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Automatic cueing of covert spatial attention by a novel agent in preschoolers and adults

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ABSTRACT

Both infants and adults exhibit rapid, automatic reorienting of covert spatial attention in the direction indicated by familiar biological signals, such as another individual's gaze, reaches, or points. Recent evidence in adults suggests that these cued responses can be influenced by representations of the other individual's perceptual experiences and capacity for intentional action. However, current developmental results and theoretical accounts of the acquisition and specialization of cued responses are consistent with a cueing mechanism based on leaner representations of perceptually familiar directional signals. The influence of mentalistic attributions on cueing during early childhood is thus unknown. We investigated whether or not abstract attributions of agency to an unfamiliar entity would modulate cueing in 4- to 6-year-old children and adults. When induced to construe a faceless novel entity as an agent, both age groups fixated targets more rapidly when they appeared in locations consistent with the agent's directional orientation; they did not do so when they had no reason to view the entity as an agent. This result provides evidence that 1) the intentional actions of a perceptually unfamiliar agent can guide attentional cueing in adults, and 2) this influence of conceptual assessment on reflexive social attention is present by early childhood.

1. Introduction

Rapid attentional responses during social interactions are adaptive, helping a person to quickly detect the target of another person's attention or actions. When attentional responses are automatic, an individual may allocate mental resources to broader social cognitive goals, further speeding responsiveness. However, automaticity can be implemented at different points in cognitive processing (e.g., after either sensory stimulation, perceptual representation, or conceptual assessment), each permitting varying degrees of responsive flexibility. Here we consider the extent to which children's abstract representations of agency influence "gaze cueing": a rapid, automatic attentional reorienting response to the direction of another person's line of sight.

Gaze cueing is a form of covert attentional reorienting, occurring without any visible changes in the observer's eye, head, or body orientation (Friesen & Kingstone, 1998; Hood, Willen, & Driver, 1998; Posner 1980). Individuals who are cued in this manner will more rapidly detect and respond to targets at locations that are congruent, as opposed to incongruent, with another's visual perspective. The speed, automaticity, and private nature of gaze cueing all distinguish it from the slower,

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more volitional, and overt reorienting of visual attention observed during bouts of "gaze following," suggesting that different cognitive mechanisms drive these two responses (Frith & Frith, 2003; Meltzoff & Brooks, 2013; Moore & Corkum, 1998).

There are dramatic developmental changes in the inputs that engage automatic covert attention over the course of the lifespan. From birth, infants are cued in the direction of another person's gaze (Farroni, Massaccesi, Pividori, & Johnson, 2004; Hood et al., 1998), but through at least the 4th month these early responses are constrained to particular contexts (e.g., when preceded by direct eye contact) and are strongly determined by physical features of the cue, such as its lateral motion (Farroni, Johnson, Brockbank, & Simion, 2000; Farroni, Mansfield, Lai, & Johnson, 2003; Matsunaka & Hiraki, 2014). By adulthood, however, the mechanisms that support gaze cueing have moved well past these limitations. There are now numerous demonstrations in which adults' gaze cueing appears to be informed by mental attributions made to the gazer. For instance, adults only produce cued responses to another person's gaze when they believe that she can see. Adults are no longer cued in the direction indicated by a gazer's eyes or head when her eyes are covered (Nuku & Bekkering, 2008, 2010), when her line of sight is obstructed (Kawai, 2011), when target objects appear outside of her field-of-view (Schulz, Velichkovsky, & Helmert, 2014; but see also Cole, Smith, & Atkinson, 2015), or when the observer believes that the cueing character is wearing opaque – as opposed to translucent – goggles (Teufel, Alexis, Clayton, & Davis, 2010).

