ABSTRACT

Title of Document: SPATIAL CUEING BY A NOVEL AGENT IN PRESCHOOL CHILDREN AND ADULTS

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In the current study we assessed preschool children and adults' reflexive, covert spatial attentional response to a novel entity. In particular, we assessed whether covert attention was selectively engaged after construing the novel entity as an agent. Previous research has demonstrated that children and adults' covert spatial attention may be flexibly engaged by a non-directional cueing stimulus (e.g., a circle), however this attentional response is neither spontaneous nor is it reflexive (i.e., participants were told that the stimulus predicted the eventual target's location). For the first time we have shown that covert spatial attention is spontaneously and reflexively engaged by a morphologically unfamiliar cueing character when it is interpreted as an agent but not otherwise. The implication of this finding for theoretical accounts of the development of covert attention and agency attributions more generally are discussed.

SPATIAL CUEING BY A NOVEL AGENT IN PRESCHOOL CHILDREN AND ADULTS

By

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Chapter 1: Introduction

Early in the first year, infants respond to another person's shift from direct- to averted-gaze in two distinct ways: *gaze following* and *gaze cueing*. Gaze following is when an observer aligns their eye gaze with the direction of another person's look. It is publicly visible and under endogenous control (Moore & Corkum, 1998). In contrast, gaze cueing is the covert reorienting of spatial attention in the direction of another person's eye gaze, produced without any visible changes in an observer's eye, head, or body orientation. It is typically much faster than gaze following, and can be either endogenously or exogenously controlled (Bertenthal, Boyer, & Harding, 2014; Daum, Ulber, & Gredebäck, 2013; Farroni, Johnson, Brockbank, & Simion, 2000; Farroni, Mansfield, Lai, & Johnson, 2003; Farroni, Massaccesi, Pividori, & Johnson, 2004; Hood, Willen, & Driver, 1998; Rohlfing, Longo, & Bertenthal, 2012).

Initially, both gaze following and gaze cueing are influenced by the physical characteristics of a person's looking behavior, as well as the environment in which these behaviors occur. When infants first begin to follow gaze overtly, they are driven to do so by the rotational movement of the gazer's head, particularly when the target of the other person's attention is nearby (D'Entremont, Hains, & Muir, 1997; Perra & Gattis, 2010). However, infants may interpret another's head movement as a diffuse directional signal rather than an intentional action toward a particular object or person (Beier & Spelke, 2012; Butterworth & Jarrett, 1991; Corkum & Moore, 1998; Moore & Corkum, 1998b; Moore, Angelopoulos, & Bennett, 1997; Woodward 2003). For example, 9-

month-olds erroneously follow the head turn of a person whose eyes are closed, suggesting that they do not fully appreciate the importance of eyes in determining another's direction of attention (Brooks & Meltzoff, 2005).

Like overt gaze following, the earliest occurrences of gaze cueing are heavily influenced by observable motion. For example, following a period of direct eye contact, 4-month-olds are only cued in the direction of another's averted gaze if they actually see the other person's eyes shift position (Farroni et al., 2000; Farroni et al., 2003). This sensitivity to observable motion is most strikingly demonstrated during presentations where the pupils of another's face remain still and facing forward while the surrounding face shifts laterally. In this case, 4-month-olds are cued in the direction of the face's translational movement rather than the direction indicated the resulting gaze orientation (Farroni et al., 2000). Together, these observations of infants' cued responses to gaze suggest that this is a perceptually driven response to movement and need not proceed from accurately representing another's intentions or perceptual states (Farroni et al., 2000; Farroni et al., 2003).

Although infants' initial responses to others' face and eye movements may occur without making mentalistic attributions to the gazer, their understanding of others' intentional actions (Woodward 1998, 1999), perceptual experiences (Luo & Johnson, 2009; Xu & Denison, 2009), and the contents of others' beliefs (Kovács, Téglás, & Endress, 2010; Southgate &Vernetti, 2014) develops rapidly during the first year. This sophistication in mentalizing is reflected in infants' overt gaze following toward the end of the first year. Specifically, infants restrict overt gaze following to circumstances where they know that another person can see. Compared to 9-month-olds, 10-month-olds are less likely to follow the head turns of an experimenter whose eyes are closed (Brooks & Meltzoff, 2005). Shortly thereafter, 12-month-olds are less likely to follow the head turns of a blindfolded experimenter after encoding the sight-blocking properties of a blindfold (Meltzoff & Brooks, 2008). By 18-months, infants reason about and respond to others' visual perspective in nuanced ways and this ability is heavily influenced by understanding that the visual faculty of another person is analogous to one's own (Meltzoff & Brooks, 2008). These examples demonstrate that although infants may rely on observable motion to follow another's gaze, they learn to interpret head orientation as indicating the direction of another's visual attention.

