THE DEVELOPMENT OF ATTENTIONAL ORIENTING TO NON-SOCIAL DIRECTIONAL CUES

by

KRISZTINA VARGA

(Under the Direction of Janet E. Frick)

ABSTRACT

The current paper examines the development of children's understanding of arrows. Infants (8-10 months), children (3-7 years) and adults were tested in a spatial cueing paradigm in which arrows were used as a litmus test for understanding the shift from perceptual to conceptual understanding. In this respect, it investigates what property or properties of an arrow cue attention in the first years of life. The present study reveals that individuals who do not yet understand the directional meaning of an arrow may be cued by its perceptual characteristics, but once an individual understands the directional meaning of an arrow, this conceptual understanding prevails over the perceptual characteristics. A framework is suggested which may help to explain the developmental shift that occurs from using the perceptual characteristics of a stimulus to orienting attention using its conceptual meaning.

INDEX WORDS: Childhood; Directional Cues; Perceptual; Conceptual; Orienting

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KRISZTINA VARGA

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KRISZTINA VARGA

Major Professor: Janet E. Frick

Committee: Patricia Miller
Richard Marsh

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
August 2009

DEDICATION

I dedicate this work to my family, without whose support I would not be where I am today.

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I would like to thank my committee for their support throughout this process. I would also like to thank Liz Simpson for her helpful comments on previous drafts, as well as the many undergraduate research assistants in the University of Georgia Infant Research Lab who helped with recruitment, testing, and coding for this project.

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CHAPTER 1: INTRODUCTION

The development of visual attention has been the focus of many studies in the last 40 years. Visual attention is an important area of study because it is an early foundation for later cognitive development. One aspect of attentional development is the ability to orient attention to a particular location in response to a *meaningful* cue, rather than attention being captured automatically. Understanding the emergence of orienting is valuable because the ability to orient and to shift attention has been implicated as an important factor for early cognition in both typically and atypically developing children (e.g., children with autism, dyslexia, and attention deficit hyperactivity disorder (ADHD); Chawarska, Klin, & Volkmar, 2003; Facoetti, Turatto, Lorusso, & Mascetti, 2001; Renner, Klinger, & Klinger, 2006; Senju, Tojo, Dairoku, & Hasegawa, 2004). Orienting behavior has been studied in infants and children using both social cues (e.g., eye gaze and pointing) and non-social cues (e.g., arrows).

Studies that use arrow cues with both children and adults have found that children as young as four years of age respond faster to a target that is cued by a valid arrow (i.e., the direction of the arrow and the location of target are congruent) than to a target that is cued by an invalid arrow (i.e., the direction of the arrow and the location of target are incongruent; Ristic, Friesen, & Kingstone, 2002). However, there has been little in the way of a theoretical framework to explain how children begin to understand arrows. The present study uses arrow cues to examine the development of orienting to non-social directional cues in infants (8-10 months), children (3-7 years), and adults (18-24 years).

First, research on orienting to socially relevant cues such as eye gaze and pointing will be examined. Second, research examining children's orienting to arrows will be presented. Third, a method will be proposed to determine whether infants, children, and adults use the directional meaning or the perceptual characteristics of an arrow cue to orient their attention. And finally, a framework will be outlined which may help explain how children learn about the conceptual meaning of arrows.

Social Directional Cues

Eye gaze and finger pointing are relevant and important cues for social communication in our everyday lives. Studies of eye gaze which use a variation of the Posner spatial cueing paradigm (see Posner, 1980) have found that infants as young as 4 months of age orient to a target when it is predicted by an eye gaze cue (Hood, Willen, & Driver, 1998). However, Farroni, Mansfield, Lai, and Johnson (2003) suggest that there must be mutual eye gaze initially in order to observe this type of orienting in young infants. In addition to the mutual eye gaze, young infants must perceive the motion of the pupils in order to orient to the direction of the target (Farroni, Johnson, Bockbank, & Simion, 2000). If the mere movement of the eye gaze cue triggers infants' eye movements, then infants may not necessarily be orienting to the appropriate location because they understand that their partner is looking at something salient; their attention may simply be captured a perceptual property of the stimulus (the movement; Brooks & Meltzoff, 2002).

Butterworth and colleagues (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991) used live models to determine whether infants readily follow the gaze of an adult. They found that infants begin to follow the direction of eye gaze cues by 6 months of age, but they do not accurately localize the target object when multiple objects are presented. By 12 months of age, infants not only can look in the direction of eye gaze, but they can follow eye gaze to direct their attention to the specific target object. Butterworth (1995) argued that by this age infants use a geometric mechanism by which they follow an invisible line between the adult's gaze and the target object in relation to themselves. However, 12-month-olds are just as likely to follow an adult's direction of head movement whether the adult's eyes are occluded by a blindfold or not, suggesting that they are not following the gaze of the adult, but rather the head movement (Brooks & Meltzoff, 2002). By 14 months of age, infants are using eye gaze to direct their attention—as they follow eye gaze only when the eyes are not occluded—rather than just relying on head movement. By 18 months of age, infants are effective at following the gaze of another person even if the person is looking at an object that is outside of the infant's visual field (Butterworth & Jarrett, 1991).

The geometric mechanism that Butterworth (1995) hypothesizes with eye gaze may be applied to finger pointing as well. Infants appear to be able to use finger-pointing cues to orient their attention by the end of the first year of life (Woodward & Guajardo, 2002). As Butterworth suggested with regard to infant's ability to follow eye gaze cues by extending a line from the eye to the target object, infants may also be extending a line from the end of the finger to the target object. Thus, children learn about social directional cues such as eye gaze and pointing during the first and second years of life.

In addition to eye gaze and finger pointing, other types of social directional cues have been used to study children's orienting responses. For example, orienting has been studied using the children's version of the Attentional Network Test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002; Rueda et al., 2004), in which fish facing to the right or left are presented. In this paradigm, children need to have an understanding that the fish is oriented in the direction where the face (particularly the eye) is directed. Another study examining 2- to 4-year-olds' theory of mind used a paradigm in which footprint cues served as directional cues (Chandler, Fritz, & Hala, 1989). The purpose of this study was to determine whether children younger than 4 attempt to deceive an experimenter who is trying to find a hidden toy. Children hid toys under buckets and inadvertently left behind a trail of footprints that led to the bucket in which the toy was hidden. The main question for this study was whether children would try to deceive an experimenter by wiping out the correct footprints, making footprints that led to the wrong location, or both. The results of the study showed that children as young as 2.5 years of age used both strategies to deceive the experimenter. In essence, the results of this study also suggest that children as young as 2.5 years of age have an understanding that footprints can give hints about the location to which attention should be directed. However, footprints have not been used specifically to test the orienting of attention. Body orientation has been recently studied with adults (Lawson, Clifford, & Calder, 2009), but is also a social directional cue that has not been examined with children. While a good framework exists for understanding the development of orienting to social cues, it is not clear how children begin to learn about other types of directional cues, such as arrows. Next, studies of orienting to arrows will be discussed, starting with an examination of their status as a symbol.