In addition to the ascription of immediate perceptual experiences, gaze cueing in adults is also modulated by the attribution (or reassessment) of a gazer's capacity for intentional action. When adults are told that, despite appearances, a cueing character is a realistic mannequin and not an actual person, gaze cueing is suspended (Wiese, Wykowska, Zwickel, & Müller, 2012). Moreover, when an adult observer is told that a robot (that does not otherwise cue attention) is being controlled by a human agent, the observer's attention will be cued in the direction that the robot's eyes appear to point (Wiese et al., 2012). Together, these findings suggest that, by adulthood, gaze cueing may be conceptually rich, incorporating representations of a cueing character's perceptual abilities and mental capacities. However, little is known about how children's cued responses achieve similar sophistication.

The acquisition and specialization of cued responses to gaze and other signals is typically described as a process of "overlearning." According to this account, repeated encounters with a directionally predictive cue will eventually organize an automatized attentional reorienting response to it (Ristic & Kingstone, 2005; Rombough, Barrie, & Iarocci, 2012; Vecera & Rizzo, 2006). Such learned associations occur during infancy (Sobel & Kirkham, 2012) and their automatization may indeed explain some developmental changes in the inputs that engage rapid attentional reorienting (e.g., the reduced role of eye contact and motion by early childhood). However, it is less clear how overlearning can explain top-down influences on the initiation of automatic reorienting in adulthood, such as its flexible modulation by mentalistic attributions. In these cases, the cued response cannot be triggered by sensitivity to inputs described in wholly perceptual terms (e.g., "things with eyes"). Rather, the engagement of a cued response must also draw upon more abstract information that helps to identify reliable directional cues, such as a conceptual understanding of others' intentionality and perceptual experiences.

Current evidence for early cueing to gaze and other directional signals is consistent with the involvement of such conceptual considerations, but can also be explained by leaner accounts of perceptual overlearning. For instance, although infants between 5 and 7 months begin to show spontaneous covert reorienting in the direction indicated by either a grasping hand or a pointing gesture (Bertenthal, Boyer, & Harding, 2014; Daum & Gredebäck, 2011; Daum, Ulber, & Gredebäck, 2013; Rombough et al., 2012; Wronski & Daum, 2014), it is unclear how infants' representations of these cues engage their automatic attentional responses. During these same ages, infants do interpret familiar manual gestures as goal-directed in tasks that do not measure automatic attentional reorienting (Woodward, 1998, 1999). However, a rapid, overlearned reorienting response may not draw upon such interpretations; instead, attentional reorienting mechanisms may merely treat these actions as perceptually familiar cues that have previously provided meaningful directional information, without first considering the goal-directedness of a grasping hand or the referential intent of a pointing finger.

Although gaze cueing and gaze following are distinct forms of attentional reorienting, researchers that previously investigated the basis for infant gaze following faced a similar interpretive challenge to the one we have posed here. In that literature, it seemed plausible that infants who overtly look where another person looks have simply learned that human head turns provide useful directional information (Butterworth & Jarrett, 1991; Moore, 2006; Moore, Angelopoulos, & Bennett, 1997). However, infants will follow the implied "gaze" of an entirely novel, faceless entity when they have reason to view it as an agent. This demonstrates that gaze following need not depend upon learning about a class of perceptually-defined signals, such as "human head turns" (Beier & Carey, 2014; Deligianni, Senju, Gergely, & Csibra, 2011; Johnson, 2000; Johnson, Slaughter, & Carey, 1998; Movellan & Watson, 1987). Rather, when infants follow the rotational motion of a novel entity, they do so because they view it as an intentional agent[1] – i.e., the sort of thing that possesses a meaningful attentional orientation (Johnson, 2003; Luo & Baillargeon, 2010) or that behaves with referential intent (Gergely, 2010). This work examining the abstract attributions that motivate overt gaze following in infants provides a useful framework for assessing the conceptual richness of cued covert reorienting in early childhood.

