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When do arrows start to compete? A developmental mouse-tracking study

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ABSTRACT

Recent work in adults has suggested that the strength of social and symbolic cues not presented at fixation (but allowing eye movements to the cue) may be determined less by their biological relevance and more by the distinctiveness of the shape of the cue. The present study examines whether these results extend to children, who may differ in their relative exposure to symbolic cues (arrows) compared to social cues. Children aged 3 to 11 were presented with congruent or incongruent pairs of cues (line drawings of gazing eyes, pointing hands, and arrows) and were asked to indicate the direction of the target cue (indicated at the start of the block) by moving the mouse towards the response box indicating its direction. Results show a similar advantage for arrows and pointing hands in young children as previously found in adults, suggesting that cue shape trumps biological relevance for cues away from fixation from an early age.

1. Introduction

The development of responses to social cues (such as eye gaze and pointing gestures) has been studied extensively (for an overview, see Frischen, Bayliss, & Tipper, 2007). For example, it has been shown that 3 months old children follow head gaze shifts (D'Entremont, Hains, & Muir, 1997) and eye gaze cues (Hood, Willen, & Driver, 1998). Joint attention, where children show evidence of understanding another person's attention, is thought to develop from around 12 months of age (Butterworth & Jarrett, 1991). Such gaze cueing effects are a marker of the understanding of others' beliefs and thoughts, known as theory of mind, which has been suggested to develop later at around four years of age (Baron-Cohen, 1995). The influence of cues provided by others has received much attention, because it may provide a distinction between learned (symbolic cues) and hard-wired (social cues) cueing effects (Baron-Cohen, 1995), and reduced responses to social cues are considered to be a marker of autism spectrum disorders (Hoehl et al., 2009).

Studies of the effects of social cues, however, have often been restricted to cues presented where the observer is already looking (e.g,. by replacing a fixation dot by the face stimulus or by presenting the face stimulus in the middle of the screen, Driver et al., 1999; Kuhn & Kingstone, 2009). In day-to-day viewing, such immediate fixations of social cues do not always occur, and instead observers first look somewhere else, after which they make an eye movement to the cue. In a recent study, we have shown that in such a situation, adults show a reduced effect of gaze cues compared to arrow cues or pointing hands (Hermens, Bindemann, & Burton, 2017). In the experiments, participants were presented with two cues, placed above and below fixation (similar to Fig. 1b). Before the start of the block, participants received an instruction indicating which cue they had to respond to (e.g., 'In this block, always respond to the direction of the arrow cue'), but participants did not know where this target cue was going to appear (above or below fixation). Eye tracking during the task suggested that participants therefore adopted a strategy in which they first waited until the cues appeared, and then made an eye movement to the target. In these experiments, faster response times were found to arrow cues, pointing hands and rotated heads, and slower response times to gaze cues embedded within a face, gazing eyes in isolation, and words indicating a direction (e.g., 'LEFT'). The experiments also examined whether the other cues in each pair interfered with responses (when the non-target cue was pointing in the opposite direction). Such interference effects were weak when response times were considered. However, when participants responded by moving a mouse cursor to a target box (i.e., they engaged in a mouse tracking paradigm, Freeman & Ambady, 2010), mouse trajectories deviated strongly in the direction of incongruent arrow, pointing hand, and rotated head cues, while no such effects on mouse trajectories were found from gazing eyes (embedded in a face, or in isolation) or direction words. Together these findings suggest that cues with a clearly visible directional shape that can be seen away from fixation (e.g., arrows, pointing hands) exert the strongest influences on participants' responses. These shape influences appear to be independent of the social or biological relevance of the cues, and occur even when participants can make an eye movement to the cue (Hermens et al., 2017). Distraction effects of simultaneously presented cues occur, but may only be revealed by mouse trajectories.

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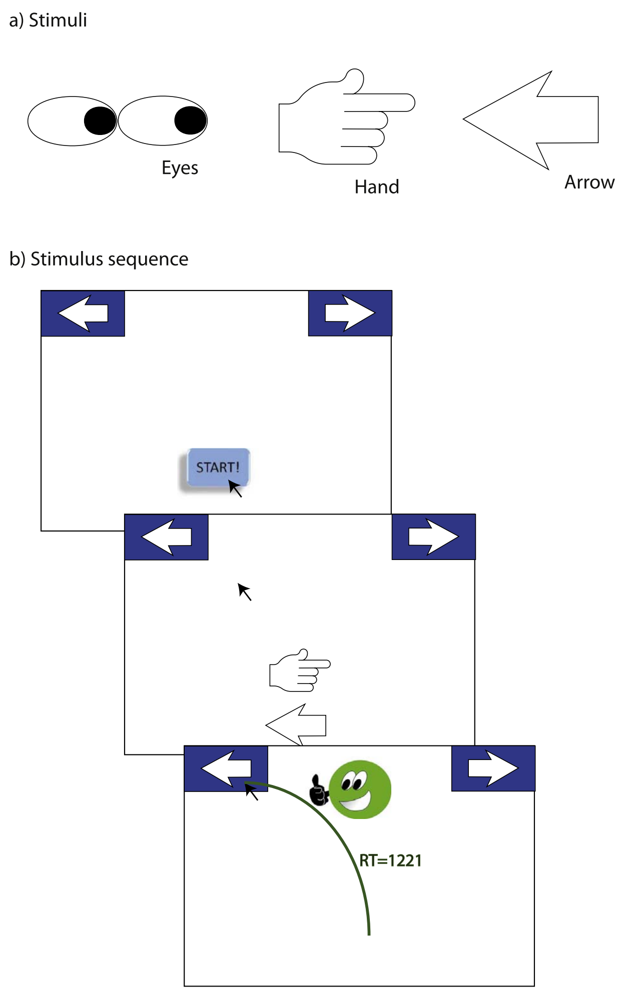