Arrow Cues

Definitions of the term symbol vary across research labs. For example, DeLoache (2004) defines a symbol as "something that someone intends to represent something other than itself" (p. 66). In this respect, symbols are representations of object that are specific to and are specified by humans. In addition, Bruner (1964) states that symbols can be arbitrary. Nelson and Shaw (2002) describe a socially shared symbolic system with regard to language development. This socially shared symbolic system is a form of communication – and therefore, social – that has a shared meaning across individuals. Based on Nelson and Shaw's definition, an arrow may not be considered social in and of itself, but it clearly has social relevance, as it serves as a communication tool. An arrow also has shared meaning across individuals and represents directionality regardless of its shape, size, color, etc. (Sabbagh, Moses, & Shiverick, 2006). In other words, people from around the world understand the meaning of an arrow without having any experience with the language and culture of a particular country. Therefore, in the present paper an arrow will be referred to as a symbol, keeping in mind a socially shared symbolic system.

As humans, we use symbols in our everyday lives starting from an early age. Although numerous lines of research have examined the development of symbolic understanding in various domains, we know little about how children begin to understand arrows. Several studies have found that children as young as 4 to 6 years of age respond faster to a target that has been cued previously by an arrow than to an uncued target (Facoetti et al., 2001; McDonald, Bennett, Chambers, & Castiello, 1999; Ristic et al., 2002; Senju et al., 2004; Wainwright & Bryson, 2005). However, based on research thus far, it is difficult to tease apart which properties of an arrow are cueing participants.

A centrally presented arrow cue may result in two types of orienting: orienting due to its symbolic nature or orienting due to its perceptual weight. Some studies with adults (Friesen, Ristic, & Kingstone, 2004; Tipples, 2002) have tried to determine whether perceptual weight (i.e., more stimulus area in the location of the arrowhead) is an influential variable and have found that the directional meaning of the arrow appears to prevail over its perceptual weight for individuals who understand its symbolic meaning. For example, Friesen et al. found no difference in orienting to a single arrowhead (i.e., an arrowhead on one side) which provides a perceptually weighted stimulus or a double arrowhead (i.e., an arrowhead on both sides pointing in the same direction), which provides no perceptual weight. In addition, Tipples found no difference in adults' orienting to arrow cues that had an arrowhead and a tail (←) and those arrowheads that had no tail (<). These results are not surprising because adults understand the symbolic meaning of an arrow, and therefore, are examining the direction in which the arrowhead(s) point(s). However, children who do not yet understand the directional meaning of an arrow may use its perceptual weight to orient their attention. To date, the directional meaning of an arrow has not been put into competition with its perceptual weight, which would help determine which aspect of the arrow cues attention in individuals who do and do not understand its symbolic meaning.

As previously mentioned, young infants may simply be following the eye gaze of adults due to a perceptual characteristic: the *movement* of the pupils (Brooks & Meltzoff, 2002). Similarly, the perceptual weight of the arrowhead may cue infants' attention nonetheless, although the direction of the arrowhead may have no meaning to them. In other words, infants' attention may be drawn toward the more complex location. In support of this view, previous studies have found that as infants age, there is an increase in attentional shifts to more complex stimuli which not only capture attention better than simpler stimuli, but are also more likely to hold infants' attention (Cohen, 1972; Cohen, DeLoache, & Rissman, 1975; Greenberg & O'Donnel, 1972; Haith, 1980; Haith & Campos, 1977). Additional evidence that infants have a preference to look at more complex stimuli comes from studies that use Teller Acuity Cards to measure infant visual acuity (McDonald et al., 1985; Teller, 1979). In this procedure, infants are shown a card which has a plain gray side and a black and white striped side; the black and white stripes become narrower with each trial and eventually appear to be gray. As long as infants can perceive the striped side of the card—which contains a more complex stimulus contour, and therefore, is presumably more interesting than the gray side—their attention is drawn to the striped side of the card instead of the plain gray side (McDonald et al., 1979). Thus, there are numerous lines of evidence that infants' will look more at stimulus areas that contain more perceptual weight. In the present investigation, it is predicted that infants should respond faster to a target that is congruent with the side that contains the weight of the arrowhead than to a target that is incongruent with the side of the weight, regardless of the direction to which an arrowhead is pointing. Understanding the development of these abilities requires an examination of the literature on children's perceptual and conceptual development, which will now be examined.

The Role of Perception in Symbolic Understanding

In the 1960s, several researchers believed that children use perceptual features of stimuli (e.g., similarities or dissimilarities) in order to group them (e.g., Inhelder & Piaget, 1964; Olver & Hornsby, 1966). More specifically, some researchers proposed that children's later cognitive abilities (e.g., conceptual and symbolic understanding) are preceded by more elementary abilities (e.g., using perceptual information to solve a conservation problem or to classify objects; Inhelder & Piaget, 1964; Medin & Ortony, 1989). For example, Piaget believed that during the first 18 months of life, infants have no conceptual thought, but rather rely on sensorimotor (perceptual) information to learn about their world (Piaget, 1952). Piaget did not believe that conceptual representations were possible until after 18 months of age, when children transition into the preoperational stage. As Mandler (1992) states, "these early categories are called perceptual because they need not have conceptual content (or in another terminology, these categories are not yet representational)” (p. 587). However, the idea that children greatly rely on perceptual information was reevaluated, as research showed evidence for some level of conceptual understanding in infancy. For example, it was found that infants are able to represent objects and thoughts through sign language (Bonvillian, Orlansky, & Novack, 1983), and that children use more than just perceptual information to group objects (Wellman & Gelman, 1988). Therefore, evidence indicates that infants are not as dependent on perceptual information as previously thought (Gelman & Baillargeon, 1983; Wellman & Gelman, 1988). Although evidence exists for young children’s use of conceptual representations in some domains (e.g., using sign language), there is room for the use of perceptual explanations in other domains. Munakta (2000) argues that researchers may try to explain their results using perceptual processes, rather than attributing conceptual thought to infants. On the other hand, researchers may conclude that infants are capable of conceptual thought, when in reality their results can be interpreted using more parsimonious explanations. Therefore, it is important for researchers to consider both perceptual and conceptual explanations for their findings.