In the present study, we adopt the same novel agent manipulation employed in earlier observations of gaze following to investigate whether abstract attributions of intentional agency engage automatic, covert reorienting in both preschool-

[1] We use the term "intentional agent" to refer to a broad set of entities whose behaviors, and thus their internal states, bear an "aboutness" relation to a target. Viewing a novel entity as either a goal-directed, perceiving agent or as a communicating agent (or both) is an abstract attribution that goes beyond perceptual descriptions of an agent's behaviors.

aged children and adults. In a between subjects manipulation, participants were induced to construe a faceless, completely novel entity as either an agent capable of engaging in a contingent, communicative interaction with an adult actor, or as a non-agentive object. Following this induction, all participants observed the rotational motion of the entity in a standard cueing paradigm. We measured the saccadic reaction time (SRT) for subjects to fixate peripherally appearing target objects following the entity's rotation; a cueing effect was inferred when subjects responded more quickly to targets appearing on the side congruent with the entity's turn. Although this technique measures overt saccades, differences in SRT reflect shifts of covert attention induced earlier by the central cue (Friesen, Moore, & Kingstone, 2005). If covert reorienting derives primarily from overlearned associations between perceptually defined signals and interesting events in the environment, a novel agent with whom one has had little experience should not engage the mechanisms that support cueing. If, however, children's covert reorienting also draws upon abstract representations of a cueing character's agency, then a novel entity should engage this system only after participants have interpreted it as an intentional agent.

We investigated this issue in preschool-aged children because several prior studies observe developments in automatic, covert reorienting during this period that bring it more closely in line with adults' attentional behaviors. First, by this age, gaze cueing no longer depends on observing the motion of a gazer's pupils (Ristic, Friesen, & Kingstone, 2002). Second, although 4-year-olds are cued by both an upright and inverted presentation of a point-light walker, 5-year-olds and adults are cued only when it is upright (Zhao et al., 2014). Third, only 5-year-olds are cued by the conventional directionality of arrows (Jakobsen, Frick, & Simpson, 2013); prior to this age, arrow cueing may depend upon an arrow's asymmetric perceptual shape rather than its symbolic meaning. Despite these achievements, however, children's responses in these contexts do not tell us whether they will also respond in adult-like ways after attributing intentional agency to an unfamiliar cueing character.

We also extended our investigation to adult participants, as the present manipulation requires more fully abstract conceptual considerations about the cueing character than prior demonstrations of top-down influences on cueing did. In all prior adult work, conceptually informed cueing was observed using cues that were produced via familiar, intentional actions of human beings, whereas in the current study, cues are produced via the self-generated, rotational motion of a novel, non-human entity without eyes.

2. Methods

2.1. Participants

Seventy-one adults and eighty-four children participated in the study. Participants were excluded from analysis based on coding criteria determined a priori (12 adults, 27 children), parent-reported developmental delays (2 children), or experimenter error (2 children). The final sample included 59 adults (mean age: 20.66 years, SD = 4.09, range: 18.0–51.42[2]; 44 female; 61% Caucasian Non-Hispanic) and 53 children (mean age: 60.04 months, SD = 7.65, range: 49–72; 26 female; 68% Caucasian Non-Hispanic).

2.2. Setup and materials

Participants viewed the study on a 23" monitor (resolution: 1920 × 1080) at a distance of 65 cm. Stimuli were generated in Blender 2.67.0 and presented using Tobii Studio 3.2. Data was collected using a Tobii TX300 remote eye-tracker (sampling rate: 300 Hz, precision: 0.15°, accuracy: 0.5°).

2.3. Calibration and task instructions

Following a 9-point calibration, participants were told that they would view a sequence of videos in which a "thing" would turn to either the left or right, followed by the appearance of a colorful object on either the left or right side of the screen. Participants were instructed to look at the target whenever it appeared.

To ensure that both children and adults understood the non-predictive nature of the entity's turns, the experimenter described possible congruent and non-congruent trials and emphasized that the location of the target's appearance was entirely random. All participants confirmed comprehension before the study began.

2.4. Design

Participants were assigned to either the Socially Contingent or Non-Contingent condition. Familiarization videos varied between conditions, but cueing trials were identical. Each participant viewed an initial familiarization video, followed by one of four pseudo-random sequences of cueing trials (8 blocks, 8 trials per block). In each sequence, trial congruency, the side of the target's appearance, 2 beep durations, and target object type were orthogonally counterbalanced. No more than

[2] One adult was an older, non-traditional undergraduate. Results are similar when analyses are performed without this individual.