Although infants reason about others' perceptual experiences in sophisticated ways, the ability to deduce the direction of another agent's attention is not constrained to entities that are persons (Beier & Carey, 2014; Deligianni, Senju, Gergely, & Csibra, 2011; Johnson, Slaughter, & Carey, 1998; Meltzoff, Brooks, Shon, & Rao, 2010; Movellan & Watson, 1987). Around the first birthday infants reliably follow the rotational movement of a completely novel and faceless entity when it is interpreted as an agent. These demonstrations of "gaze" following provide strong evidence that overt following in the second year is a social response that is selectively enacted after representing an agent's intentional actions.

Because gaze following and gaze cueing have distinct behavioral profiles, they are likely supported by distinct cognitive systems (Meltzoff & Brooks, 2013). This analysis, combined with the abundant documentation of conceptually rich gaze following, has led some researchers to view gaze cueing as a relatively lean and unsophisticated mechanism (Driver et al., 1999; Friesen & Kingstone, 1998; Friesen, Ristic, & Kingstone, 2004; Langton 2009; Langton, Watt, & Bruce, 2000) Although gaze cueing offers quick, adaptive responses to others' looks, unlike the conceptual development underlying overt gaze following, this mechanism may remain fundamentally the same across the lifespan (Friesen & Kingstone, 1998; Hietanen 1999; Langton & Bruce, 1999). On this view, covert attentional responses to gaze are primarily elicited by detecting the familiar perceptual features that co-vary with the direction of others' attention. Because of their familiarity with the perceptual features of averted gaze, participants may rapidly orient attention to indicated locations without having represented another's perceptual states. In addition to eye movements, infants' and young children's covert attention is directed by a variety of signals including gestures like pointing (Daum et al., 2013) and grasping (Daum & Gredebäck, 2011; Wronski & Daum, 2014), as well as purely conventional symbols such as arrows (Ristic & Kingstone, 2009; Jakobsen, Frick, & Simpson, 2013). However, like eye movements these inputs to the cueing mechanism may be defined by their physical description rather than the intentions or meaning behind them.

Familiarity with perceptual cues can also explain the refinement of input to the cueing mechanism. For example, although infants' covert responses to gaze initially rely on mutual eye contact and perceptible motion of the pupils, these cues are no longer necessary for children and adults (Mansfield, Farroni, & Johnson, 2003; Ristic, Friesen, & Kingstone, 2002). This development in the specific inputs that engage the cueing mechanism might be merely revisionary: altering the perceptually grounded inputs that engage it.

Recent research on gaze cueing in adults complicates this picture. There are now numerous demonstrations of top-down influences on gaze cueing, as well as this response's susceptibility to rich, conceptual considerations about the visual perspective of the cueing character. These findings discourage viewing adults' covert attention to gaze as indicating a simple overlearned behavioral response. The first of these findings revealed that how an adult interprets a directional cue – as depicting either eyes on a face or wheels on a car - determines whether she covertly orients in response to this image's movement (Ristic & Kingstone, 2005). In this case, adults selectively orient attention in the direction indicated by the cue when the cue is interpreted as representing eyes. Adults' gaze cueing is also influenced by various physical constraints on the cueing character, such as covering his eyes (Nuku & Bekkering, 2008, 2010), obstructing his line of sight (Kawai, 2011), or placing target objects out of his field of view (Schulz 2014; although see Cole, Smith, & Atkinson, 2015 for contrary evidence). Other researchers have attained top- down modulation of covert orienting to gaze by inducing participants to make abstract mental attributions to the very same cueing character, such as whether they believe the character is a real person, mannequin, a human-operated robot (Wiese, Wykowska, Zwickel, & Müller, 2012), or whether they believe that a gazer is wearing transparent or opaque goggles (Teufel, Alexis, Clayton, & Davis, 2010). Together, these results demonstrate that in adulthood, gaze cueing may be conceptually rich, incorporating representations of either a cueing character's perceptual abilities or her mental capacities. Despite this reappraisal of gaze cueing in adulthood, there are no empirical investigations of when in development covert spatial orienting becomes conceptually informed.

Aims of Current Study

The primary goal of the current study was to investigate whether children's covert orienting to a cueing character might adult-like, incorporating rich conceptual considerations about a cueing character. To this end, we utilized a demonstration of agency that has elicited overt gaze following in infants and mentalistic descriptions of a novel entity's behavior in adults (Beier & Carey, 2014; Johnson, Booth, & O'Hearn, 2001). This demonstration of agency has not previously been employed in tasks measuring covert attention. Our experimental manipulation consisted of influencing whether participants were likely to interpret a cueing character as an agent based on whether or not they saw the character act in a contingent, communicative interaction with an actor.