Inhelder & Piaget (1964) asked “how far purely perceptual relationships can provide a starting-point” (p. 6) for conceptual understanding. Several researchers argue that children may use perceptual properties to form conceptual knowledge (e.g., Mandler, 1988; Mandler, 1992; Springer, 2001). For example, Mandler (1988) states that infants not only have the ability to perceive their environment, but that this perception is intertwined with some level of early symbolic representation, which leads to conceptual thought. The next two sections outline a theoretical framework which presents two possible ways in which perceptual information relates to conceptual understanding: perceptual boundedness and perceptual support (Springer, 2001).

Perceptual boundedness. Perceptual boundedness is defined using surface-level perceptual information which may hinder correct responding. Springer (2001) presents three views which address cognitive limitations with regard to perceptual boundedness. *Structural views* suggest that because children do not have the cognitive structures to be able to use task-relevant information, they rely on perceptual information. For example, Piaget believed that preoperational children perform poorly on conservation tasks because they only attend to the perceptual characteristics presented in the task (Piaget, 1952). In addition, structural views hold that training cannot help children overcome their perceptual boundedness because they do not have the capacity to overcome their cognitive limitation. *Competency views* hold that children—and adults—show perceptual boundedness in areas in which they are not experts. In contrast to structural views, competency views suggest that the limitation can be overcome through training. Finally, *susceptibility views* propose that children perform poorly on tasks not because they lack cognitive ability, but because they are distracted by task-irrelevant perceptual information. Piaget's (1952) conservation task can be used as an example again, in which preoperational children are distracted by the perceptual properties presented in the task. However, Springer (2001) argues that children are not as perceptually bound as previously thought, and that perceptual boundedness is not one deficit, but multiple deficits in structure, competency, or susceptibility.

Perceptual support. Perceptual support is a developmental change in which children initially rely on surface-level perceptual information to guide their responses, which later helps their conceptual understanding (Springer, 2001). The *realist argument* holds that perceptual information is typically correct (i.e., representative of reality), and therefore, it can provide support for the development of conceptual understanding. For example, if an individual is shown a picture of a novel animal, which has a wing-like appendage, the individual may attribute flying to that novel animal based on what s/he knows about animals with wings. The *conflict argument* states that children use perceptual information to guide their behavior when they are presented with problems with which they are not familiar. Finally, the *fluency argument* holds that prior to having a conceptual understanding, children use perceptual information to guide their behavior.

Purpose and Hypotheses

Springer (2001) uses perceptual boundedness and perceptual support to discuss the role of perception in the development of a number of domains, including concept formation, conservation, and language (e.g., Gelman & Baillargeon, 1983; Oakes, Coppage, & Dingel, 1997; Quinn & Eimas, 1996; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). However, the roles of perceptual boundedness and perceptual support have not been used to examine the development of children's understanding of arrows. In the current paper, Springer's framework will be used to speculate about how children learn about arrows. Previous studies which have used arrows as cues have not discussed how children's understanding of arrows develops (Facoetti et al., 2001; McDonald et al., 1999; Ristic et al., 2002; Senju et al., 2004). In addition, previous studies have not systematically evaluated the contribution of weight and directional information, which are inherently confounded in a typical arrow cue. Springer's framework allows for examination of the development of understanding non-social directional cues by providing a means for interpreting how children use arrows to direct their attention.

The purpose of this paper is to examine the development of children's symbolic understanding of arrows. Several stimuli were used which pitted the perceptual weight of an arrow against its directional meaning (explained further below). In this study, 8- to 10-month-olds were tested because they presumably do not understand the directional meaning of an arrow, so if they are cued, they are likely using the perceptual weight of the cue to orient their attention. Three- to five-year-olds were chosen because based on previous research, children of this age should be cued by arrows (Ristic et al., 2002). However, it is not clear which property of the arrow cue young children may use, because a typical (weighted) arrow presents the perceptual weight and the directional meaning on the same side of the cue. By 5 to 7 years of age, it is expected that children understand the directional meaning of arrows, and therefore, arrows should cue them in a similar manner as they cue adults.

CHAPTER 2: METHOD

Participants

Names of infants were obtained from newspaper birth notices and their families were contacted via phone calls. Children were recruited through word-of-mouth and through an already exisiting database. Adults volunteered through the University of Georgia Research Participant (RP) pool. Participants were excluded if they have suffered from serious health problems which would prevent them from being able to participate (i.e., uncorrected vision problems). The final sample was comprised of 57 infants with an average age of 38 weeks (range: 33-47; 37 males), 75 3- to 5-year-olds with an average age of 3.9 years (42 males), 37 5- to 7-year-olds with an average age of 5.9 years (16 males), and 45 young adults with an average age of 19.9 years (24 males; Table 1).

Apparatus

Infants and young children (3- to 5-year-olds) sat in an infant seat or on their parent's lap 60 cm from a presentation screen (43 cm by 58 cm) in an area enclosed by a 2.3 m by 1.3 m black curtain. The stimuli were presented using rear projection on an InFocus projector (model LT755). Each session was recorded using two Panasonic VHS cameras (model AG-188-Proline); one camera recorded the infant and the other recorded the stimulus being presented on the screen. These images were combined using a Videonics Digital Video Mixer (model MX-1). Scoring of the behaviors was done offline using the Noldus Observer 5.0.

For older children (5- to 7-year-olds) and adults, a Dell Precision 380 presented stimuli on a 19 inch (41 cm by 26 cm) colored monitor. Participants sat 60 cm from the monitor.

Participants' responded via button press on a Cedrus RB Series response box (model RB-530). The stimuli were presented to all participants using Inquisit software by Millisecond (Version 2.0.61004.7).

Infants and young children were presented with pictures on a screen in order to record their eye movement responses because they cannot accurately and reliably make button presses to respond to targets. Older children and adults were presented with pictures on a computer screen and asked to make button press responses because the button press response is a more engaging task than making eye movements toward the pictures.