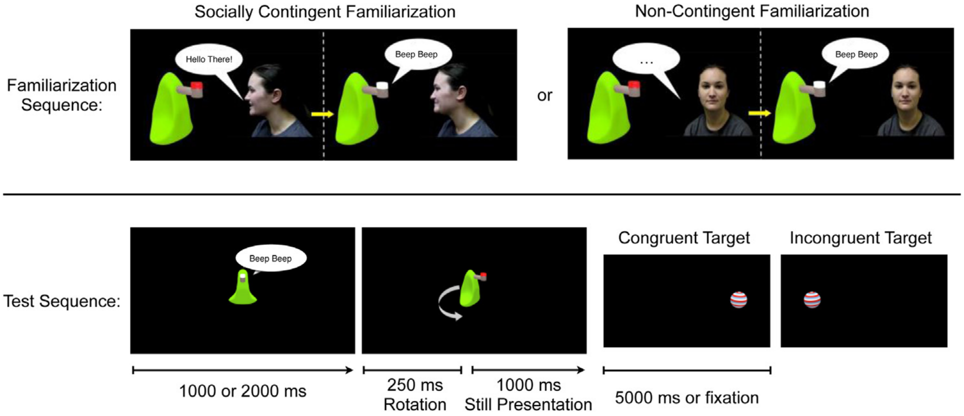

Fig. 1. Schematic depiction of events during familiarization and test trials.

2 turns in a given direction, 2 congruent or incongruent trials, or 2 targets of the same type were shown in a row. Each block after the first was preceded by a short re-familiarization video.

2.5. Familiarization videos

Familiarization videos (56 s) featured a novel animated entity and a human actor (Fig. 1). In the Socially Contingent condition the entity and the actor appeared to have a contingent, turn-taking conversation. The motionless entity appeared to speak to the actor by beeping, while a protuberance at its front end flashed simultaneously. The actor smiled and spoke to the entity in English. Both the actor's and the entity's lines had variable durations, mimicking the natural flow of conversation. In the Non-Contingent condition, the entity's behavior was identical to the Socially Contingent condition, but the actor did not turn toward or speak to the entity and thus never established a contingent interaction with it. Re-familiarization clips (20 s) were produced from short subsets of the primary familiarization video.

2.6. Cueing trials

Each cueing trial began with the brief, central presentation of a colorful shape (4.65° visual angle). Next, the entity appeared at screen center, facing toward the participant (4.02° x 7.35°). After 1000 ms, it beeped and flashed its protuberance (1000 or 2000 ms) and rotated (250 ms) to the left or right. After 1000 ms, the entity simultaneously disappeared from the screen as the target object appeared at a peripheral location (9.0° from the entity's edge). The target remained onscreen until participants fixated it or 5 s had elapsed.

2.7. Coding and data reduction

Coders evaluated whether the participant watched the screen for the entire trial duration, attended to the entity as it turned, fixated on the entity until the target's appearance, and made an uninterrupted saccade to the target when it appeared (i.e., Watching Criteria). A trial's data was excluded from analysis if any of these Watching criteria were violated or if the gaze plot overlying the participant video was deemed insufficient to judge (i.e., Tracking Criteria). Initial coder agreement for acceptable trials was good (Cohen's Kappa for Adults = 0.62, Children = 0.79). Disagreements were resolved by discussion (sometimes including the first author as blind arbiter) resulting in 100% agreement. As is customary for cueing studies, we excluded trials whose SRT was less than 100 ms (deemed anticipatory) or greater than 2 SD above a participant's mean SRT.

Adults were excluded from analysis if Tracking was questionable (fewer than 75% of trials acceptable, Socially Contingent: 4, Non-Contingent: 2) or they were inattentive (fewer than 50% of trials met Watching criteria, SC: 4, NC: 3). Children who provided fewer than eight (4 congruent, 4 incongruent) acceptable trials (SC: 16, NC: 11) were excluded. After coding, participants had similar numbers of trials in each condition (Table 1).