Additionally, the current investigation will resolve two outstanding questions about the flexibility of the cueing mechanism that arise from recent research with adults. First, enriched forms of gaze cueing may be grounded in familiar perceptual modalities such as vision. Currently, the strongest demonstrations of top-down effects on gaze cueing employ characters with either perceptible (e.g., a humanoid robot, (Wiese et al., 2012)) or strongly implied eyes (e.g., a be-goggled person, (Teufel et al., 2010)). Thus, we do not know whether top-down control of covert attention is specific to circumstances where the participant is considering another's perceptual states and the cueing character's eyes are clearly visible or strongly implied. Second, it is possible that enriched forms of gaze cueing are human-centric. In the report where the cueing stimulus was a humanoid robot (Wiese et al., 2012), participants were only cued by the robot's eye shifts when they were told that a human was operating the robot; hence, their intentional attributions concerned the operator's – and not the robot's – goals. By utilizing a novel and faceless agent whose movement was self-generated, we are able to test the hypothesis that either human-like eyes or human control are necessary for the modulation of "gaze" cueing by intentional attributions.

Justification of Ages Tested

For this initial developmental investigation we employed a sample of both preschool children (between 4- and 6-years-of-age) and adults because there are no studies that explore our specific aims at any age. We investigated preschool children because this age group is the youngest to respond in adult-like ways across a variety of covert attention tasks. First, children between 3- and 5-years demonstrate adult-like gaze cueing in the absence of the observable motion of the pupils (Ristic et al., 2002). Second, although four-year-olds are cued by both an upright and inverted presentation of a point-light walker, 5-year-olds and adults are selectively cued by this stimuli's up-right presentation (Zhao et al., 2014). Third, 5-year-old children are the youngest age to be cued by the conventional directionality of arrows (Jakobsen et al., 2013); a response frequently observed in adults (Friesen et al., 2004; Frischen, Bayliss, & Tipper, 2007; Langdon & Smith, 2005; Tipples 2002, 2008). Despite adult-like sophistication in the inputs to the cueing mechanism, children's responses in these contexts do not address the specific aims of the current study. They do not tell us whether children will also respond in adult-like ways after attributing intentional agency to a cueing character, nor whether representing the implied attentional direction of a non-human and novel agent without eyes will lead to cueing in either age group.

Chapter 2: Methods

Participants

Seventy-one adults and eighty-four 4- to 6-year-old children participated in the study. Adults participated for course credit, while children were recruited from a database of area families who had previously expressed interest in research participation at the University of Maryland. The final sample consisted of 59 adults (Mean Age: 20.66 years, SD = 4.09 years, range: 18.0 – 51.42[1] years; 44 female) and 53 children (Mean Age: 60.04 months, SD = 7.65 months, range: 49 – 72 months; 26 female). Ethnicity information was self-reported by adults (61% Caucasian and Non-Hispanic) and parent-reported for children (68% Caucasian and Non-Hispanic). Participants were randomly assigned to either the Socially Contingent (28 adults; 26 children) or Non-Contingent (31 adults; 27 children) condition.

As detailed in the Coding section, we applied strict inclusion criteria to ensure high eye-tracking data quality. Based on these criteria, 12 adults and 27 children were tested but excluded from the final sample. Four additional children were tested but excluded for other reasons: 2 due to experimenter error, and 2 due to parent-reported developmental delays.

[1]. The large range in adult ages was due to the presence of single undergraduate participant. Adults' age (in days) was entered as a covariate in a 2 (Target 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, $F(1, 52) = .18$, p = .67.

Setup and Materials

The experiment was conducted in a minimally furnished room. The participant sat in an age-appropriate chair and viewed the study presentation on a 23” widescreen color monitor (1920 x 1080 resolution) at a distance of 65 cm. Behind the video display, a floor-to-ceiling curtain divided the room in half. The experimenter operated the study from the other side of this curtain. Caretakers did not accompany their children into the testing space but were able to observe the procedure via a live camera feed. Gaze data was collected using a Tobii TX300 remote eye-tracker (300 Hz sampling rate, 0.4° - 0.6° accuracy, and approx. 0.15° precision). The animated stimulus materials were generated in Blender Version 2.67.0 and presented using Tobii Studio Version 3.2.

Design

Participants viewed an initial familiarization video and up to 64 cueing trials. The trials were presented in 8 blocks of 8 trials each. Each block following the first was preceded by a short re-familiarization video. The familiarization and re-familiarization videos varied between conditions, but cueing trials were identical.

Each participant viewed one of four pseudo-random sequences of cueing trials. Trial congruency, the side of the target object’s appearance, 2 beep durations (described in Cueing Trials), and the identity of the target object were completely counterbalanced. No more than 2 turns in a given direction, congruent or incongruent trials, or 2 identical target objects were shown in a row.

Calibration and Task Instructions

The experimenter calibrated the participant using Tobii Studio's 9-point Manual calibration procedure. The experimenter then informed participants that they would view a series of recurring videos in which a "thing" at the center of the screen would turn to either the left or to the right. After the thing turned to the left or to the right, a colorful object would appear on either the left or right side of the screen. Participants were instructed to watch the thing turn and to look at the colorful object whenever it appeared.