Stimuli

Prior to the beginning of each trial, all participants were presented with a centering stimulus (e.g., a colorful flashing bulls-eye) which was 12º by 12º on the presentation screen and 10º by 10º on the computer monitor. In order to test the hypothesis, ten cues were presented to the participants (see Figure 1). *Weighted* cues provide perceptual weight on one side of a horizontal line. *Balanced* cues provide perceptual weight on both sides of a horizontal line. *Arrow* cues provide directional information, whereas *square* cues do not provide directional information. Participants were presented with one of six cues in the center of the screen (Figure 1): (a) a weighted arrow (typical arrow), in which there is an arrow pointing either to the right or the left; (b) an ambiguous weighted arrow, in which the arrowhead is pointing in one direction but the "weight" of the arrow is on the opposite side; (c) a balanced arrow, in which arrowheads appear on both sides of the line and are pointing in the same direction; (d) an ambiguous balanced arrow, in which two arrowheads are on opposite sides and are pointing in opposite directions; (e) a weighted square, in which a square replaces the arrowhead on only one side; and

(f) a balanced square, in which a squares replace the arrowheads on both sides of the tail. The length of the cues was 10º on the presentation screen and 8º on the computer monitor.

Targets were equally likely to appear on the right or the left of center and remained on the screen until a response was made. On half of the trials, the cues were valid whereas on the other half of the trials the cues were invalid. For arrow cues (weighted and balanced), valid trials were those in which the target was congruent with the direction to which the arrow points, and invalid trials were those in which the target was incongruent with the direction to which the arrow points. For weighted square cues, valid trials were those in which the target was congruent with the location of the perceptual weight, and by contrast, invalid trials were those in which the target was incongruent with the location of the perceptual weight. In the case of ambiguously weighted arrows, the targets were either congruent with the perceptual weight but incongruent with the direction of the arrow, or the targets were congruent with the direction that the arrow points, and therefore, incongruent with the perceptual weight. The ambiguous balanced arrow and balanced square cues provided no perceptual weight and they also did not indicate a clear directional location for the target, and consequently, were used as neutral (control) conditions. The target stimuli were a variety of cartoon objects (e.g., cat, treasure map, car, apple) which were 10º by 12º on the presentation screen and 8º by 10º on the computer monitor. The inner edge of the targets subtended 9º and the outer edge subtended 20º on the presentation screen and 8º and 17º on the computer monitor.

Procedure

All participants. A spatial cueing paradigm was used (Figure 2; Posner, 1980) to elicit orienting. Cueing refers to eliciting attention using the presentation of a stimulus (the cue) and examining whether or not it aids in the process of responding to a target. The paradigm included several steps. First, the participant fixated a central stimulus. Next, a cue appeared in the center of the screen, and then was turned off. Finally, a target appeared in the periphery. Reaction time (RT) to respond to the location of the target was the dependent measure. Participants were presented randomly with one of the six arrow cues (counterbalanced for location of weight and/or direction), followed by a target. The cues were either valid, invalid, or neutral. After all procedures were explained to the participants and/or their parents, informed consent and assent were obtained.

Infants. Infants were seated in an infant seat or in their parent's lap in front of a presentation screen. Prior to the start of the trial, the centering stimulus was presented in the center of the screen to attract the infants' attention. When the experimenter decided that the infant had fixated center, the trial started. At the beginning of the trial, the centering stimulus was turned off and the cue appeared for 1000 ms. After the cue was turned off, a target appeared immediately in the periphery either to the right or to the left. The target remained on the screen until the infant made an eye movement or for approximately three seconds. Up to 100 trials were presented to infants.

3- to 5-year-olds. Young children were seated in their parent's lap in front of a presentation screen. The procedures for the 3- to 5-year-olds were similar to those used for the infants. When the experimenter determined that the child was fixated on the center of the screen, she began the trial. The cue appeared for 1000 ms. After the cue was turned off, the target immediately followed until the child made an eye movement and verbally identified the target. Young children were asked to name the pictures that appeared on the screen in order to make the "game" more exciting for them. Experimenters observed the children's eye movements to the targets, but did not code their naming response of the target object. Up to 100 trials were presented to young children.

5- to 7-year-olds and adults. Participants were seated in a chair in front of a computer screen and were told that they were going to play a treasure hunt game in which they have to find the treasures as quickly as they can. They were instructed to keep their eyes on the centering stimulus and to press the left button on a response box if the target appeared on the left side of the screen and the right button on a response box if the target appeared on the right side of the screen. Participants were given 10 practice trials to ensure that they kept their eyes on the center of the screen and that they understood the directions.

Prior to each trial, participants were presented with a centering stimulus, which appeared for 1500 ms. After the presentation of the centering stimulus, a cue appeared in the center of the screen for 300[1] ms. After the cue was turned off, the target appeared immediately to the right or left of center. After a response was made, the centering stimulus appeared and then the next trial began. Five blocks of 20 trials each were presented to each participant. At the end of each block, participants were given feedback on how quickly they found the "treasures" and were given the opportunity to take a break, continue playing the game, or to stop playing the game.

Coding

Infants' and young children's RT to make an eye movement following the presentation of the target were coded off-line frame-by-frame (33 ms intervals) from video using the Noldus Observer 5.0. Trials were eliminated for several possible reasons: (1) if the participant did not keep his/her eyes on the cue for the entire duration of the cue presentation, (2) if the participant did not make a direct eye movement to one of the possible target locations during the presentation of the cue, (3) if the RT of the participant was greater than 2000 ms (the effect of the cue may have worn off). Usable trials were those in which participants were fixated on the cue for its entire duration and after the presentation of the target participants made a look to one of the two possible target locations. In other words, participants had to be on task for the entire duration of the trial. Cohen’s Kappa was used to assess inter-rater reliability. Inter-rater reliability on whether each trial was usable was 92% (range 86-100%) and for RT to initiate an eye movement following the target was 96% (range 92-100%). The older children’s and adults' RTs were recorded on a computer through button presses.

CHAPTER 3: RESULTS

Prior to analyses, incorrect trials, trials in which the RT was greater than 2000 ms, and trials that were above or below 2.5 standard deviations (SD) from the mean were removed. Infants contributed a total of 2122 trials, of which 16 were incorrect (<.01%), 1107 were unusable (52%, see above) and 22 were 2.5 SD above or below the mean (<.02%); therefore, infants contributed 977 trials to the final analyses. Three- to five-year-olds contributed a total of 2961 trials, of which 15 were incorrect (<.01%), 1364 were unusable (46%), 4 were slower than 2000 ms (<.01%), and 28 were 2.5 SD above or below the mean (<.01%); therefore, 3- to 5-year-olds contributed 1550 trials to the final analyses. Five- to seven-year-olds contributed a total of 2840 trials, of which 131 were incorrect (<.05%), 12 were slower than 2000 ms (<.01%), and 22 were 2.5 SD above or below the mean (<.01%); therefore, 5- to 7-year-olds contributed 2675 trials to the final analyses. Adults contributed a total of 4500 trials, of which 123 were incorrect (<.03%), 6 were slower than 2000 ms (<.01%), and 29 were 2.5 SD above or below the mean (<.01%); therefore, adults contributed 4342 trials to the final analyses.

