Journal of Experimental Child Psychology 116 (2013) 609–624

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

I see what you're saying: Voice signals influence children's judgments of direct and averted gaze

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ARTICLE INFO

Article history:
Received 5 April 2013
Revised 7 July 2013
Available online 27 August 2013

Keywords:
Gaze
Eye contact
Voice
Cone of gaze
Children
Cross-modal

ABSTRACT

Adults use gaze and voice signals as cues to the mental and emotional states of others. We examined the influence of voice cues on children's judgments of gaze. In Experiment 1, 6-year-olds, 8-year-olds, and adults viewed photographs of faces fixating the center of the camera lens and a series of positions to the left and right and judged whether gaze was direct or averted. On each trial, participants heard the participant-directed voice cue (e.g., "I see you"), an object-directed voice cue (e.g., "I see that"), or no voice. In 6-year-olds, the range of directions of gaze leading to the perception of eye contact (the cone of gaze) was narrower for trials with object-directed voice cues than for trials with participant-directed voice cues or no voice. This effect was absent in 8-year-olds and adults, both of whom had a narrower cone of gaze than 6-year-olds. In Experiment 2, we investigated whether voice cues would influence adults' judgments of gaze when the task was made more difficult by limiting the duration of exposure to the face. Adults' cone of gaze was wider than in Experiment 1, and the effect of voice cues was similar to that observed in 6-year-olds in Experiment 1. Together, the results indicate that object-directed voice cues can decrease the width of the cone of gaze, allowing more adult-like judgments of gaze in young children, and that voice cues may be especially effective when the cone of gaze is wider because of immaturity (Experiment 1) or limited exposure (Experiment 2).

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0022-0965/$ - see front matter
http://dx.doi.org/10.1016/j.jecp.2013.07.005

Introduction

The direction of people's gaze provides a cue to the focus of their attention and thereby allows inferences about their intentions (Baron-Cohen, 1995; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Senju & Johnson, 2009). Direct gaze can signal interest in the viewer, threat, or dominance, whereas averted gaze can signal attention directed toward an object in the environment, deception, or avoidance (Argyle & Cook, 1976; Einav & Hood, 2008; Kendon, 1967). Voice cues can also convey information about a person's attention and/or intention. For example, saying a person's name can signal the intent to communicate (Moray, 1959; Senju & Csibra, 2008), whereas an object-directed voice cue (e.g., "That looks nice!") can signal attention toward an object in the environment (e.g., Parise, Cleveland, Costabile, & Striano, 2007). The combination of information from voice and gaze cues may facilitate social judgments by allowing individuals to use information from voice cues to interpret ambiguous gaze cues. Previous research indicates that children's judgments of direct and averted gaze do not become adult-like until around 8 years of age (Vida & Maurer, 2012a). Here, we asked whether children combine information from gaze and voice cues when making judgments of direct and averted gaze and whether the combination allows young children to make more adult-like judgments of gaze. We investigated these questions by having 6-year-olds, 8-year-olds, and adults judge the direction of gaze in photographs of faces while hearing voice cues implying that the model was looking at the participants (e.g., "I see you") or at an object in the environment (e.g., "I see that").

Adults' judgments of direct and averted gaze

Adults can detect horizontal and vertical differences of approximately 1° in the direction of someone else's gaze toward objects in the environment (e.g., Symons, Lee, Cedrone, & Nishimura, 2004; Vida & Maurer, 2012b, 2012c). However, the range of directions of gaze over which adults perceive eye contact (the cone of gaze) is much larger at approximately 5.5° in width (Gibson & Pick, 1963; Lord & Haith, 1974; Vida & Maurer, 2012a) and 7° in height (Vida & Maurer, 2012a). These values indicate that adults tend to attribute eye contact over a range of directions of gaze corresponding with the width and height of an adult's own face (Vida & Maurer, 2012a). Adults' tendency to attribute eye contact over a relatively large range of directions of someone else's gaze may minimize social costs associated with missing an invitation to interact with someone who is looking toward them.

In the only previous study of the effect of voice cues on judgments of direct and averted gaze, adults viewed faces that had direct gaze or gaze averted in a series of directions to the left and right (Stoyanova, Ewbank, & Calder, 2010). Each face was accompanied by a voice calling the participant's own first name or another person's first name. The cone of gaze was wider when the participant heard his or her own name than when the participant heard another person's name. Hearing one's own name could signal that someone is directing attention toward the participant, whereas hearing another person's name could signal that someone is attending to another person in the environment. Hence, the effect of voice cues in Stoyanova and colleagues (2010) could indicate that the cone of gaze becomes wider when the participant hears his or her own name, becomes narrower when the participant hears another person's name, or both.

Development of sensitivity to direct and averted gaze

From birth, infants respond preferentially to eye contact, at least when shown faces with direct gaze and gaze averted far to the side. When shown such a pairing, newborns look longer at the face that makes eye contact (Farroni, Csibra, Simion, & Johnson, 2002). By 4 months of age, infants not only look but also smile longer at faces with direct gaze (Hains & Muir, 1996; Symons, Hains, & Muir, 1998), and the N240 event-related potential (ERP) is larger for such faces compared with faces with averted gaze (Farroni, Johnson, & Csibra, 2004). The ERP difference may reflect greater cortical processing of faces with direct gaze. By 4 or 5 months of age, infants will look in the same direction as a face with averted gaze (e.g., look to the left when the face looks to the left), but only after a period of mutual gaze (Farroni, Mansfield, Lai, & Johnson, 2003). Together, these results suggest that from early during the first year of life, infants detect and respond selectively to eye contact.

By 3 years of age, children can make explicit judgments about direct and averted gaze when differences in the direction of gaze are large. When shown pairs of faces in which gaze is direct in one face and averted 25° in the other, 3-year-olds, but not 2-year-olds, are able to report which face is making eye contact (Doherty, Anderson, & Howieson, 2009). By 6 years of age, children are sensitive to much smaller differences between direct and averted gaze. In one study, both children (6-, 8-, 10-, and 14-year-olds) and adults viewed photographs of models fixating the center of a camera lens and a series of positions to the left/right or up/down. The width of the horizontal cone of gaze was more than 50% larger in 6-year-olds (8.47°) than in adults (5.49°), and decreased to an adult-like width by 8 years of age (Vida & Maurer, 2012a). The vertical cone of gaze was statistically adult-like by 6 years of age. Thus, 6-year-olds attribute eye contact to a face that is in fact looking within approximately 4.25° to either side of straight ahead (approximately 2° beyond the edge of a child's own face), whereas older children and adults attribute eye contact to a face looking within approximately 2.75° to either side of straight ahead, a range corresponding roughly with the width of the participant's own face. The narrowing of the horizontal cone of gaze between 6 and 8 years of age could reduce social costs associated with attributing eye contact when a person's gaze is actually averted (e.g., perceiving others as attempting to establish a social interaction when they are actually looking at another target in the environment). Together, these results suggest that sensitivity to direct and averted gaze is present from birth but that judgments do not become adult-like until approximately 8 years of age.