3. Results

3.1. Preliminary analyses

Children's interest in the initial familiarization videos did not vary by condition (looking duration, SC: 39.7 s; NC: 42.6 s), $t(51) < 1$, $p = 0.47$. Adults viewed the familiarization video slightly longer in the Non-Contingent condition (SC: 47.6 s; NC: 55.0 s), $t(57) = 3.07$, $p = 0.01$. A 2 (Target Congruency) x 2 (Condition) x 2 (Sex) x 4 (Randomization sequence) repeated-

Table 1
Summary of saccadic reaction times (SRT) and the number of acceptable trials across ages, condition, and trial type.

		Socially Contingent Condition				Non-Contingent Condition			
		Saccadic RT (ms)		Number of Trials		Saccadic RT (ms)		Number of Trials	
Age Group	Trial Type	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Children	Congruent	426	118	13.12	5.45	380	110	12.63	6.25
	Incongruent	461	143	12.81	5.24	377	111	12.96	5.75
Adults	Congruent	289	47	22.82	4.35	322	71	22.19	4.34
	Incongruent	305	51	22.50	5.27	321	58	21.71	4.05

Note: *M* = Mean. *SD* = Standard Deviation

measures ANOVA on SRTs revealed no effects of Sex, Randomization, or interactions involving these factors and Congruency in either age group. Sex and Randomization sequence were not considered further.

3.2. Main analyses

We conducted a 2 (Condition) x 2 (Target Congruency) repeated measures ANOVA for each age group, as well as planned comparisons within each condition. Given the directional definition of the cueing effect, and our clear hypothesis with respect to the agency manipulation, one-tailed tests are reported for planned comparison *t*-tests and non-parametric tests, throughout.

3.2.1. Children

For the analysis of children's responses, there was a main effect of Condition, $F(1, 51) = 4.03$, $p = 0.05$, $\eta_p^2 = 0.07$, and a marginally significant effect of Congruency $F(1, 51) = 3.86$, $p = 0.06$, $\eta_p^2 = 0.07$. The critical Congruency x Condition interaction was significant, $F(1, 51) = 5.35$, $p = 0.03$, $\eta_p^2 = 0.09$. In the Socially Contingent condition, the mean cueing effect was 35 ms ($SD = 73$ ms), $t(25) = 2.46$, $p = 0.01$, $d_z = 0.48$, $r = 0.86$. In the Non-Contingent condition, the mean cueing effect was −3 ms ($SD = 44$ ms), $t(26) = 0.34$, $p = 0.63$, $d_z = 0.07$, $r = 0.92$. The mean difference between conditions was significant, $t(51) = 2.30$, $p = 0.01$, $d_s = 0.63$.

Non-parametric tests corroborated these results. The tendency for children to exhibit a cueing effect depended on condition membership, Fisher's exact test, $p = 0.02$. Nineteen of 26 participants (73.1%) in the Socially Contingent condition and 11 of 27 (40.7%) in the Non-Contingent condition showed a cueing effect, binomial tests: $p = 0.01$ and 0.22, respectively.

Because the ages of child participants ranged across a 2-year window, we explored the influence of age on the Congruency x Condition interaction. Participant age (in days) was entered as a covariate in a 2 (Congruency) x 2 (Condition) repeated measures ANCOVA. Of interest was a potential three-way interaction between Target Congruency, Condition, and Age. This interaction was not significant, $F(1, 49) < 1$.

Additional analyses explored how participant attrition may have influenced these results. The original inclusion criteria were established a priori, based on our assessment of the number of trials per participant that would offer a robust analysis of cell means. To explore the impact of this decision, analyses were re-run based on more liberal criteria that included children who provided at least 2 (compared to the original 4) acceptable trials per congruency condition. This adjustment re-introduced a roughly equal number of participants into each condition (SC: 5; NC: 6), increased the strength of our non-parametric effects, and did not alter the direction of our parametric results.