The results for the younger age groups (infants and 3- to 5-year-olds) were analyzed separately from the results for the older age groups (5- to 7-year-olds and adults) because the eye movement and button press responses require different processes, and therefore, would involve inherent differences in RT. Within the younger and older age groups, the effects of weight and direction were analyzed using separate ANOVAs because in some cases the same cue contributed both weighted and directional information, which violates the independence assumption of ANOVAs. Prior to conducting analyses, cue conditions with similar properties based on weight or direction were combined (see Figure 3 for combinations; see Table 2 for cue means). Therefore, four separate mixed design ANOVAs were conducted: (1) weight results for infants and 3- to 5-year-olds, (2) direction results for infants and 3- to 5-year-olds, (3) weight results for 5- to 7-year-olds and adults, and (4) direction results for 5- to 7-year-olds and adults.

The mixed design ANOVAs testing the effect of perceptual weight had a within-subjects factor of Validity (3: valid weight, invalid weight, balanced) and a between-subjects factor of Age (2: infants, 3- to 5-year-olds, or 2: 5- to 7-year-olds, adults). The mixed design ANOVAs testing the effect of direction had a within-subjects factor of Validity (3: valid direction, invalid direction, non-directional) and a between-subjects factor of Age (2: infants, 3- to 5-year-olds, or 2: 5- to 7-year-olds, adults).

Infants and 3- to 5-Year-Olds

Weight results. The ANOVA examining weight for the younger age groups revealed a main effect of validity, $F(2, 250) = 5.030$, $p = .007$, and a main effect of age, $F(1, 125) = 231.837$, $p < .001$. Three- to five-year-olds responded faster to the targets (M = 204 ms, SD = 26) than infants (M = 312 ms, SD = 61). Bonferroni adjusted paired samples t-test showed that infants and 3- to 5-year-olds responded faster in the valid weighted condition (M = 245 ms, SD = 79) than in the invalid weighted condition (M = 259 ms, SD = 75), $t(128) = 2.322$, $p = .029$, $d = .21$. Infants and 3- to 5-year-olds were also faster to respond in the valid weighted condition (M = 244 ms, SD = 80) than the balanced condition (M = 258 ms, SD = 69), $t(129) = 2.626$, $p = .033$, $d = .23$ (Figure 4). Based on these results, infants and young children appear to be cued by the weight of the cues.

Direction results. The ANOVA examining direction for the younger age groups revealed only a main effect of age, $F(1, 122) = 226.849$, $p < .001$. Three- to five-year-olds responded faster to the targets (*M* = 206 ms, *SD* = 27) than infants (*M* = 314 ms, *SD* = 61; Figure 5). There was no effect of validity, indicating that infants and young children do not orient their attention based on directional information provided in the cues.

Five- to Seven-Year-Olds and Adults

Weight results. The ANOVA examining weight for the older age groups revealed a main effect of validity $F(2, 158) = 7.289$, $p = .001$, and a main effect of age, $F(1, 79) = 236.198$, $p < .001$. Adults responded faster to the targets (*M* = 298 ms, *SD* = 39) than 5- to 7-year-olds (*M* = 616 ms, *SD* = 135). Bonferroni adjusted paired samples t-test showed that 5- to 7-year-olds and adults responded faster in the valid weighted condition (*M* = 433 ms, *SD* = 186) than in the invalid weighted condition (*M* = 451 ms, *SD* = 189), $t(80) = 3.717$, $p = .001$, $d = .41$. Both age groups also responded faster in the valid weighted condition than the balanced condition (*M* = 446 ms, *SD* = 186), $t(80) = 2.474$, $p = .045$, $d = .27$ (Figure 6). Based on this data, it appears that older children and adults are cued by the weight of the cue.

Direction results. The ANOVA examining direction for the older age groups revealed a main effect of validity, $F(2, 156) = 14.937$, $p < .001$ and a main effect of age, $F(1, 78) = 233.350$, $p < .001$. Adults responded faster to the targets (*M* = 297 ms, *SD* = 41) than 5- to 7-year-olds (*M* = 616 ms, *SD* = 132). Bonferroni adjusted paired samples t-test showed that 5- to 7-year-olds and adults were faster to respond to valid directional cues (*M* = 428 ms, *SD* = 183) than invalid directional cues (*M* = 460 ms, *SD* = 191), $t(79) = 4.441$, $p < .001$, $d = .49$, and both age groups also responded faster to valid directional cues (*M* = 425 ms, *SD* = 184) than to non-directional cues (*M* = 446 ms, *SD* = 186), $t(80) = 4.543$, $p < .001$, $d = .25$ (Figure 7). Older children and adults appear to orient their attention based on the directional meaning of cues.

Further analyses. Due to the finding that the older age groups (5- to 7-year-olds and adults) used the directional information in the cue to orient their attention, further analyses were conducted to determine whether the typical arrow condition—which provides weighted information and directional information in the same location—was the driving factor for the results for these age groups for both the weight and direction results. First, it was confirmed that there was a difference in the congruent and incongruent weighted conditions with and without the inclusion of the typical arrow condition. Both age groups responded faster when the typical arrow was included in the valid weighted condition (M = 433 ms, SD = 186) than when it was not included (M = 448 ms, SD = 197), $t(80) = 5.316$, $p < .001$, $d = .59$. Participants responded slower when the typical arrow was included in the invalid weighted condition (M = 451 ms, SD = 189) than when it was not included (M = 442 ms, SD = 187), $t(80) = 3.79$, $p < .001$, $d = .42$. Thus, in order to determine whether the typical arrow may have been driving the results for the weighted condition, it was removed from the analysis. Again, the within-subjects factor was Validity (3: valid weight (no typical arrow), invalid weight (no typical arrow), balanced) and the between-subjects factor was Age (2: 5- to 7-year-olds, adults). This time, the analysis revealed only a main effect of age, $F(1, 79) = 227.969$, $p < .001$, with the adults (M = 297 ms, SD = 35) responding to targets faster than 5- to 7-year-olds (M = 621 ms, SD = 141; Figure 8). These results indicate that the older age groups were not strongly cued by weight, as the weight effect appears to have been driven entirely by the inclusion of the typical arrow.