Voices influence children's responses to gaze cues as early as infancy. Voice cues implying that an adult's attention is directed toward infants versus toward an object influence infants' responses to shifts in the adult's gaze. For example, at 6 months of age (youngest age tested), infants are more likely to orient in the direction of an adult's averted gaze when hearing infant-directed speech than when hearing adult-directed speech (Senju & Csibra, 2008). At 10 to 13 months of age (the youngest age tested), infants' response to a novel toy depends on whether or not the adult seen during familiarization looked at, and spoke about, the toy with which infants were familiarized (Parise et al., 2007). At 16 or 17 months of age (the youngest age tested), infants who are asked to point to the referent of a novel noun choose the object an adult was looking at when they first heard the noun (Baldwin, 1991). Together, these results suggest that sensitivity to combinations of gaze and voice cues is, at least to some degree, present before 2 years of age.

In sum, previous studies indicate that voice cues influence adults' judgments of direct and averted gaze (e.g., Stoyanova et al., 2010) and influence infants' behavioral responses to gaze cues (e.g., Parise et al., 2007). Previous research also indicates that children's sensitivity to direct and averted gaze does not become adult-like until around 8 years of age (Vida & Maurer, 2012a). The purpose of the current study was to investigate whether voice cues modulate children's judgments of direct and averted gaze. In Experiment 1, 6-year-olds, 8-year-olds, and adults made judgments of gaze while hearing an object-directed voice cue (e.g., "I see that"), the participant-directed voice cue (e.g., "I see you"), or no voice. By including a no voice condition, we were able to assess, for the first time, whether object-directed voice cues, which can be interpreted as indicating that the model is looking at an object in the environment, can decrease the width of children's cone of gaze, thereby allowing more adult-like judgments of gaze, and whether participant-directed voice cues, which can be interpreted as indicating that the model is looking at the participant, increase the width of the cone of gaze similarly in children and adults. In Experiment 2, we reduced the exposure time for the model's face to see whether the added uncertainty would alter the effect of voice cues on adults' judgments of gaze.

Experiment 1

In the first experiment, we investigated whether voice cues modulate children's judgments of direct and averted gaze during the period when the cone of gaze is decreasing to an adult size (between 6 and 8 years of age) (Vida & Maurer, 2012a). Specifically, 6-year-olds, 8-year-olds, and adults viewed photographs of faces fixating the center of the camera lens and a series of positions to the left and right and pressed a button to indicate whether the model's gaze was direct or averted toward one of two identical toy jewels placed to the left and right of the model's face. As each face was presented, participants heard an object-directed voice, the participant-directed voice, or no voice. We compared the width of the cone of gaze among the three voice conditions to see whether it was smaller for the object-directed voice condition and/or larger for the participant-directed voice condition.

Method

Participants

Participants were English-speaking 6-year-olds (6 years 6 months ± 3 months, *M* = 6.52 years, 11 girls and 13 boys), 8-year-olds (8 years 6 months ± 3 months, *M* = 8.51 years, 15 girls and 9 boys), and adults (18–24 years, *M* = 20.30 years, 17 women and 7 men) (*n* = 24/group). Adult participants were undergraduate students who received course credit for participation. Child participants were recruited from a database of children whose parents volunteered to participate in research at the time of the children's birth. All participants were visually screened and had normal or corrected-to-normal vision. Adults and 8-year-olds were required to have at least 20/20 letter acuity on the Lighthouse eye chart and normal stereoacuity as measured by the Randot test. The 6-year-olds met the same stereoacuity criterion, but the acuity criterion was relaxed to 20/25 because acuity is still improving in this age range (Adams & Courage, 2002; Ellemberg, Lewis, Liu, & Maurer, 1999). An additional 2 children were tested but were replaced because they failed visual screening (1 8-year-old) or because their response curves were so broad that we were unable to estimate the width of the cone of gaze in at least one voice condition (1 6-year-old) (see Results for description of this measure).

Stimuli

Faces. All face stimuli came from the stimulus set used in Vida and Maurer (2012a). Stimuli were full-color digital photographs of adults with a neutral expression fixating the middle of the camera lens and a series of positions ranging from 1.6° to 8.0° to the left and right in increments of 1.6° (see Fig. 1). The stimulus set consisted of three male models and three female models (all Caucasian). All facial images were displayed at life size and at an eye height of 113 cm on a Dell P1130 Trinitron 21-inch monitor set to a resolution of 1152 × 870 and a refresh rate of 75 Hz. The experiment was run in MATLAB (7.6.0, R2008a, MathWorks, Natick, MA, USA) using the Psychophysics Toolbox extensions (Brainard, 1997) on an Apple computer.

Voices. Voice stimuli were digital audio recordings of four native English-speaking adults (two male and two female) saying phrases implying that they were either looking at participants (participant-directed voice set) or looking at an object in the environment (object-directed voice set). All voices were recorded with an AT-812 dynamic microphone (Audio-Technica, Stow, OH, USA) and a Duet audio interface (Apogee Electronics, Santa Monica, CA, USA) controlled by an Apple computer running Reaper software (Cockos, San Francisco, CA, USA). Each voice clip was normalized in MATLAB to achieve consistent loudness across clips. Any periods of silence at the beginning and/or end of each voice clip were removed in MATLAB.

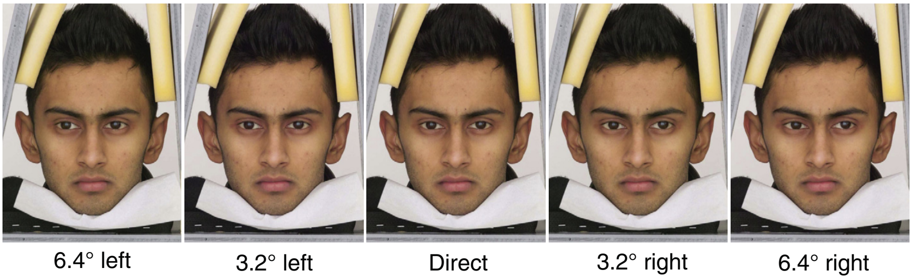

Fig. 1. Examples of face stimuli for one of the six models presented in the current study.

Speakers were instructed to use an enthusiastic, positive-sounding tone of voice for all phrases. There were six phrases in each set. The following phrases were in the participant-directed voice set: "Hello," "Hi there," "You're good," "You're nice," "You're super," and "I see you." The following phrases were in the object-directed voice set: "That's nice," "That's good," "That's cool," "What's that?," "That's shiny," and "I see that." In each set, four phrases had two syllables and two phrases had three syllables. An independent-samples *t* test indicated that there was no difference in duration between the participant-directed stimuli ($M = 1039.02$ ms, $SD = 268.24$) and the object-directed stimuli ($M = 1063.46$ ms, $SD = 156.60$), $p > .70$. Voices were presented at a typical conversational level (approximately 60 dB) through a pair of Reveal Digital Series 80-W desktop speakers placed 30 cm to the left and right of the computer monitor.

Apparatus

Participants were positioned 150 cm in front of the computer monitor and speakers. Participants used a chin rest to maintain a consistent head position and an eye height of 113 cm (the eye height of the model) above the floor. Two identical plastic toy jewels, 3 cm in diameter, were mounted on narrow wooden boards and were positioned 58 cm from participants (92 cm from the monitor) at a height of 113 cm (the eye height of the model and participants). The jewels were placed 4.5 cm to either side of midline (9 cm apart). From participants' position, the jewels appeared to the left and right of the model's face.