The experimenter took great care to avoid using language that might influence how participants viewed the entity. The term "thing" was used to refer to the entity because it is ambiguous with respect to agentive status; similarly, "turn" can describe both an agentive and inanimate motion.

The experimenter also emphasized to participants that the entity's turn was non-predictive with respect to the target's subsequent appearance. Using a finger to point to each location on the video screen, the experimenter explained that sometimes the entity would turn toward the right and the colorful object would appear on the right, that sometimes the entity would turn to the right and the colorful object would appear on the left, and so on for leftward turns. The experimenter explained that this set of possible outcomes meant that the direction in which the entity turned was not informative about the eventual location at which the colorful object would appear, and then re-iterated that the side at which the colorful object appeared was entirely random. This detailed description of the video sequences, as well as the term "random", ensured that the non-predictive nature of the sequence was clear to participants – particularly to children. All participants verbally acknowledged that they understood this task feature before the study began.

Procedure

Familiarization Videos

The initial familiarization videos were 56s in duration and featured a novel animated entity and a human actor. These two characters were presented in an arrangement suggesting that they occupied the same physical space (Figure 1). The faceless entity bore no resemblance to any known creature. Between blocks, participants viewed approximately 20s segments of the original familiarization film.

In the Socially Contingent familiarization video, the entity and the actor appeared to have a turn-taking conversation. At the start of the video, the entity emitted two short beeps while its protuberance flashed simultaneously. Seeming to hear these beeps, the actor smiled and turned toward the entity saying, "Oh hello there, long time no see!" The entity responded with a new series of beeps and flashes, and the conversation continued for the duration of the video. Both the actor's and the entity's lines had variable durations, mimicking the natural flow of conversation.

In the Non-Contingent familiarization video, the entity's behavior was exactly the same as in the Socially Contingent condition. However, the entity's beeps and blinks did not establish a contingent, turn-taking conversation with the actor. The actor's image in this film was a video recording in which she faced forward, held a neutral expression, blinked naturally, and made subtle postural adjustments, but never turned toward the entity or spoke.

Cueing Trials

Each cueing trial began with the appearance of an attention-grabbing event: the future target object for that trial appeared at the center of the screen, accompanied by a playful noise. Target objects were a sphere, cube, cylinder, or an icosphere (each subtending approximately 4.65° x 4.65° of visual angle). The target object remained onscreen until participants fixated it for approximately 1s or until 10s elapsed.

Next, the novel entity appeared at the center of the screen, motionless and facing forward toward the participant (subtending approx. 4.02° x 7.35°). After 1000ms, the entity beeped and flashed its protuberance. This beeping and flashing lasted 1000ms for half of the gaze-cueing trials, and 2000ms for the other half. The entity then rotated 60° over a 250 ms interval so that its protuberance was aimed at either the right or left side of the display. After another 1000ms, the entity disappeared as the target object appeared at a peripheral location that was either congruent or incongruent with the direction of the entity's turn (target objects appeared at approx. 9.0° of visual angle to either side of the entity). The trial ended after the participant fixated the target object for approximately 1s or until 5s elapsed.

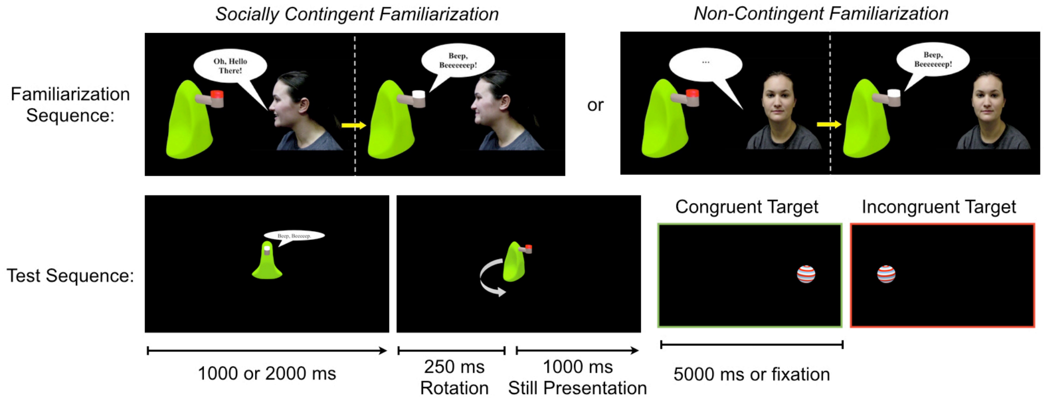

Figure 1 – Schematic depiction of events during familiarization and cueing trials.