Because the weight results indicate that the typical arrow was driving the effect, the effect of the typical arrow was also examined with regard to the direction results. First, it was confirmed that participants responded faster in the valid direction condition which included the typical arrow (M = 425 ms, SD = 184) than the valid direction condition without the typical arrow(*M* = 436 ms, *SD* = 193), $t(80) = 4.595$, $p < .001$, $d = .51$, and that they responded slower in the invalid direction condition that included the typical arrow (*M* = 460 ms, *SD* = 191) than the invalid direction condition that did not include the typical arrow (*M* = 454 ms, *SD* = 191), $t(79) = 2.131$, $p = .036$, $d = .24$. The mixed design ANOVA with the within-subjects factor of Validity (3: valid direction (no typical arrow), invalid direction (no typical arrow), non-directional) and the between-subjects factor as Age (2. 5- to 7-year-olds, adults). The analysis revealed only a main effect of age, $F(1, 78) = 229$, $p < .001$, with the adults (*M* = 296 ms, *SD* = 37) responding to targets faster than 5- to 7-year-olds (*M* = 398 ms, *SD* = 138; Figure 9). Again, the typical arrow was driving the original direction effect. Thus, the removal of the typical arrow cue negated both the weight and the direction effect.

It was expected that 5- to 7-year-olds and adults would understand the directional meaning of arrows, whether they are weighted or balanced, so further exploratory analyses were conducted with regard to the direction effect. When the two remaining stimuli—the balanced arrow and the ambiguous weighted arrow—were examined separately, the results showed that 5- to 7-year-olds and adults were faster to respond to the valid balanced arrow (*M* = 420 ms, *SD* = 190) than the invalid balanced arrow (*M* = 458 ms, *SD* = 179), $t(78) = 3.534$, $p = .001$, $d = .40$. However, there was no difference in RT between the valid and invalid ambiguous weighted arrows ($p > .05$).

CHAPTER 4: DISCUSSION

The purpose of this paper was to examine children's development of understanding of arrows. Of particular interest was whether participants who presumably do not understand the directional meaning of an arrow use its perceptual properties to orient their attention. The results of the study revealed several interesting findings which will be evaluated using Springer's (2001) framework of perceptual boundedness and perceptual support.

Infants

As predicted, infants were cued by the perceptual weight of the stimuli. Infants were not expected to understand that arrows have directional meaning; therefore, it was not surprising that they were not cued by direction. This finding in infants can be interpreted using Springer's (2001) structural view, which proposes that children use perceptual information to guide their behavior because they do not yet have the cognitive structures to be able to use task-relevant information. In this case, infants may be perceptually bound in a structural sense and simply do not have a conceptual understanding of arrows; therefore, they rely on the perceptual information to make a response. Although the competency view holds that individuals can be trained in order to use the appropriate dimension of an arrow cue to direct their attention, this interpretation does not seem justified. With infants, an interpretation using the competency view would probably mean that the infants can learn an association between the arrow and the location where a target may appear, but they would not likely have a thorough understanding of an arrow's directional meaning even after training. An interpretation using the susceptibility view would suggest that infants have an understanding of an arrow's directional meaning, but that they are distracted by its perceptual characteristics; however, this explanation is unlikely, as infants did not show any evidence of directional understanding.

The fact that infants use perceptual weight to guide their responding may help lead them to a conceptual understanding during early childhood. One explanation for how this may occur is through an associative learning process in which infants are exposed to arrow cues and shift their attention due to its perceptual characteristics initially. Slowly, they may realize that when an arrow cue is present, something interesting is occurring in that particular location, and therefore, they start to association the arrow cue with indicating directionality.

It is important to take into account Munakata's (2000) argument that researchers may unfairly claim that infants are using perceptual processes rather than conceptual ones (e.g., in violation-of-expectation paradigms), when in reality conceptual processes may be at play. In the present study, it is hard to make the argument that infants show conceptual understanding of arrow cues, as they showed no evidence of having any directional understanding. Rather, they only showed an effect for the perceptual weight of the stimuli. Specifically, the paradigm was designed so that the perceptual and conceptual processes could be teased apart. Therefore, it is safe to assume that infants use perceptual properties to direct their attention rather than conceptual ones.

Three- to Five-Year-Olds

Similar to infants, 3- to 5-year-olds were cued by the perceptual weight of the stimuli. Surprisingly, 3- to 5-year-olds showed no evidence of using the directional meaning of the cue to orient their attention. The results of the present study contradict the results of previous studies, which have shown that 4- to 6-year-old children are cued by arrows (Ristic et al., 2002). Although the results of the present study suggest that 3- to 5-year-olds are cued only by the perceptual weight of the cues, they may still understand an arrow's directional meaning, particularly because children of this age have symbolic understanding in many other domains.

Symbolic understanding. During the first few years of life, children begin to have some symbolic understanding. Yonas, Granrud, Chov, and Alexander (2005) found that the height and angle at which 9-month-olds reach for objects depicted in photographs and non-pictorial displays varies from reaching behavior directed toward three-dimensional objects, suggesting that may not interpret the photograph as a real object. Another example of young children's development of symbolic understanding can be seen in 2.5-year-olds who cannot find an object hidden in a large room after they see it hidden in a small model of the large room; however, they can perform this task correctly by 3 years of age (DeLoache, 1987, 2000). DeLoache (2000) proposes that infants and young children fail on these tasks until they achieve *dual representation*, or the ability to treat the model both "concretely, as an object itself" and "abstractly, as a representation of something else" (DeLoache & Marzolf, 1992, p. 328).

Another example of children's symbolic understanding can be seen in their language development. Infants and children have to learn to associate words with particular objects. For example, infants begin to associate the meaning of familiar words with familiar objects (e.g., "mommy" and "daddy") around 6 months of age (Tincoff & Jusczyk, 1999), and between 8 and 16 months of age infants begin to use both signed and verbal language to refer to objects (Bonvillian et al., 1983; Folven & Bonvillian, 1991; Ozcaliskan & Goldin-Meadow, 2005; Tardif et al., 2008). Also, infants realize that when they hear the word "ball," their mother is referring to a round, bouncy object. Later, children learn about the sounds associated with each letter of the alphabet, and the letters associated with words (Lonigan, Burgess, & Anthony, 2000). Based on previous research, it appears that even infants have some level of symbolic understanding in some domains (e.g., pictures), but not until about age 3 do they have symbolic understanding in other domains (e.g., dual representation). It is predicted that the understanding of arrows comes later than the understanding of other types of symbols because children may not have as much experience with arrows and they are not explicitly taught about the meaning of arrows. Based on the evidence presented above, it is likely that 3- to 5-year-olds have an understanding of arrows. However, several factors may have made it difficult for them show this understanding.