Participants entered responses on a computer keyboard placed on a table directly in front of them. Participants used the "F" key with a leftward-pointing arrow taped over the top to indicate left responses, the "H" key with a rightward-pointing arrow taped over the top to indicate right responses, the "G" key with a blue circle taped over the top to indicate direct responses, and the "X" key with a red circle taped over the top to respond to catch trials (see "Design" section below for description). The experimenter used an additional computer keyboard to advance the experiment.

Design

Participants completed a test block in which they judged the direction of gaze in the face of a single model. Before each test block, participants received a practice block with a different model of the opposite sex. The presentation of models was counterbalanced across participants so that each of the six models appeared four times in test trials and four times in practice trials across the participants in a given age group.

The practice block consisted of 12 trials, with the model fixating the center of the camera lens (4 trials) and the points farthest away from center (4 trials at 8.0° left and 4 trials at 8.0° right), presented in a random order. During practice trials, participants received feedback indicating whether their responses were correct or not (a cartoon image of a happy face with a 1000 Hz tone for correct responses and a cartoon image of a sad face with a 400 Hz tone for incorrect responses). Participants were allowed three attempts to reach a criterion of 75% accuracy. All adults, all 8-year-olds, and 22 6-year-olds reached criterion on the first attempt. The other 2 6-year-olds required a second attempt to reach criterion. No voices were presented during the practice block.

In the test block, for each voice condition, participants viewed the face of one of six models fixating the camera lens and a series of 11 positions covering a range from 8.0° left to 8.0° right in steps of 1.6°. Participants completed 8 trials at each fixation position for a total of 88 trials per voice condition. In the no voice condition, no sound was presented. In the object-directed and participant-directed voice conditions, on each trial participants heard the voice of a person matching the sex of the face. For each participant, the identity of the speaker was randomly selected from among two speakers of the appropriate sex. Each participant saw the same model's face and heard the same model's voice on each trial. On each trial, the voice clip to be presented was randomly selected from among six voice clips in the appropriate set. Trials from the three voice conditions were intermixed and presented in a random order with the constraint that the same voice cue was not presented on consecutive trials. Participants received breaks after 88 and 164 trials. To assess attentiveness, we included 5 catch trials that appeared at random positions within each set of 88 trials with the constraint that catch trials were never fewer than 5 trials apart. In each catch trial, a cartoon image of rocks appeared on the screen.

Participants were instructed to press a button to sound an alarm when they saw this image. During the test block, participants received general encouragement but no trial-specific feedback.

Procedure

After the procedure was explained, written consent was obtained from a parent of each child participant and verbal assent was also obtained from 8-year-olds. After positioning the participant appropriately in the apparatus, the experimenter displayed a photograph of the model that would appear in the practice block. The experimenter explained the task as follows (with appropriate adjustments if the model was male):

> This is Jenny. She is an explorer who loves to search for buried treasure!

After pressing a key to present a cartoon image of the inside of a cave, the experimenter continued as follows:

> Jenny has been searching for treasure deep in this cave, and now she is lost! To find her way out of the cave, she has to look at you and follow you. The problem is that there are some treasures in the cave, like these jewels. Jenny loves jewels, and she always wants to stop and look at them when she notices them. If Jenny is looking at the jewels instead of looking at you, she could get lost. Your job will be to help Jenny stay on course by watching her face carefully and deciding if she is looking at you or away from you toward one of the jewels. If you think Jenny is looking at you, press this button [experimenter points to blue button]. If she is looking away from you toward this jewel [points to left jewel], press this button [points to left arrow]. If she is looking away from you toward this jewel [points to right jewel], press this button [points to right arrow].

The experimenter then initiated practice trials. Once the participant reached criterion, the experimenter introduced the model to be presented in the test block and then delivered the following instructions:

> This is James. Like Jenny, he is an explorer who is lost in the cave. We're going to help James find his way out the cave, just like we did with Jenny.

The experimenter then pressed a button to display a photograph of rocks and delivered the following instructions:

> James is lost in a part of a cave that has lots of rocks. If you see rocks like these, you can sound an alarm to warn James so that he doesn't trip on the rocks. To sound the alarm, press this button [experimenter points to red button]. Also, James loves to talk, so you'll hear him saying lots of different things. Try to ignore what he says and just pay attention to where he is looking.

At the start of each test trial, a black fixation cross appeared at the center of the screen. When the participant appeared to fixate the cross, the experimenter, who could see the participant but not the monitor with the face stimuli, pressed a key to present a photograph of the model's face accompanied, if applicable, by a clip of the speaker's voice. The face remained on the screen until the voice clip had finished playing and the participant had entered an appropriate response. Participants typically completed the entire procedure in approximately 30 min.

Results

Accuracy on catch trials

Accuracy on catch trials was very high in each group (6-year-olds: $M = .99$, $SD = .02$; 8-year-olds: $M = .99$, $SD = .03$; adults: $M = .99$, $SD = .01$). Because the group means were identical and near ceiling, we did not carry out statistical analyses to evaluate group differences for these data. The high accuracy in each age group suggests that participants in all age groups were attentive throughout the procedure.

Curve fitting

For each participant, we calculated the proportion of the 8 trials at each fixation position on which the model was judged to be looking directly toward the participant, left, or right (see Fig. 2). To quantify sensitivity to direct and averted gaze, as in Vida and Maurer (2012a), we fit logistic functions relating each participant's proportions of left and right responses to the fixation positions. All fits were carried out using the glmfit routines from the Statistics Toolbox in MATLAB. The sum of the left and right functions was then subtracted from 1 to define a third function fitting the proportion of direct responses. Goodness of fit was within the acceptable parameters described in Vida and Maurer (2012a) for all fits. Following Vida and Maurer, we calculated the width of the cone of gaze as the difference (in degrees) between the points of intersection between the fitted direct function and the fitted left and right functions. These points of intersection correspond to the fixation positions where the participant was equally likely to judge that the model was making eye contact or looking off the face in a particular direction. The angular distance between the right and left points of intersection provides a measure of the width of the cone of gaze.

Width of cone of gaze

We carried out an age (6 years, 8 years, or adult) by voice condition (no voice, participant-directed voice, or object-directed voice) mixed analysis of variance (ANOVA) with the width of the cone of gaze as the dependent variable (see Fig. 3). There were main effects of age, $F(2,69) = 10.40$, $p < .001$, $\eta_p^2 = .23$, and voice condition, $F(2,138) = 6.52$, $p < .005$, $\eta_p^2 = .09$. There was also a significant interaction between age and voice condition, $F(4,138) = 3.49$, $p < .02$, $\eta_p^2 = .09$.