Coding and Data Reduction

Trained coders evaluated eye-tracking data quality and whether participants remained on task by viewing an animated gaze plot overlain upon the stimulus video presentation. For each trial, two coders independently determined whether the participant **a)** watched the screen for the duration of the trial, **b)** attended to the entity as it turned, **c)** fixated on the entity from its turn until the target's appearance, and **d)** made a smooth, uninterrupted saccade to the target when it appeared. A trial's data was excluded from the final analyses if the participant did not meet all of these criteria (i.e., Watching Criteria). A trial's data was also excluded if the overlain gaze plot was deemed insufficient (i.e., Tracking Criteria) by the coder to make a judgment about the Watching criteria (see Table 1 for mean number of accepted trials for each age and condition). Initial coder agreement for acceptable trials was "good" (average Cohen's Kappa = .71; Adults = .62, Children = .79). Disagreements on trials were resolved by discussion, sometimes including the first author as blind arbiter. By these means, coders reached 100% agreement on the acceptability of all trials.

These coding criteria ensured that our final data reflected only covert shifts of attention prior to the target appearance. Following standard practice for eye-tracking measurements of spatial cueing, we also excluded trials whose stimulus response time (SRT; latency to fixate the target after its appearance) was less than 100ms or greater than 2 standard deviations above a participant's mean SRT for otherwise acceptable trials. These criteria further ensured that the final data did not include trials in which participants made anticipatory saccades or delayed shifts of attention.

Data from an adult participant was included in the final analysis if at least 75% of possible trials were acceptable on the Tracking dimension (6 adults excluded: Contingent condition = 4, Non-Contingent condition = 2) and 50% of possible trials were acceptable based on Watching Criteria (7 adults excluded: Contingent condition = 4, Non-Contingent condition = 3). A child's data was included in the final analyses if she provided at least eight (4 congruent and 4 incongruent) trials after coding (27 children excluded: Contingent condition = 16, Non-Contingent condition = 11).

Chapter 3: Results

Preliminary Analyses

Preliminary analyses examined whether participants varied across conditions in their attention during the initial familiarization sequences. Between conditions, children watched the initial familiarization sequences for similar durations, $t(51) < 1$. However, adults in the Non-Contingent condition watched the familiarization video slightly more than those in the Socially Contingent condition, 55.0 vs. 47.6 seconds, $t(57) = 3.07$, $p = .01$.

Additionally, a 2 (Target Congruency) x 2 (Condition) x 2 (Sex) x 2 (Age Group) x 4 (Randomization) repeated-measures ANOVA revealed no effects of Sex or Randomization on SRTs, nor interactions involving either of these factors and Congruency. These factors were not included in subsequent analyses.

Main Analyses

A 2 (Condition) x 2 (Target Congruency) 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. This analysis revealed main effects of Target Congruency, $F(1, 108) = 6.30$, $p = .01$, $\eta^2 = .06$, and Age, $F(1,108) = 35.42$, $p < .001$, $\eta^2 = .25$, and a Condition x Age interaction, $F(1, 108) = 6.77$, $p = .01$, $\eta^2 = .06$. Critically, there was also an interaction between Target Congruency and Condition, $F(1, 108) = 8.19$, $p = .01$, $\eta^2 = .07$. Viewing the novel entity as an agent led to a greater cueing effect. This interaction did not vary by age group: Target Congruency x Condition x Age, $F(1,108) = 1.26$, $p = .27$, $\eta^2 = .01$.

Next, we assessed the influence of the agency manipulation on the cueing effect within each age group. At each age, we conducted a 2 (Condition) x 2 (Target Congruency) repeated-measures ANOVA, as well as planned comparisons within each condition. A cueing effect was defined as a within-subject difference score (Mean Incongruent SRT – Mean Congruent SRT) and compared against a difference score of 0 ms. Given the directional definition of the cueing effect and our clear hypothesis with respect to the agency manipulation, one-tailed tests were used for planned comparison t-tests and non-parametric tests.

Children

For children, there was an effect of Condition, $F(1, 51) = 4.02$, $p = .05$, $\eta^2 = .07$, and a marginally significant effect of Target Congruency $F(1, 51) = 3.82$, $p = .06$, $\eta^2 = .07$. The critical Target Congruency x Condition interaction was significant, $F(1, 51) = 5.29$, $p = .03$, $\eta^2 = .09$. In the Socially Contingent condition, the mean cueing effect was 34 ms (SD = 73 ms), $t(25) = 2.45$, $p = .01$. In the Non-Contingent condition, the mean cueing effect was -3 ms *(SD = 44 ms)*, $t(26) = .34$, $p = .74$. The difference between conditions was significant, $t(51) = 2.30$, $p = .013$, 1-tailed.

Non-parametric tests corroborated these results. The tendency for children to exhibit a cueing effect depended on condition membership, Fisher's exact test, p = .017, 1-tailed. Nineteen of 26 participants in the Socially Contingent condition and 11 of 27 participants in the Non-Contingent condition showed a cueing effect, binomial tests: p = .02 and .22, respectively, 1-tailed.