Limitations and future directions. If 3- to 5-year-olds understand that arrows have a directional meaning, then Springer's (2001) structural view would not be able to help explain the results; children would not be cognitively limited in understanding directionality indicated by arrows. However, 3- to 5-year-olds may just be beginning to understand the directional meaning of arrows, and therefore, may have had some difficulty in showing their understanding in this particular paradigm. Because children of this age are likely not yet experts with arrows (competency view), they may have needed more time to process the cues than was presented (1000 ms), and because the cues were presented for such a short time, children may have been distracted by the perceptual information provided in the cue, rather than the directional information (susceptibility view). Previous studies that have used the typical arrow cue with children have also presented the cues for a short period of time (Facoetti et al., 2001; McDonald et al., 1999; Ristic et al., 2002; Senju et al., 2004; Wainwright & Bryson, 2005), in which case, children may not have been able to process the directional information presented, and therefore, may have used the perceptual information to direct their attention.

There are several aspects of this paradigm which may have hindered children's ability to show their understanding of arrows. First, the cues may not have been presented for a sufficient amount of time for children to be able to process them. Second, based on the evidence that children have symbolic understanding in some domains within the first years of life, it is possible that the measure used in the present study—reaction time—was not an appropriate measure for children to be able to demonstrate their symbolic understanding of arrows. Some studies with infants which examine whether they orient their attention to the location of a cue (e.g., a flash in the periphery or an eye gaze cue) have used the infants' direction of look rather than the latency to orient to the location (Butcher, Kalverboer, & Geuze, 1999; D'Entremont, Hains, & Muir, 1997; Johnson & Tucker, 1996; Simion, Valenza, Umilta, & Barba, 1995; Valenza, Simioin, & Umilta, 1994). In fact, D'Entremont et al. found no difference in latency between infants' correct and incorrect turns. Therefore, using RT as the dependent measure may not have been an appropriate measure to use to determine whether infants and 3- to 5-year-olds understand the directional meaning of an arrow.

In a follow-up study, 21 1- to 4-year-old children were presented with a typical arrow cue (Figure 1a) which always pointed to the location of a toy hidden in one of two buckets (to the right or to the left; Beck, Swindler, Stansky, Johnson, Varga, & Frick, 2009). Children were to reach for the bucket that they thought contained the toy. The results showed that children as young as 2.5 years of age were more likely to reach to the bucket containing the hidden toy when cued by a typical arrow than to the bucket that was not cued. To our knowledge, the youngest children to have shown attentional orienting in response to an arrow cue have been 4 years of age (Ristic et al., 2002). The results of the follow-up study showed that children as young as 2.5 years of age used the arrow cue to orient their attention. However, based on the follow-up study, no conclusions can be drawn about whether 2.5-year-olds were using the directional meaning of the arrow or its perceptual weight to orient their attention.

A second follow-up study is currently being conducted in which children are presented with all six original cue types followed by bilateral targets rather than unilateral ones (Varga & Frick, in preparation). The cue and targets remain on the screen until the child points to the location where s/he thinks the toy is hidden. The direction of first point and direction of first look are of interest, rather than RT. This paradigm should help determine which property of the stimulus children are using to cue their attention. Across the three studies, it will be possible to speculate whether children between 3 to 5 years of age may be perceptually bound in structure, competency, or susceptibility.

Five- to Seven-Year-Olds and Adults

Initial analyses of the data for the older participants (5- to 7-year-olds and adults) revealed that they were cued by both weight and direction. It was unexpected that the older age groups would be cued by weight because once participants understand the directional meaning of an arrow, it is expected that the conceptual meaning would prevail over the perceptual properties. As expected, older participants were cued by direction. It was suspected that because a typical arrow presents both weight and direction information on the same side of the cue, it could be that the typical arrow was driving both the weight and direction results; therefore, the data were further explored to clarify their interpretation. In this follow-up exploratory analysis, when the typical arrow condition was removed, there was no longer an effect of weight. More interestingly, there was no direction effect either, which was surprising because it is expected that adults would understand the directional meaning of the balanced arrow.

Exploratory analyses of the remaining conditions revealed that the older age groups were cued by the balanced arrow, but not cued by the ambiguous weighted arrow. The ambiguous weighted arrow was used in the study in order to pit weight and direction into direct competition within the same stimulus. Individuals who understand the directional meaning of the arrow were simply not cued by the ambiguous weighted arrow, possibly because they did not recognize it as an arrow or because the directional aspect was lost. Thus, our attempt to place weight and direction in competition with one another may have been unsuccessful in this ambiguous weighted arrow condition (Figure 1d), complicating our interpretation of the data. However, the fact that the older age groups were cued by the balanced arrow cue supports the idea that they were in fact cued by the directionality indicated by the arrow. In essence, the directional meaning associated with the typical arrow cue prevails over all of the other cues presented for the older participants. The older participants do not appear to be perceptually bound in any of the three views presented by Springer (2001) and they did not appear to be cued by perceptual weight; instead, they used the directional meaning of only the typical arrow to direct their attention.

Contributions to Our Understanding of Attentional Development

The development of children's understanding of arrows has not previously been studied systematically. This study is the first—to our knowledge—to examine when children understand the directional meaning of arrows and to speculate about how children's understanding of arrows develops. Based on the results of this study, it appears that children may use perceptual information to direct their attention if they do not yet have a conceptual understanding of arrows, as well as if they have conceptual understanding of arrows but are not provided enough time to process the information. With the case of typical arrows, it is possible that the use of the perceptual information helps children learn about their conceptual meaning.

Orienting is an aspect of visual attention that may have implications for broader cognitive abilities. As mentioned previously, arrows can be used to study orienting behavior in both typically and atypically developing children. Children who have cognitive or developmental delays also have difficulty with orienting their attention in a voluntary manner in response to an arrow cue. For example, children with either attention deficit hyperactivity disorder (ADHD) or autism who were presented with valid and invalid arrow cues were slower to respond to both cues than control children (McDonald et al., 1999; Senju et al., 2004). The authors suggest that children with ADHD or autism show a limitation in general cognitive function as indicated by their slower RT. In addition, children with ADHD may be putting all of their attention into the arrow cue, expecting that it will be valid. As a result, when an invalid arrow cue is presented, they have difficulty disengaging and shifting their attention from the location where they expected the target to appear, resulting in slower RTs than control children who do not appear to have these difficulties (McDonald et al., 1999). This demonstrates that children with ADHD may have more impaired cognitive flexibility than typically developing children.