We followed up the age by voice condition interaction with repeated-measures ANOVAs evaluating the simple main effect of voice condition in each age group. There was a simple effect of voice condition in 6-year-olds, $F(2,46) = 8.41$, $p < .002$, $\eta_p^2 = .27$, but not in 8-year-olds ($p > .50$) or adults ($p > .90$). We followed up the simple main effect of voice condition in 6-year-olds with Holm–Bonferroni-corrected paired-samples *t* tests (Holm, 1979) comparing the width of 6-year-olds' cone of gaze between each possible pair of voice conditions. The 6-year-olds' cone of gaze was significantly narrower in the

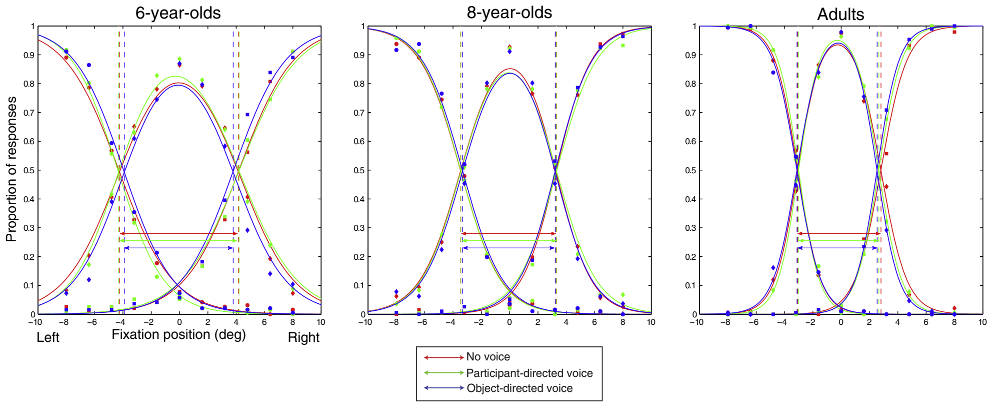

Fig. 2. Logistic functions fit to the mean proportion of each response type in Experiment 1 for the no voice (red), participant-directed voice (green), and object-directed voice (blue) conditions. Each plot displays the data for one age group as a function of the direction of gaze (in degrees). The axis labels given for 6-year-olds apply to the other age groups as well. In each plot, each data point represents the mean proportion of a given response type across all participants of that age for a given voice condition and fixation position (in degrees). Data points marked with a circle represent "averted left" responses, diamonds represent "direct" responses, and squares represent "averted right" responses. The curves to the left in each plot fit "averted left" responses, the curves in the center fit "direct" responses, and the curves to the right fit "averted right" responses. The dashed vertical lines show the crossover points between the "direct" curve and the "left" and "right" curves. The horizontal arrows represent the width of the cone of gaze. Curves, data points, dashed lines, and arrows are colored by voice condition according to the colors shown in the legend. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

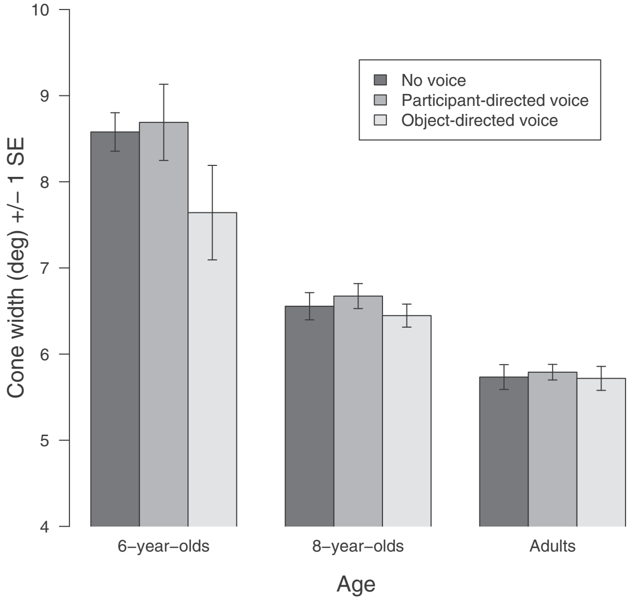

Fig. 3. Mean widths of cone of gaze (in degrees) ± 1 standard error as a function of age and voice condition in Experiment 1.

object-directed voice condition ($M = 7.64°$, $SD = 2.53$) than in the participant-directed voice condition ($M = 8.69°$, $SD = 2.40$), $t(23) = 4.71$, $p < .001$, $\alpha = .017$, $d = 0.43$, and in the no voice condition ($M = 8.57°$, $SD = 2.98$), $t(23) = 3.26$, $p < .005$, $\alpha = .025$, $d = 0.34$. However, 6-year-olds' cone of gaze did not differ between the no voice condition and the participant-directed voice condition ($p > .70$). In light of previous research indicating that 6-year-olds' cone of gaze is wider than that of adults but reaches an adult-like width by 8 years of age (Vida & Maurer, 2012a), we also investigated whether there was an effect of age on the width of the cone of gaze in each voice condition. We carried out one-way ANOVAs evaluating the simple main effect of age for each voice condition. For each voice condition, there was an effect of age ($ps < .01$, η_p^2 values > .10). In each voice condition, a Dunnett's post hoc comparing the width of the cone of gaze of 6- and 8-year-olds with that of adults indicated that the cone of gaze was significantly narrower in adults than in 6-year-olds ($ps < .005$), with no differences between adults and 8-year-olds ($ps > .20$).

Effect of voice cues on proportions of "direct" and "averted" responses in 6-year-olds

Our finding that 6-year-olds' cone of gaze was narrower in the object-directed voice condition than in the other voice conditions could reflect a general tendency to avoid attributing eye contact when hearing an object-directed voice cue regardless of the direction of the model's gaze, that is, for unambiguous direct gaze, and for shifts of gaze to the sides, regardless of size. We conducted three analyses to evaluate this possibility. The first analysis arises from the prediction that any such general tendency to avoid reporting eye contact would lead to a lower frequency of "direct" responses for faces with straight gaze (i.e., images in which the model was fixating the center of the camera lens) in the object-directed voice condition than in the other voice conditions. To evaluate this prediction, we calculated the proportion of each 6-year-old participant's "direct" responses for straight gaze in each voice condition. We then carried out a repeated-measures ANOVA with voice condition as the independent variable and the proportion of direct gaze responses for straight gaze as the dependent variable. There was no effect of voice condition ($p > .75$), a result suggesting that the observed effect of voice condition on 6-year-olds' cone of gaze does not reflect a general tendency to avoid attributing eye contact when hearing object-directed voice cues.