Finally, because the ages of child participants ranged across a 2-year window, we explored the influence of age in days on the Target Congruency x Condition interaction that we observed in this age group. Participant age (in days) was entered as a covariate in a 2 (Target 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, $F(1, 49) < 1$.

Adults

For adults, the ANOVA did not show any significant effects: Condition, $F(1,57) = 2.83$, p = .10, $\eta^2 = .05$, Target Congruency $F(1, 57) = 2.28$, p = .14, $\eta^2 = .04$, and Target Congruency x Condition, $F(1, 57) = 2.58$, p = .11, $\eta^2 = .04$. However, planned analyses of both conditions and their interaction revealed the same pattern of results obtained in children. The cueing effect score in the Socially Contingent condition was significant, 16 ms (SD = 33 ms), $t(27) = 2.56$, p = .01. In contrast, the cueing effect score in the Non-Contingent condition was 0 ms *(SD = 44 ms)*, $t(30) = .06$, p = .95. Comparison of the cueing effect scores of each condition approached significance, $t(57) = 1.61$, $p = .06$.

Non-parametric tests also suggested that the tendency for adults to exhibit a cueing effect depended on condition membership, Fisher's exact test, p = .09, 1-

tailed. Twenty-one of 28 participants in the Socially Contingent condition and 17 of 31 participants in the Non-Contingent condition showed a cueing effect, binomial tests: p = .007 and .36 respectively, 1-tailed.

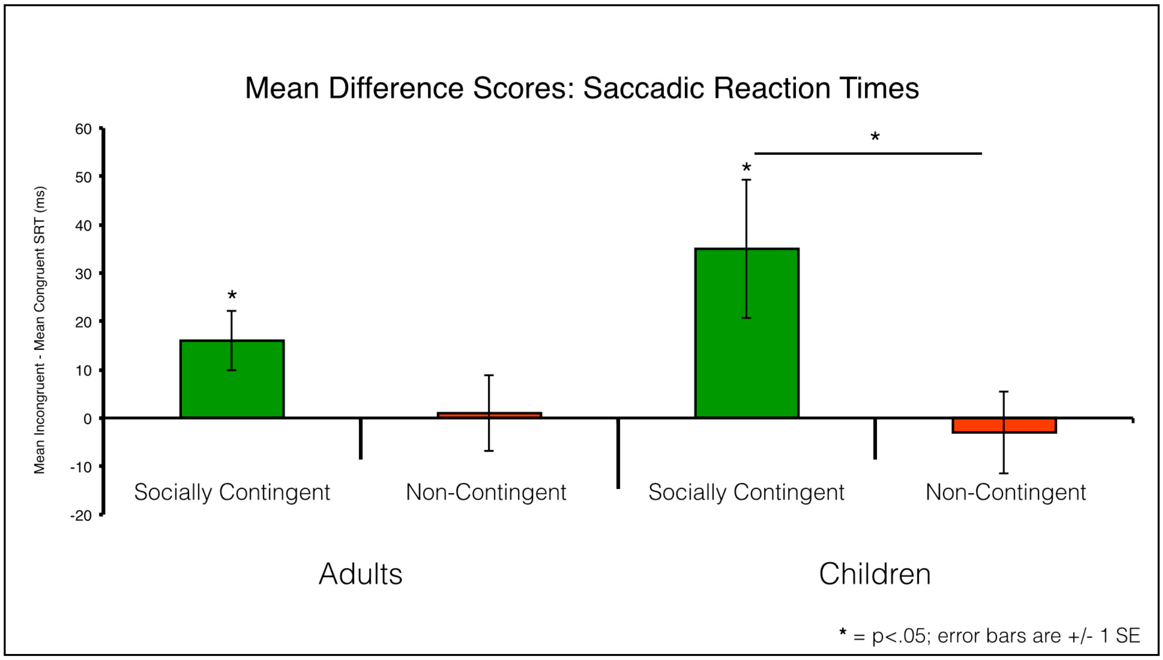

Figure 2 – Mean difference scores of saccadic reaction times to targets on incongruent and congruent trials.

		Mean # Trials (*SD*)		Mean SRT (*SD*)		Cueing Effect (*SD*)
	Condition	**Congruent**	**Incongruent**	**Congruent Mean SRT**	**Incongruent Mean SRT**	**Mean Difference**
Adults	**Socially Contingent**	22.82 (*4.35*)	22.50 (*5.27*)	289 (*47*) ms	305 (*51*) ms	16 (*33*) ms
	Non-Contingent	22.19 (*4.34*)	21.71 (*4.05*)	321 (*71*) ms	321 (*58*) ms	0 (*44*) ms
Children	**Socially Contingent**	13.12 (*5.45*)	12.81 (*5.24*)	426 (*118*) ms	460 (*143*) ms	35 (*73*) ms
	Non-Contingent	12.63 (*6.25*)	12.96 (*5.75*)	380 (*110*) ms	377 (*111*) ms	neg. 3 (*44ms*)