3.2.2. Adults

For the analysis of adults' responses, the ANOVA did not show any significant effects: Condition, $F(1, 57) = 2.83$, $p = 0.10$, $\eta_p^2 = 0.05$, Congruency $F(1, 57) = 2.22$, $p = 0.14$, $\eta_p^2 = 0.04$, and Congruency x Condition, $F(1, 57) = 2.58$, $p = 0.11$, $\eta_p^2 = 0.04$. Although the interaction was not significant, planned analyses of both conditions and their comparison revealed the same pattern of results obtained in children. The cueing effect in the Socially Contingent condition was significant, 16 ms ($SD = 33$ ms), $t(27) = 2.56$, $p = 0.01$, $d_z = 0.48$, $r = 0.78$. In contrast, the cueing effect in the Non-Contingent condition was 0 ms ($SD = 44$ ms), $t(30) = 0.07$, $p = 0.53$, $d_z = 0.01$, $r = 0.78$. Comparison of the cueing effect scores between conditions was marginally significant, $t(57) = 1.61$, $p = 0.06$, $d_s = 0.42$.

Non-parametric tests also provided evidence consistent with a tendency for adults' cueing effects to vary based on condition membership. Although the interaction effect was marginal, Fisher's exact test, $p = 0.09$, 21 of 28 participants (75.0%) in the Socially Contingent condition and 17 of 31 (54.8%) in the Non-Contingent condition showed a cueing effect, binomial tests: $p = 0.01$ and 0.36, respectively.

3.3. Analysis across age groups

A final analysis compared the responses of children and adults. This analysis should be considered exploratory because there was a significant heterogeneity of variance, due to differences between the two age groups, Levene's Test for Congruent Trials, $F(3,108) = 6.96$, $p < 0.001$; for Incongruent Trials, $F(3, 108) = 6.95$, $p < 0.001$. However, the results of this analysis are

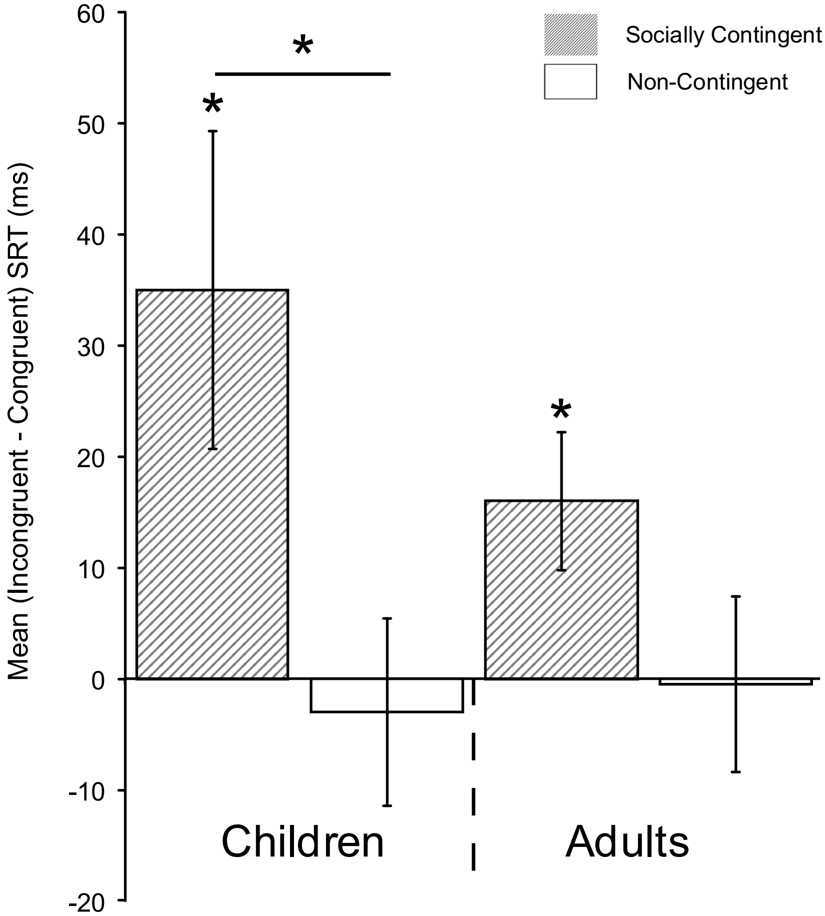

Fig. 2. Mean cueing effects for each condition and age group. * = $p < 0.05$, one-tailed. Error bars depict +/− 1 SEM.