Two additional analyses arose from the prediction that a general tendency to avoid attributing eye contact when hearing an object-directed voice cue could lead participants to enter more "averted" responses in both the unexpected direction (e.g., responding "left" when gaze is directed to the right) and the expected direction (e.g., responding "right" when the model's gaze is directed to the right) and to do so regardless of the deviation of gaze. To evaluate this possibility, we calculated the proportions of 6-year-olds' "averted" responses in the unexpected and expected directions for each deviation of gaze from direct and each voice condition. We carried out a repeated-measures ANOVA with deviation of gaze from direct (1.6°, 3.2°, 4.8°, 6.4°, or 8.0°) and voice condition as independent variables and the proportion of responses in the unexpected direction as the dependent variable. There was a significant effect of deviation of gaze, $F(4,92) = 3.96$, $p < .006$, $\eta_p^2 = .15$, which indicates that the proportion of responses in the unexpected direction decreased with increasing deviations of gaze from direct, but there was no effect of voice condition and no interaction (*ps* > .20). This result indicates that 6-year-olds were sensitive to the deviations in eye gaze. However, the sensitivity of this analysis may have been limited because the proportion of responses in the unexpected direction was at or near zero for larger deviations of gaze from direct. Inspection of Fig. 2 confirms that there was no clear trend toward a difference between voice conditions in the proportion of responses in the unexpected direction. We carried out a similar ANOVA with the proportion of responses in the expected direction as the dependent variable. There was an effect of deviation of gaze, $F(4,92) = 225.55$, $p < .001$, $\eta_p^2 = .91$, which indicates that the proportion of responses in the expected direction increased with the deviation of gaze from direct (see Fig. 2), as would be expected if the responses reflect processing of the eye gaze cue, not just the voice. There was also an effect of voice condition, $F(2,46) = 6.76$, $p < .004$, $\eta_p^2 = .23$. There was no interaction ($p > .35$). We followed up the effect of voice condition with Holm–Bonferroni-corrected paired-samples *t* tests comparing the proportion of responses in the expected direction between each pair of voice conditions. There was no difference between the no voice condition ($M = .55$, $SD = .15$) and the participant-directed voice condition ($M = .55$, $SD = .12$), $p > .80$. However, the proportion of responses in the expected direction was higher in the object-directed voice condition ($M = .59$, $SD = .13$) than in the no voice condition, $t(23) = 3.43$, $p < .003$, $\alpha = .017$, $d = 0.28$, and in the self-directed voice condition, $t(23) = 3.35$, $p < .004$, $\alpha = .02$, $d = 0.32$. Our finding that object-directed voice cues led to more attributions of averted gaze in the expected direction when gaze was in fact averted to the side (e.g., responding "right" when gaze was in fact averted to the right), with no effect on attributions of averted gaze in the unexpected direction (e.g., responding "left" when gaze was in fact averted to the right), is consistent with our finding in the main analysis of a narrower cone of gaze in the object-directed voice condition. In conjunction with our finding of no effect of voice cues on the proportion of "direct" responses to straight gaze, this pattern suggests that the narrower cone of gaze in the object-directed voice condition does not reflect a general tendency to avoid attributing eye contact regardless of the direction of gaze. Rather, it appears to reflect an increased tendency to attribute averted gaze in the expected direction when gaze is actually averted.

Slope of response curves

An additional question is whether voice cues and age influence the steepness of the transition between "direct" and "averted" responses. To investigate this question, we examined the slope parameter of the logistic functions fit to "averted" responses. A larger slope parameter indicates a steeper transition between "direct" and "averted" responses.

We carried out a mixed ANOVA with voice condition and age as independent variables and slope as the dependent variable. There was a significant effect of age, $F(2,69) = 21.58$, $p < .0001$, $\eta_p^2 = .38$, with no effect of voice condition and no interaction (*ps* > .35). A Dunnett's post hoc indicated that the slope was shallower in both 6-year-olds ($M = 1.88$, $SD = 1.95$) and 8-year-olds ($M = 2.52$, $SD = 2.33$) than in adults ($M = 7.57$, $SD = 4.81$), *ps* < .001. Hence, voice cues did not influence the steepness of the transition between "direct" and "averted" responses, but the transition became steeper after 8 years of age.

Discussion

The current results provide the first information on the influence of voice cues on children's sensitivity to directed and averted gaze. Voice cues affected judgments of gaze in 6-year-olds but not in 8-year-olds or adults. The 6-year-olds' cone of gaze was narrower when they heard a voice cue implying that the model was looking at an object in the environment (e.g., "I see that") (7.64°) than when they heard a voice cue implying that the model was looking at the participants (8.69°) or when no voice was presented (8.57°), with no difference between the latter two. Follow-up analyses indicated that the narrower cone of gaze in the object-directed voice condition does not reflect a general tendency to avoid attributing eye contact or a change in the slope of the fitted curves but instead reflects an increased tendency to attribute averted gaze in the expected direction when gaze is actually averted. Although 6-year-olds' cone of gaze was narrower in the object-directed voice condition than in the other voice conditions, their cone of gaze was nevertheless wider than that of 8-year-olds and adults in every voice condition.

Our finding that object-directed voice cues led to a narrower cone of gaze in 6-year-olds suggests that 6-year-olds combine information from gaze and voice cues when making judgments of eye gaze. Importantly, our results also suggest that combining information from gaze and voice cues can allow 6-year-olds, in whom judgments of direct and averted gaze are not yet adult-like (Vida & Maurer, 2012a), to make more adult-like judgments of gaze. Without a voice cue, 6-year-olds judged that the model was looking directly at them when gaze was in fact within approximately 4.25° to either side of straight ahead (approximately 2° beyond the edge of participants' face). This pattern was not observed in 8-year-olds and adults, who attributed eye contact within a range corresponding roughly with the width of the participant's own face. With the object-directed voice cues, 6-year-olds attributed eye contact within approximately 3.8° to either side of straight ahead (approximately 1.5° beyond the edge of the participant's face).

We were surprised that voice cues had no effect on the cone of gaze in the two older groups despite previous evidence that hearing one's own name rather than a different name increases the width of adults' cone of gaze (Stoyanova et al., 2010). It is possible that object-directed voice cues exert a stronger effect in young children because, unlike adults, children tend to weight auditory cues more strongly than visual cues when both are present (e.g., Sloutsky & Napolitano, 2003). However, it is also possible that the effect is not limited to young children but is instead linked to the amount of uncertainty in participants' judgments of gaze. In cross-modal tasks, signals in an irrelevant modality exert a stronger influence when signals in the target modality are degraded or ambiguous (e.g., Collignon et al., 2008; de Gelder & Vroomen, 2000). Although the boundaries of the cone of gaze are, by definition, located at the position where participants are most uncertain about whether gaze is direct or averted, the distance of the boundaries from straight gaze may reflect general differences in participants' certainty about the direction of gaze. Reducing adults' ability to discriminate between direct and averted gaze by decreasing the brightness of the stimulus leads to a stronger bias to attribute direct gaze when gaze is actually averted (e.g., Martin & Rovira, 1981). Similarly, adults are less accurate in discriminating between leftward and rightward gaze for inverted faces than for upright faces (e.g., Jenkins & Langton, 2003; Schwaninger, Lobmaier, & Fischer, 2005), and their cone of gaze is wider for inverted faces (Vida et al., 2013). Hence, the wider cone of gaze in 6-year-olds than in 8-year-olds and adults in the current experiment, and in previous research (Vida & Maurer, 2012a), may reflect greater uncertainty about the direction of gaze in 6-year-olds. Voice cues may have influenced judgments of gaze in 6-year-olds, but not in older children and adults, because 6-year-olds were more uncertain about the direction of gaze.

Another possible contributor to age differences in the effect of voice cues is the spatial relation between the boundaries of the cone of gaze and the edges of the participant's face. By 8 years of age, the width and height of the cone of gaze correspond roughly to the width and height of the participant's own face, a pattern suggesting that the boundaries of the cone of gaze may be calibrated to match the dimensions of the participant's own face (Vida & Maurer, 2012a). This calibration may set a lower limit for the size of the cone of gaze, so that, under typical viewing conditions, the cone of gaze is unlikely to be narrower than the participant's face. Hence, object-directed voice cues might not have decreased the width of the cone of gaze in 8-year-olds and adults because the width of their cone of gaze was at the minimum value in the absence of voice cues. Because 6-year-olds' cone of gaze was much wider than one's own face and that of 8-year-olds and adults, there may have been more room for 6-year-olds' judgments to be influenced by an informative voice cue.

