13,* 2259-2264. doi: 10.1097/00001756-200212030-00018

Ristic, J., Mottron, L., Friesen, C.K., Iarocci, G., Burak, J.A., & Kingstone, A. (2005). Eyes are special but not for everyone: The case of autism. *Cognitive Brain Research, 24,* 715 – 718. doi: 10.1016/j.cogbrainres.2005.02.007

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Reviews Neuroscience, 27,* 169 – 192. doi: 10.1146/annurev.neuro.27.070203.144230

Roberts, K.P. (2002). Children's ability to distinguish between memories from multiple sources: Implications for the quality and accuracy of eyewitness statements. *Developmental Review, 22,* 403 – 435. doi: 10.1016/S0273-2297(02)00005-9

Schofield, W.N. (1976). Do children find movements which cross the body midline difficult? *Quarterly Journal of Experimental Psychology, 28,* 571- 582. doi: 10.1080/14640747608400584

Sommerville, J.A., & Hammond, A.J. (2007). Treating another's actions as one's own: children's memory of and learning from joint activity. *Developmental Psychology, 43,* 1003 – 1018. doi: 10.1037/0012-1649.43.4.1003

Tomasello, M. (1995). Joint attention as social cognition. In C. Moore & P.J. Dunham (Eds.) *Joint attention: Its origins and role in development.* (pp. 103 - 130). Hillsdale, NJ: Erlbaum.

Tomasello, M., Kruger, A.C., & Ratner, H.H. (1993). Cultural learning. *Behavioural and Brain Sciences, 16,* 495 – 452. doi: 10.1017/S0140525X0003123X

van Elk, M., van Shie, H.T., & Bekkering, H. (2008). Conceptual knowledge for understanding others' actions is organized primarily around action goals. *Experimental Brain Research, 189,* 99 – 107. doi: 10.1007/s00221-008-1408-7

Vlamings, P.H.J.M., Stauder, J.E.A., van Son, I.A.M., & Mottron, L. (2005). Atypical visual orienting to gaze- and arrow-cues in adults with high functioning autism. *Journal of Autism and Developmental Disorders, 35,* 267 – 277. doi: 10.1007/s10803-005-3289-y

Whiten, A., Flynn, E., Brown, K., & Lee, T. (2006). Imitation of hierarchical action structure by young children, *Developmental Science, 9,* 574-582. doi: 10.1111/j.1467-7687.2006.00535.x

Wohlschläger, A., & Bekkering, H. (2002). The role of objects in imitation. In M.I. Stamenov, & V. Gallese (Eds.). Mirror neurons and the evolution of brain and

language. Advances in consciousness research. (pp. 101 – 113). Amsterdam: John

Benjamins Publishing Company.

Footnotes

[1]Tomasello has distinguished among three types of copying behaviours; *imitation* occurs when both the model's actions and intentions are reproduced; the term [goal] *emulation* is used when children understand the goal or intended action but use their own strategies to achieve the outcome (Tomasello, 1990), and when children do *not* understand the purpose of the actions but reproduce them anyway, they are mimicking (Tomasello, Kruger & Ratner, 1993). Because copying behaviours in the current paper include all three types, for simplicity we use the term "imitation" only, as many others have done (e.g., Bekkering et al., 2000; Meltzoff & Decety, 2003; Whiten et al., 2006).

[2]the reader is referred to van Elk, van Shie, & Bekkering (2008) for research concerning adults' accuracy in identifying grip-violations in goal-related actions.

Table 1

Mean proportion inaccurate grasps and significant comparisons as a function of grasp-

type

Grasp-Type	Mean (*SD*)	Sig comparisons
Gazed-at /Functionally-related (GF)	.32 (.14)	*Gfu, ngF, ngfu*
Gazed-at /Functionally-unrelated (Gfu)	.43 (.22)	*GF, ngfu*
Not Gazed-at/ Functionally-related (ngF)	.45 (.20)	*GF*
Not Gazed-at /Functionally-unrelated (ngfu)	.50 (.23)	*GF, Gfu*

Table 2

Mean proportion inaccurate grasps and significant comparisons as a function of trial type and age group

	3-year olds	**6-year olds**	**Adults**
GF	.37 (.12)[a]	.37 (.14)[a]	.22 (.13) [a]
Gfu	.58 (.17)[bc]	.45 (.17)[ab]	.25 (.18) [a]
ngF	.51 (.15)[b]	.52 (.16)[b]	.32 (.21) [a]
ngfu	.63 (.16)[c]	.58 (.22)[b]	.28 (.14) [a]

Note: means sharing the same superscript letter in column do not differ significantly.
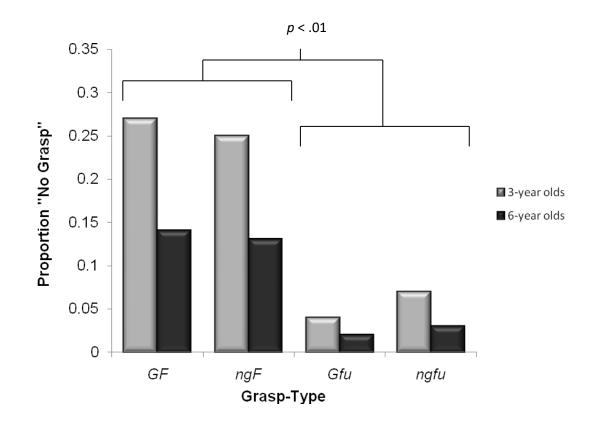
Note: standard deviation in parentheses.

Figure 1. Proportion "No Grasp" as a function of trial type in children.