still informative because the ratio of variances is well within the guidelines offered by Howell (2012). A 2 (Congruency) x 2 (Condition) x 2 (Age Group) repeated-measures ANOVA assessed the influence of viewing the novel entity as an agent on the presence of a cueing effect across both age groups. Adults had quicker SRTs overall, *Age*: $F(1, 108) = 35.42$, $p < 0.001$, $\eta_p^2 = 0.25$, and a Condition x Age interaction indicated that the agency manipulation speeded adults' responses while slowing children's responses, $F(1, 108) = 6.78$, $p = 0.01$, $\eta_p^2 = 0.06$. There was a main effect of Congruency, $F(1, 108) = 6.30$, $p = 0.01$, $\eta_p^2 = 0.06$, and a significant interaction between Congruency and Condition, $F(1, 108) = 8.25$, $p = 0.01$, $\eta_p^2 = 0.07$. Viewing the novel entity as an agent led to a greater cueing effect, and this interaction did not vary by age: Congruency x Condition x Age, $F(1, 108) = 1.28$, $p = 0.27$, $\eta_p^2 = 0.01$ (Fig. 2).

4. Discussion

This study provides evidence that abstract attributions of intentional agency engage automatic reorienting of covert spatial attention in both preschool-aged children and adults. Children's most rapid, automatic social behaviors do not appear to be limited to overlearned responses to specific, perceptually defined stimuli. The present results suggest that these behaviors can also be informed by children's rich, conceptual appraisals of the entities that they encounter.

The effects we observed were not due to globally heightened attention in the Socially Contingent condition. Children attended equally to each condition's familiarization video, and adults were even slightly more interested in the Non-Contingent familiarization video; moreover, both ages contributed an equal number of acceptable cueing trials across conditions. Nor can perceptual learning within the study session account for this finding, as both the entity's rotational motion and its non-predictive nature were constant across conditions.

Rather, subjects were only cued by the entity's turn when they viewed it as an intentional agent whose orientation provided a meaningful directional, and perhaps communicative, signal. This finding both supports and extends previous research on the detection and representation of intentional agents. Young children who view an entity as an intentional agent may interpret its behavior as goal directed (Johnson, Booth, & O'Hearn, 2001; Shimizu & Johnson, 2004) and produce voluntary social responses toward it, such as gaze following, imitation, and helping (Beier & Carey, 2014; Johnson et al., 2001; Johnson, Ok, & Luo, 2007; Johnson et al., 1998; Kenward & Gredebäck, 2013; Movellan & Watson, 1987). The present results suggest that in addition to these deliberate behaviors, representations of intentional agents also guide children's most rapid, automatic social behaviors, such as the cueing of covert spatial attention. This occurs spontaneously (because subjects received neither instruction nor demonstration of the entity's directionality) and reflexively (because subjects were explicitly told that the entity's turns did not predict target locations).

Recent findings describe a variety of ways in which conceptual considerations influence automatic spatial attention in adults, but little is known about the age at which such modulation may be possible or how it arises. The present work finds evidence for conceptually informed cueing in a group of children from 4 to 6 years of age, with little suggestion of further developmental change between this age range and adulthood. However, when considering each age group separately, it should be noted that our effects were clearest among children. Although adults showed the predicted pattern of cueing across conditions (i.e., cueing in the Socially Contingent condition and no cueing in the Non-Contingent condition), there was no significant interaction between conditions and the cueing effect. A possible reason for this outcome is that we chose to keep the timing of events within each trial constant across age groups. Because the size of a cueing effect can vary over different delays between the directional cue and target onset, and because adults process information more quickly overall, the timing of our presentation may have been more optimal for children than adults. This consideration raises the possibility that a procedure with different timing parameters might reveal ongoing development from early childhood to adulthood.