Experiment 2

In Experiment 2, we attempted to increase adults' uncertainty, and consequently the width of their cone of gaze, by having the face disappear after 600 ms rather than having it remain until participants responded, as it did in Experiment 1. We expected that increasing adults' uncertainty and/or the width of their cone of gaze would lead to greater influence of voice cues on judgments of gaze.

Method

Participants

Participants were 24 adults (18–27 years, $M = 21.14$ years, 17 women and 7 men), not tested in Experiment 1, who met the same visual screening criteria as adults in Experiment 1. One additional participant was tested but was excluded and replaced because the participant was obviously inattentive during the procedure.

Design and procedure

The design and procedure were the same as in Experiment 1 except that each face was replaced by a blank screen 600 ms after onset instead of remaining visible until the participant entered a response.

Results

Accuracy on catch trials

Accuracy on catch trials was very high ($M = .98$, $SD = .06$), a result suggesting that participants were attentive throughout the procedure.

Width of cone of gaze

For each participant, we used the method described in Experiment 1 to estimate the width of the cone of gaze in each voice condition (see Figs. 4 and 5). To examine the effect of limiting the duration of exposure on adults' sensitivity to direct and averted gaze, we carried out a planned one-tailed independent-samples *t* test evaluating the specific hypothesis that adults' cone of gaze was wider in the no voice condition of Experiment 2 than in the no voice condition of Experiment 1. The cone of gaze was marginally significantly wider in Experiment 2 ($M = 6.44°$, $SD = 1.97$) than in Experiment 1 ($M = 5.71°$, $SD = 1.38$), $t(46) = 1.48$, $p = .07$, $d = 0.42$. This pattern is consistent with previous findings that when uncertainty about the difference between direct and averted gaze is higher, adults show a stronger bias to attribute eye contact when gaze is actually averted (Martin & Rovira, 1981; Vida et al., 2013).

We carried out a repeated-measures ANOVA with voice condition as the independent variable and width of the cone of gaze as the dependent variable. There was a significant effect of voice condition, $F(2,46) = 5.40$, $p < .01$, $\eta_p^2 = .19$. We followed up this effect with Holm–Bonferroni-corrected paired-samples *t* tests (Holm, 1979) evaluating all pairwise differences among voice conditions. In the object-directed voice condition, the cone of gaze was significantly narrower ($M = 5.81°$, $SD = 1.94$) than in the no voice condition ($M = 6.44°$, $SD = 1.97$), $t(23) = 3.21$, $p < .004$, $\alpha = .017$, $d = 0.33$, and was marginally significantly narrower than in the participant-directed voice condition ($M = 6.15°$, $SD = 1.92$), $t(23) = 2.11$, $p = .04$, $\alpha = .025$, $d = 0.18$. There was no difference in the width of the cone of gaze between the no voice and participant-directed voice conditions ($p > .20$). Hence, the effect of voice condition was qualitatively similar to that observed in 6-year-olds in Experiment 1.

Effect of voice cues on proportions of "direct" and "averted" responses

We used the methods described in Experiment 1 to investigate whether the narrower cone of gaze in the object-directed voice condition could reflect a general tendency to avoid attributing eye contact when hearing those voice cues regardless of the direction of gaze. We first asked whether voice condition affected the proportion of "direct" responses for unambiguous straight gaze. There was no effect of voice condition ($p > .55$). We also asked whether voice condition affected the proportions of "averted" responses in the unexpected and expected directions for each deviation of gaze from direct.

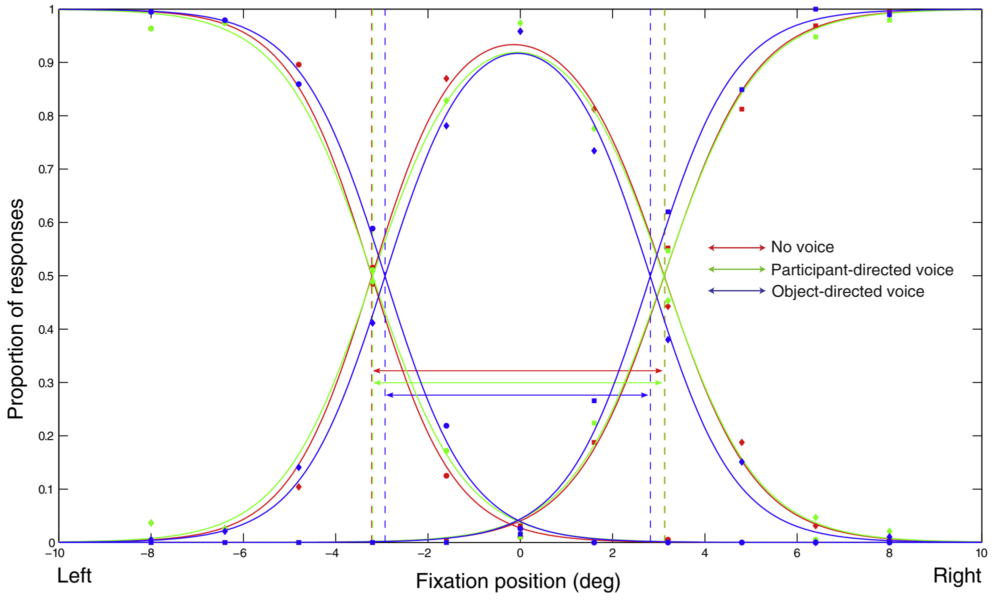

Fig. 4. Logistic functions fit to the mean proportions of each response type for adults in Experiment 2 as a function of fixation position (in degrees) and voice condition. All other details are as in Fig. 2.

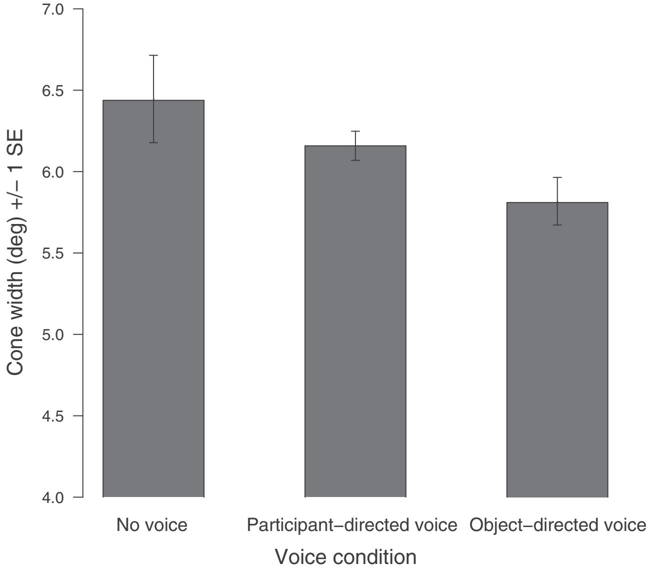

Fig. 5. Mean widths of cone of gaze (in degrees) ± 1 standard error as a function of voice condition in Experiment 2.