Table 1 – Summary of trial data

Chapter 4: Discussion

The current study demonstrates, for the first time, that the turning behavior of a novel, faceless agent directs covert spatial attention in both children and adults. Specifically, we observed that participants in both age groups showed an overall tendency to more rapidly fixate peripheral targets when they appeared at locations that were congruent, as opposed to incongruent, with the novel agent's turns. Participants showed this effect despite their unfamiliarity with the entity, never seeing the entity's front end provide meaningful directional information during familiarization, and being explicitly told that its turns were not predictive of the target's eventual location. This cueing effect was not present in either age group when the cueing character was unlikely to be interpreted as an agent. Thus, by the time that children enter preschool, an abstract, human independent notion of intentional agency may selectively direct covert attentional orienting.

The current study further elucidates the nature of covert attentional orienting in children and the early influence that social attributions (i.e., inferred agency) play in engaging this response. The current study is not the first to use a "novel" cueing stimulus to influence covert attention in preschool-age children. Children as young as 3 years-of-age are able to volitionally orient attention in the direction "indicated" by a non-directional shape (i.e., a circle) when they are told that the shape is predictive (with 80% certainty) of the eventual location of the target (Ristic & Kingstone, 2009). Children did not spontaneously show this attentional response when the shape was not predictive of the target location. This finding suggests that while young children are able to flexibly ascribe directionality to a cueing stimulus, this ability may depend on both explicit instruction as well as the additional expectation that the cue is predictive of the target location. The current study demonstrates for the first time that when a novel cueing character is interpreted as an agent, this character engages covert attention spontaneously (i.e., participants were not instructed about the entity's directionality) and that this attentional response is reflexive (i.e., participant's were told the "thing's" turns did not predict the target location). Although children between 3 and 5 years begin to show reflexive attentional orienting in response to non-predictive arrows (Ristic & Kingstone, 2009), studies designed to assess age-related changes in this ability detect this effect most robustly by 5 years (Jakobsen et al., 2013). In the current study, we found no age-related differences between 4- and 5-year-olds' reflexive attentional response to the novel agent. This finding invites speculating that spontaneous and reflexive attentional responses to inferred agency precede similar attentional responses to conventional symbols. Future versions of the current study ought to be employed in younger populations to determine when in development inferred agency engages this reflexive attentional response.

The pattern of cueing effects that we observed are not due to either the entity's rotational motion or participants' heightened attention towards the cueing character. There was no rotational motion of the entity during familiarization sequences and the entity's rotational motion during cueing trials was held constant across conditions. Children did not show any difference between conditions in the extent to which they watched the screen during the initial familiarization film. Although adults differed slightly in this respect (see Results), this difference was in the *opposite* direction of what would be expected if increased attention to these events were responsible for our results. Second, if there were differences in participants' attention to the entity during cueing trials our coding scheme would have uncovered these differences. Coders identified an almost identical number of acceptable trials between conditions in each age group (see Table 1).

Rather, the pattern of effects that we observed between conditions was due to our demonstration of agency during familiarization. The demonstration of agency that we utilized is drawn from previous research demonstrating goal-attribution (Johnson et al., 2001; Shimizu & Johnson, 2004) and overt gaze following (Beier & Carey, 2014; Johnson et al., 1998; Movellan & Watson, 1987) of novel agents in infants, as well as mentalistic descriptions of novel agents in adults (Beier & Carey, 2014). Thus, the current study extends these findings and demonstrates that the same demonstration of agency that elicits these behaviors and attributions across the lifespan also engage covert spatial attention by early childhood.

The current study helps clarify how the cueing mechanism might develop. Recent work has demonstrated the top-down control of covert attention by agentive attributions in adulthood (Ristic & Kingstone, 2005; Teufel et al., 2010; Wiese et al., 2012). However, previous research on covert attention in both infants and children does not require that participants represent the agency of a cueing character for their interpretation (Daum & Gredebäck, 2011; Farroni et al., 2000;

Farroni et al., 2003; Hood et al., 1998; Rohlfing et al., 2012; Wronski & Daum, 2014). The current finding narrows the gap between these infant and adult literatures, and suggests that by 4 years-of-age the cueing mechanism incorporates abstract representations that include intentional agency. This finding invites renewed attention to the relevant inputs to covert spatial attention in infancy.