Our primary aim was to assess conceptual influences on cueing in our sample of children as a whole. Consequently, an examination of potential changes within the sample's 2-year age range must be considered exploratory. With this caution in mind, however, we note that there were no developmental trends within our child sample. It is possible that a larger sample would provide the power to detect a trajectory similar to that reported by Jakobsen and colleagues (2013), who found that children younger than 5 years are cued by the asymmetric perceptual weighting of arrows, while only older children are cued by an arrow's symbolic meaning. However, it is also possible that the conceptual influences on cueing we report are also present in even younger children.

Even infants view socially contingent entities as agents whose orientation provides a meaningful directional signal. The current findings among preschoolers thus motivate future investigations into the emergence of conceptually informed cueing in even younger children. As discussed earlier, infants' automatic, cued responses to familiar biological actions (e.g., gaze, reaches, points) do not necessarily proceed from representing the intentional nature of these actions, even if such representations inform their other cognitions and behaviors. Although our results do not resolve the challenge of interpreting whether children's cued responses to eye gaze are as conceptually rich as those of adults (Teufel et al., 2010), they are consistent with the notion that automatic cueing in early childhood can proceed on the basis of abstract conceptual assessments rather than just perceptual familiarity. The present use of a novel agent to assess the richness of cueing is well suited for further research in infants and toddlers. To determine the earliest instances of such richness, future studies should adopt both the demonstration of agency employed here – participation in a contingent social interaction – and other behavioral properties of agents to which infants have previously displayed sensitivity, e.g., self-propulsion, equifinal movement to a possible goal, action effects on a target, or rational responses to environmental constraints (Biro & Leslie, 2007; Csibra, Biró, Koós, & Gergely, 2003; Gergely, Nádasdy, Csibra, & Biro, 1995; Hernik, Fearon, & Csibra, 2014; Hofer, Hauf, & Aschersleben, 2005).

Future studies varying the evidence provided for a novel entity's agency could also clarify exactly what types of agency attributions lead participants to cued reorienting responses. In the present work, the entity's self-generated beeps during familiarization and self-generated rotations during the test trials were insufficient on their own. Viewing the beeps as part of a contingent communicative or social interaction with the human actor was critical. This evidence may have motivated participants to view the entity as a mentalistic agent capable of perception and goal-directed action, as a communicative agent capable of expressing referential intent, or an integrated version of both. It would be fruitful to investigate whether or not participants would be cued by the orientation of an entity that has acted in a goal-directed manner, outside of a communicative context. Moreover, because similar considerations are the subject of current debates about the basis upon which infants overtly follow the implied gaze of a novel agent (for summary, see Beier & Carey, 2014), research should consider whether the same range of agency representations supports gaze following and gaze cueing.

Finally, the present results advance our understanding of the development of cueing in two additional ways. First, although the effect sizes were modest, they provide evidence for the most abstract conceptual influence on cueing yet observed. Previous findings of conceptually informed cueing in adults were based upon participants' assessments of human-controlled actions (e.g., a human operating the eyes of a robot; Wiese et al., 2012). Because our novel cueing character's turns were internally generated, any conceptually-influenced cueing must have been based upon general expectations about the meaningfulness of actions made by intentional agents, and not just human-specific behaviors. Second, although we encourage further research in older and younger groups, the parallel patterns of results observed in preschoolers and adults provide a critical bridge between existing literatures on automatic cueing in developmental and adult populations. This is particularly necessary, as the largely motion-driven cueing seen in early infancy diverges so greatly from the conceptually informed cueing that is possible in adulthood. Here we have provided evidence that viewing an entity as an intentional agent has similar effects on automatic spatial reorienting in children and adults, suggesting continuity across development in the specific ways that conceptual knowledge may influence cueing.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cogdev.2016.08.001.

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