We carried out a repeated-measures ANOVA with deviation of gaze and voice condition as independent variables and the proportion of "averted" responses in the unexpected direction as the dependent variable. There were no effects of gaze or voice condition, and there was no interaction (*ps* > .30). The proportion of responses in the unexpected direction was at or near zero for most deviations of gaze from direct, a pattern that may have limited the sensitivity of our analyses. Inspection of Fig. 4 confirms that there was no clear trend toward a difference between voice conditions in the proportion of responses in the unexpected direction. We carried out an additional ANOVA with the proportion of "averted" responses in the expected direction as the dependent variable. There were effects of deviation of gaze, $F(4,92) = 191.97$, $p < .001$, $\eta_p^2 = .89$, and voice condition, $F(2,46) = 5.17$, $p < .01$, $\eta_p^2 = .69$, but no interaction ($p > .10$). We followed up the effect of voice condition with Holm–Bonferroni-corrected paired-samples t tests comparing the proportion of averted responses in the expected direction between each pair of voice conditions. There was no difference between the no voice condition ($M = .70$, $SD = .12$) and the participant-directed voice condition ($M = .71$, $SD = .13$), $p > .60$. However, the proportion of responses in the expected direction was higher in the object-directed voice condition ($M = .74$, $SD = .12$) than in the no voice condition, $t(23) = 3.13$, $p < .006$, $\alpha = .017$, $d = 0.33$, and in the participant-directed voice condition, $t(23) = 2.56$, $p < .02$, $\alpha = .02$, $d = 0.32$. Together, these results suggest that, as in 6-year-olds in Experiment 1, the effect of object-directed voice cues in the current experiment does not reflect a general tendency to avoid attributing eye contact.

Slope of response curves

We used the methods described in Experiment 1 to investigate whether voice cues influenced the steepness of the transition between "direct" and "averted" responses. We carried out a repeated-measures ANOVA with voice condition as the independent variable and slope as the dependent variable. There was no effect of voice condition ($p > .80$). Hence, as in Experiment 1, voice cues did not influence the steepness of the transition between "direct" and "averted" responses.

Discussion

Adults' cone of gaze in the no voice condition in the current experiment (6.44°) was slightly wider than that of adults in the no voice condition in Experiment 1 (5.71°), a result suggesting that limiting the duration of exposure to faces increased adults' uncertainty about the direction of gaze. Unlike adults in Experiment 1, adults' cone of gaze in the current experiment was narrower in the object-directed voice condition (5.81°) than in the no voice (6.44°) and participant-directed voice (6.15°) conditions, with no difference between the latter two. Follow-up analyses indicated that the effect of object-directed voice cues does not reflect a general tendency to avoid attributing direct gaze but instead reflects an increased tendency to attribute averted gaze in the expected direction when gaze is actually averted. Follow-up analyses also indicated that voice cues did not influence the steepness of the transition between "direct" and "averted" responses. This pattern is identical to that found in 6-year-olds in Experiment 1 with unlimited exposure time.

General discussion

The current study provides the first information on the influence of voice cues on children's judgments of direct and averted gaze. In Experiment 1, voice cues affected the width of the cone of gaze in 6-year-olds but not in 8-year-olds or adults. The 6-year-olds' cone of gaze was narrower when they heard an object-directed voice cue (e.g., "I see that") than when they heard the participant-directed voice cue (e.g., "I see you") or no voice, with no difference between the latter two. In Experiment 2, adults' judgments of gaze were made more difficult by limiting the duration of exposure to the face. Adults' cone of gaze tended to be wider than in Experiment 1, and the effect of voice cues on adults' judgments of gaze was the same as in 6-year-olds in Experiment 1.

In the current study, object-directed voice cues affected judgments of eye gaze in 6-year-olds, but not in older participants, when the task was relatively easy (Experiment 1), and they affected adults' judgments when the task was more difficult (Experiment 2). This pattern suggests that the effect of object-directed voice cues may be related to participants' uncertainty about the difference between direct and averted gaze, so that the effect will tend to be larger when uncertainty is higher regardless of whether the uncertainty is caused by immaturity or limited exposure. This interpretation is consistent with previous findings from adults that a cue in an irrelevant modality has a larger influence when the target stimulus is degraded or ambiguous (e.g., Collignon et al., 2008). The current results are also consistent with the possibility that the minimum width of the cone of gaze is limited by the size of the participant's own face (see Vida & Maurer, 2012a), so that voice cues are likely to decrease the width of the cone of gaze only when it is wider than the participant's face in the absence of voice cues, as in 6-year-olds in Experiment 1 and adults in Experiment 2. Together, the results of Experiments 1 and 2 suggest that both adults and children as young as 6 years combine information from gaze and object-directed voice cues when making judgments of eye gaze and that this ability can lead to a narrowing of the cone of gaze, thereby allowing more adult-like judgments of gaze in young children.

Children's ability to combine information from gaze and voice cues has implications for understanding the development of real-world social cognition. The finding in the current study and in previous research (Vida & Maurer, 2012a) of a wider cone of gaze in 6-year-olds than in 8-year-olds and adults suggests that when the direction of gaze is the only available cue to the focus of a person's attention, 6-year-olds will be more likely than older children and adults to make errors in social judgments. Specifically, 6-year-olds may be more likely to infer that a person is paying attention to them when the person is actually attending to something else in the environment. However, the current results suggest that when both gaze and object-directed voice cues are present, 6-year-olds will be less likely to make these erroneous social judgments.

The observed influence of voice cues on children's judgments of eye gaze could also play a role in developmental changes in judgments of gaze. The cone of gaze narrows considerably between 6 and 8 years (Vida & Maurer, 2012a), a change that may reflect the accumulation of experience with the social and visual properties of gaze cues. Our results suggest that voice cues could facilitate this development by allowing children to make more adult-like judgments and/or by providing feedback about whether children made appropriate interpretations. Individual differences in exposure to such cues might also lead to individual differences in the speed of acquiring adult-like sensitivity to direct and averted gaze.

One remaining question is why the participant-directed voice cues (e.g., "I see you") did not lead to a wider cone of gaze than was observed in the no voice condition at any age. This is especially surprising because a previous study reported that an adult's cone of gaze is larger when the adult hears his or her own name rather than someone else's name (Stoyanova et al., 2010). However, the absence of a no voice condition in that study makes it impossible to distinguish a widening of the cone of gaze when hearing one's own name from a narrowing of the cone of gaze when hearing another person's name. One possibility is that participant-directed voice cues are effective only if they are personalized (e.g., the participant's first name). Future research could investigate this possibility by having participants make judgments of gaze while hearing someone calling the participant's own name, another name, or no name at all.