Although the cueing mechanism may not initially require representing the intentionality of a cueing character for its operation, infants might nevertheless show differential covert responses to a cueing character's agency if such agency were appropriately demonstrated. For example, a recent set of studies demonstrate that covert attention is recruited by the presentation of either a static or dynamic grasping gesture in early infancy, but that this attentional response does not extend to identical presentations of either an unfamiliar mechanical claw or skin-colored object (Daum & Gredebäck, 2011; Wronski & Daum, 2014). These findings eloquently mirror expectations in looking-time studies in which infants reliably encode the behaviors of a reaching hand (but not a mechanical claw) as being goal-directed (Woodward 1998). However, follow up studies have shown that infants may nevertheless represent an unfamiliar mechanical claw's actions as goal-directed if the claw exhibits self-propelled motion, equifinality in its movements, and produces an action effect on a target object (Biro & Leslie, 2007; Biro, Csibra, & Gergely, 2007). Insofar as this cluster of behaviors are interpreted by the infant as "clues" to the mechanical claw's agency, it is an open question whether a mechanical claw or other unfamiliar object that demonstrated all of these behaviors would engage covert spatial attention. The potential efficacy of such a manipulation on covert attention in infancy is bolstered by confirmation in the current study that a cueing character need not possess familiar morphological features or be operated by a human to engage the cueing mechanism if it the cueing character is interpreted as an agent.

A second aim of the current study was to assess whether the cueing mechanism of adults and young children could be engaged by a character that did not have eyes, whose movements were self-generated, and whose operation was not explicitly under human control. The current findings confirm that such a character is sufficient to engage covert spatial attention, but only after being interpreted as an agent. Because the cueing character in our study did not have eyes or other familiar perceptual organs, there are open questions about how participants actually interpreted the entity's rotational motion during cueing trials. Specifically, it is not clear to what extent participants viewed the turning behavior of the cueing character as either alterations in the entity's implied direction of attention or the initiation of a goal-directed action.

If participants interpreted the novel agent's turns as shifts in attentional direction, then the congruency effect should not occur in versions of this study that interpose either a proximal or distal visual occluder between the agent and the target object. Such manipulations negatively influence adult's covert responses to gaze (Kawai, 2011; Nuku & Bekkering, 2008; Teufel et al., 2010; although see Cole, Smith, & Atkinson, 2015 for counter-evidence) as well as overt gaze following in infancy and early childhood (Brooks & Meltzoff, 2002, 2005; Caron, Butler, & Brooks, 2002; Meltzoff & Brooks, 2008). However, distal occluders that block an agent's visual access to an object may also be interpreted as restricting an agent's movements. Future versions of the current study that contain familiarization videos in which a novel entity either does or does not act in a goal-directed manner would better elucidate whether observing the goal-directed behaviors of a novel entity elicits the same orienting responses that occur while observing the intentional actions of human agents.

Conclusion

For the first time we have shown that reflexive, covert spatial attentional is driven by an abstract and human-independent notion of intentional agency by childhood. In this discussion we have tried to highlight both the theoretical importance of this finding as it relates to the development of covert attention, as well as participants' interpretation of novel entity's behaviors more generally. The same ambiguity surrounding participants' interpretation of the turning behavior of our cueing character is applicable to other studies that have employed novel entities. However, we hope to have proposed generative future directions that other researchers will employ to disambiguate these interpretations, as well as elucidate the nature of agency attributions and the development of covert attentional orienting more generally.

Appendix A

Institutional Review Board Approval – Children

DATE: January 9, 2014

TO: Jonathan Beier, PhD
FROM: University of Maryland College Park (UMCP) IRB

PROJECT TITLE: [410239-4] Cognitive and social processes in children: Representation and evaluation of items, individuals, and events

REFERENCE #:

SUBMISSION TYPE: Continuing Review/Progress Report

ACTION: APPROVED
APPROVAL DATE: January 9, 2014
EXPIRATION DATE: January 12, 2015
REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review category #*6 & 7*

Thank you for your submission of Continuing Review/Progress Report materials for this project. The University of Maryland College Park (UMCP) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate revision forms for this procedure which are found on the IRBNet Forms and Templates Page.

All UNANTICIPATED PROBLEMS involving risks to subjects or others (UPIRSOs) and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

This project has been determined to be a Minimal Risk project. Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of January 12, 2015.
Please note that all research records must be retained for a minimum of three years after the completion of the project.

<u>Institutional Review Board Approval - Adults</u>

DATE: July 25, 2014

TO: Jonathan Beier, Ph.D.
FROM: University of Maryland College Park (UMCP) IRB

PROJECT TITLE: [357272-5] Cognitive and social processes in adults: Representation and evaluation of items, individuals, and events

REFERENCE #:
SUBMISSION TYPE: Continuing Review/Progress Report

ACTION: APPROVED
APPROVAL DATE: July 25, 2014
EXPIRATION DATE: August 25, 2015
REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review categories # 6 and 7

Thank you for your submission of Continuing Review/Progress Report materials for this project. The
University of Maryland College Park (UMCP) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant.

Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate revision forms for this procedure which are found on the IRBNet Forms and Templates Page.

All UNANTICIPATED PROBLEMS involving risks to subjects or others (UPIRSOs) and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

This project has been determined to be a Minimal Risk project. Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of August 25, 2015.
Please note that all research records must be retained for a minimum of three years after the completion of the project.

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