Fig. 1. a) The stimuli in the experiment. On each trial, the target (one of the three stimuli, defined at the start of the block) was shown together with a distractor (one of the remaining stimuli). b) Stimulus sequence. Participants started with a screen showing a start button in the bottom of the screen and two response buttons in the top of the screen with the target for that block. After clicking with the mouse on the start button, two stimuli were presented above and below where the start button was shown (which was removed from the screen immediately after the mouse click). One of these stimuli was the target shown in the two response boxes at the top of the screen (an arrow in this case). Participants were instructed to indicate the direction of the target by moving the mouse cursor to the corresponding box in the top of the screen and clicking the mouse button. A feedback screen showed the mouse trajectory, the response time, and a smiley face. Green colors were used when the response was correct, whereas feedback was shown in red for an incorrect response. For incorrect responses, the smiley face looked unhappy and was pointing its thumb downwards. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The results by Hermens et al. (2017) agree with the findings of other studies that have looked at the effects of social and symbolic cues presented away from fixation. For example, Burton, Bindemann, Langton, Schweinberger, and Jenkins (2009) used a paradigm in which one cue was presented at fixation (the cue that had to be responded to) and another cue away from fixation. They found that rotated heads and pointing hands interfered with responses to gazing eyes, but that gazing eyes did not interfere with responses to pointing hands and rotated heads. In their study, the cues were presented for a short amount of time, so that participants could not make an eye movement, but the experiments by Hermens et al. (2017) with the same cues suggest that Burton et al. (2009) would have found the same results if they had left the stimuli on the screen and allowed participants to make an eye movement to the distractor stimulus. Similar results were found by Langton (2000), who found for competing cues provided by a single actor (e.g., looking up while pointing down) head-gaze cues and arrows both influenced responses to pointing gestures. Interestingly, Nummenmaa and Hietanen (2009) found similarly strong cueing effects from gazing eyes and arrows, but they also reported that the strength of cueing appeared to be linked to the exact stimulus used.

All these studies have considered adults, who have strong exposure to arrows in day to day life and may therefore be primed to respond to these cues by associating them with a direction. In children, exposure to arrow cues may be reduced compared to adults. While there does not seem to be documented evidence that children encounter and look at arrows less often than gaze shifts and pointing gestures, there are indicators that arrows may be weaker cues in children than in adults, and that gaze cues provide strong cueing in children. For example, Senju, Tojo, Dairoku, and Hasegawa (2004) found that while children (average age = 11.1 years) were sensitive to unpredictive distractor arrows (with 50% cue validity), no evidence of cueing was found when the arrows were counterpredictive (20% cue validity). Gaze cues did influence children's responses under both conditions. In adults, counterpredictive cues have been found to yield equally strong cueing as gaze cues (Tipples, 2008). Likewise, Jakobsen, Frick, and Simpson (2013) found that infants (9 months old) and young children (3–4 years old) were driven by the perceptual weight distribution of the central cue (with square endings having similar cueing effects as arrowheads), while older children (5–6 years) old and adults (19 years old) were driven by the shape of the cues. This suggests that for younger children, cues that are unbalanced should yield strong cueing, independently of the shape of the cue. Not all studies, however, have found stronger responses to gaze cues than to arrows in children. For example, Kuhn et al. (2010) found similar cueing effects of arrows in adults and older children (10 years old) in an oculomotor task, and Barnes, Kaplan, and Vaidya (2007) found interference from arrows in both younger (6–9 years old) and older children (10–13 years) when responding to centrally presented direction words (LEFT/RIGHT). Likewise, Ristic, Friesen, and Kingstone (2002) found cueing by arrows in young children (3–5 years old) when responding to the appearance of a peripherally presented target. All these studies have found that gaze cues are at least as strong as arrows, but also have in common that the cues were presented at fixation.

The present study investigates whether the results in adults (Hermens et al., 2017), where arrow cues and pointing hands had stronger influences than gazing eyes when not presented at fixation, extend to children, who can be assumed to have weaker exposure to arrows. Children (3 to 11 years) performed a mouse tracking task (Freeman & Ambady, 2010), in which they responded to a target cue, presented simultaneously with a distractor cue (Fig. 1). Mouse tracking was used, because it was shown previously that mouse trajectories reveal influences of simultaneously presented distractor cues that may not be detected with response times (Hermens et al., 2017). Three cues were compared: eye gaze, pointing hands (both biologically relevant) and arrows (a symbolic cue). If the results in children mimic the results in adults (Hermens et al., 2017), stronger influences (as targets on response times, as distractors on mouse trajectories) are expected for hand and arrow cues. If exposure to a cue is the main driver of the strength of a cue, it can be expected that younger children (aged 3–5 years) show stronger cueing to social (eye gaze and pointing hands) than to symbolic cues (arrows). With increasing age, exposure to arrows can be expected to increase, and the difference in cueing effects between social and symbolic cues is expected to decrease if exposure is driving the cueing effects. The exact shape of the function linking age to cueing effects for the different types of cues is difficult to predict, because the exact exposure to the different types of cues is unknown, and it is unclear how much exposure is needed to achieve optimal cueing, and whether stronger exposure automatically leads to stronger attention (cues that are encountered less may draw more attention, simply because of novelty of the stimulus).