The current results leave several additional questions open for future research. For example, because voice cues affected judgments of eye gaze in 6-year-olds, the youngest age group able to complete the current procedure, the current results do not indicate when in development the effect of voice cues emerges. Future studies could investigate this question by testing children younger than 6 years with a modified version of our procedure. In addition, it is possible that we would have observed a different effect of voice condition if we had used a baseline condition including voice cues that provide no information about the focus of a person's attention (e.g., nonsense speech or speech in a language foreign to the participant). The mere presence of a voice could influence judgments of gaze by alerting or distracting participants. Future studies could investigate these possibilities by replicating the current study with a baseline condition including a voice cue that provides no information about the focus of a person's attention. Finally, because all speakers in the current study used a positive-sounding tone of voice, the current results do not indicate whether variations in the affective properties of voices could influence judgments of gaze. Previous research indicates that the cone of gaze of both adults (Ewbank, Jennings, & Calder, 2009) and 8-year-olds (Rhodes, Addison, Jeffery, Ewbank, & Calder, 2012) is wider for angry faces than for fearful or neutral faces, with no difference between the latter two. Future studies could investigate whether the emotional prosody of a voice exerts a similar influence on children's and adults' judgments of gaze.

Conclusions

The current investigation has provided the first information on the influence of voice cues on children's judgments of the direction of gaze. Our results suggest that both children and adults combine information from gaze and voice cues when making judgments of eye gaze and that voice cues may be especially effective when the cone of gaze is wider because of immaturity or limited exposure to the face stimulus. Importantly, our results also suggest that the ability to combine information from gaze and voice cues may allow young children to make more adult-like judgments about others' attention and intention than they are able to make in the absence of relevant voice cues.

Acknowledgments

We thank Erica D'Angelo and Desiree Law for their valuable assistance in data collection. This research was supported by Grant 9797 from the Natural Sciences and Engineering Council of Canada (NSERC) to D.M. and by an NSERC Vanier Canada Graduate Scholarship (CGS-V) to M.D.V.

References

Adams, R. A., & Courage, M. L. (2002). Using a single test to measure human contrast sensitivity from early childhood to maturity. *Vision Research, 42*, 1205–1210.
Argyle, M., & Cook, M. (1976). *Gaze and mutual gaze*. New York: Cambridge University Press.
Baldwin, D. A. (1991). Infants' contribution to the achievement of joint reference. *Child Development, 63*, 875–890.
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: Lawrence Erlbaum.
Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The "Reading the Mind in the Eyes Test" revised version: A study with normal adults and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, 42*, 241–251.
Brainard, D. H. (1997). The Psychophysics Toolbox. *Spatial Vision, 10*, 433–436.
Collignon, O., Girard, S., Gosselin, F., Roy, S., Saint-Amour, D., Lassonde, M., et al (2008). Audio-visual integration of emotion expression. *Brain Research, 1242*, 126–135.
de Gelder, B., & Vroomen, J. (2000). The perception of emotions by ear and by eye. *Cognition & Emotion, 14*, 289–311.
Doherty, M. J., Anderson, J. R., & Howieson, L. (2009). The rapid development of gaze judgment ability at 3 years. *Journal of Experimental Child Psychology, 104*, 296–312.
Einav, S., & Hood, B. M. (2008). Tell-tale eyes: Children's attribution of gaze aversion as a lying cue. *Developmental Psychology, 44*, 1655–1667.
Ellemberg, D., Lewis, T. L., Liu, C. H., & Maurer, D. (1999). Development of spatial and temporal vision during childhood. *Vision Research, 39*, 2325–2333.
Ewbank, M. P., Jennings, C., & Calder, A. (2009). Why are you angry with me? Facial expressions of threat influence perception of gaze direction. *Journal of Vision, 9*, 1–7.
Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proceedings of the National Academy of Sciences of the United States of America, 99*, 9602–9605.
Farroni, T., Johnson, M. H., & Csibra, G. (2004). Mechanisms of eye gaze perception during infancy. *Journal of Cognitive Neuroscience, 16*, 1320–1326.
Farroni, T., Mansfield, E. M., Lai, C., & Johnson, M. H. (2003). Infants perceiving and acting on the eyes: Tests of an evolutionary hypothesis. *Journal of Experimental Child Psychology, 85*, 199–212.
Gibson, J. T., & Pick, A. D. (1963). Perception of another person's looking behavior. *American Journal of Psychology, 76*, 386–394.
Hains, S. M. J., & Muir, D. W. (1996). Infant sensitivity to adult eye direction information. *Child Development, 67*, 1940–1951.
Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics, 6*, 65–70.
Jenkins, J., & Langton, R. H. (2003). Configural processing in the perception of eye-gaze direction. *Perception, 32*, 1181–1188.
Kendon, A. (1967). Some functions of gaze-direction in social interaction. *Acta Psychologica, 26*, 22–63.
Lord, C., & Haith, M. M. (1974). The perception of eye contact. *Perception and Psychophysics, 16*, 413–416.
Martin, W. W., & Rovira, M. L. (1981). An experimental analysis of discriminability and bias in eye-gaze judgment. *Journal of Nonverbal Behavior, 5*, 155–163.
Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology, 11*, 56–60.
Parise, E., Cleveland, A., Costabile, A., & Striano, T. (2007). Influence of voice cues on learning about objects in joint attention contexts. *Infant Behavior & Development, 30*, 380–384.
Rhodes, G., Addison, B., Jeffery, L., Ewbank, M., & Calder, A. J. (2012). Facial expressions of threat influence perceived gaze direction in 8-year-olds. *Public Library of Science One, 7*, e49317.
Schwaninger, A., Lobmaier, J. S., & Fischer, M. H. (2005). The inversion effect on gaze perception reflects processing of component information. *Experimental Brain Research, 167*, 49–55.
Senju, A., & Csibra, G. (2008). Gaze following in humans depends on communicative signals. *Current Biology, 18*, 668–671.
Senju, A., & Johnson, M. H. (2009). The eye contact effect: Mechanisms and development. *Trends in Cognitive Sciences, 13*, 127–134.

Sloutsky, V. M., & Napolitano, A. C. (2003). Is a picture worth a thousand words? Preference for auditory modality in young children. *Child Development, 74*, 822–833.
Stoyanova, R. S., Ewbank, M. P., & Calder, A. J. (2010). "You talkin' to me?": Self-relevant auditory signals influence perception of gaze direction. *Psychological Science, 21*, 1765–1769.
Symons, L., Hains, S. M. J., & Muir, D. W. (1998). Look at me: Five-month-old infants' sensitivity to very small deviations in eye gaze during social interactions. *Infant Behavior and Development, 21*, 531–536.
Symons, L. A., Lee, K., Cedrone, C. C., & Nishimura, M. (2004). What are you looking at? Acuity for triadic eye gaze. *Journal of General Psychology, 131*, 451–469.
Vida, M. D., & Maurer, D. (2012a). The development of fine-grained sensitivity to eye contact after 6 years of age. *Journal of Experimental Child Psychology, 112*, 243–256.
Vida, M. D., & Maurer, D. (2012b). Gradual improvement in fine-grained sensitivity to triadic gaze after 6 years of age. *Journal of Experimental Child Psychology, 111*, 299–318.
Vida, M. D., & Maurer, D. (2012c). Sensitivity to vertical differences in triadic gaze is slow to develop. *Journal of Vision, 12*, 634.
Vida, M. D., Maurer, D., Calder, A. J., Rhodes, G., Walsh, J. A., Pachai, M. V., & Rutherford, M. D. (2013). The influences of face inversion and facial expression on sensitivity to eye contact in high-functioning adults with autism spectrum disorders. *Journal of Autism and Developmental Disorders*. http://dx.doi.org/10.1007/s10803-013-1802-2.