Conclusions

A large number of studies have examined children's understanding of social directional cues such as eye gaze and finger pointing (e.g., Butterworth, 1995; Farroni et al., 2000), but far less have examined children's performance using non-social directional cues (e.g., Ristic et al., 2002). The ones that have examined children's performance using arrows have not proposed any type of developmental model to explain how this ability emerges. Whether directional cues are social or non-social, their functions serve an important purpose in our daily lives. Even infants can recognize and follow social directional cues; however, it is not clear when children can recognize and use non-social directional cues. Based on the findings of the present study, it appears that children younger than 5 years of age use the perceptual characteristics of the cues to direct their attention, and it is not until sometime after age 5 that children use the directional meaning of an arrow to orient their attention. It makes sense that the understanding of social directional cues emerges before the understanding of non-social directional cues, as infants are emerged in a social environment from birth and humans may have specially evolved modules which respond to biologically relevant stimuli (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Crump, Milliken, & Ansari, 2008). The question that remains is how children learn about non-social directional cues such as arrows. One possible explanation is that infants and children are exposed to arrows in their daily lives (as are adults), and therefore, are exposed to their perceptual properties. It is important to keep in mind that in most cases, arrows that we are exposed to look similar to the typical (weighted) arrow (Figure 1a) presented to the participants in the current study, which present perceptual and directional information in the same location. So, it may be possible that from an early age even infants are beginning to learn about the properties of an arrow.

The results of the study can be examined in light of Springer's (2001) views of perceptual support. The realist argument would suggest that the fact that an arrow cue typically has weight and direction presented on the same side means that children, and even infants, can use this to help guide their responses. Additionally, because the cues were presented so quickly, children who do not yet have much experience with arrow cues may have relied on the perceptual characteristics of the cues to direct their attention – in essence because they may not have been able to inhibit their responses to the perceptual information – resulting in faster responses to weight rather than direction (conflict argument). Finally, according to the fluency argument, children may initially use the perceptual properties of cues to direct their attention, which slowly helps them learn about the conceptual meaning. Based on the results of this study, children initially use the perceptual characteristics of the cue to direct their attention. With experience, they may begin to understand the directional meaning of the cues (Crump et al., 2008).

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Footnotes

[1] In a pilot study, all participants were presented with the cues for 300 ms. However, the 300 ms cue presentation time appeared to be too short for the infants and young children to process the information, so the cue length was increased to 1000 ms for them, which is consistent with cue presentation times for eye gaze studies with infants (1000 ms - Hood et al., 1998; 750 to 1500 ms – Farroni et al., 2000; Farroni et al., 2003). The cue presentation time remained at 300 ms for the older children and adults. The literature varies greatly on the cue length for participants who make button presses but cueing effects have been found in previous studies with cue presentation times that range between 75 ms and 500 ms (Friesen et al., 2004; Kylliainen, & Hietanen, 2004; Ristic, Wright, & Kingstone, 2007; Tipples, 2002).

FIGURES

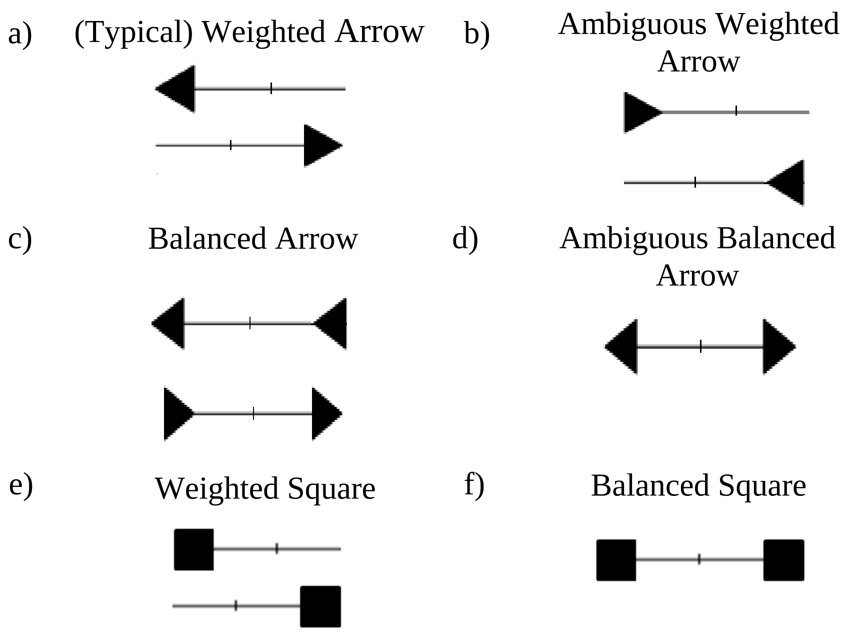

Figure 1. Cue conditions. *Weighted* cues provide perceptual weight on one side of a horizontal line. *Balanced* cues provide perceptual weight on both sides of a horizontal line. *Arrow* cues provide directional information, while *square* cues do not provide directional information.

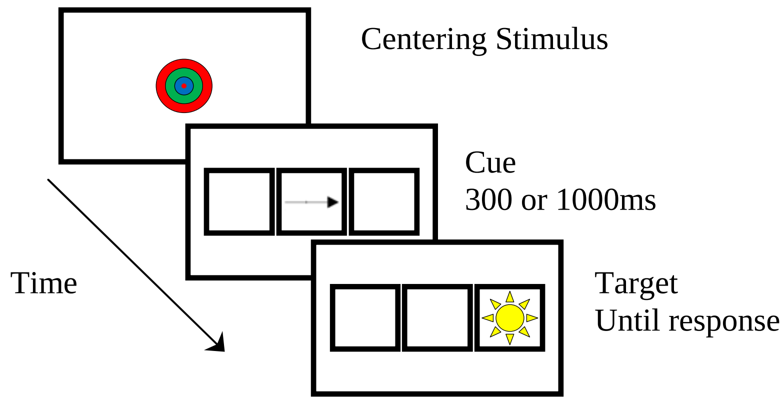

Figure 2. Sequence of events within a trial. The centering stimulus was presented until and experimenter determined that the infants and the 3- to 5-year-olds were fixated on the center of the screen; it remained on for 1500 ms for the 5- to 7-year-olds and adults. Next, the cue was presented for either 300 or 1000 ms. Immediately after the cue was turned off, the target appeared either in the location that was congruent with the cue (valid trial) or in the location that was incongruent with the cue (invalid trial).

(a)

(b)

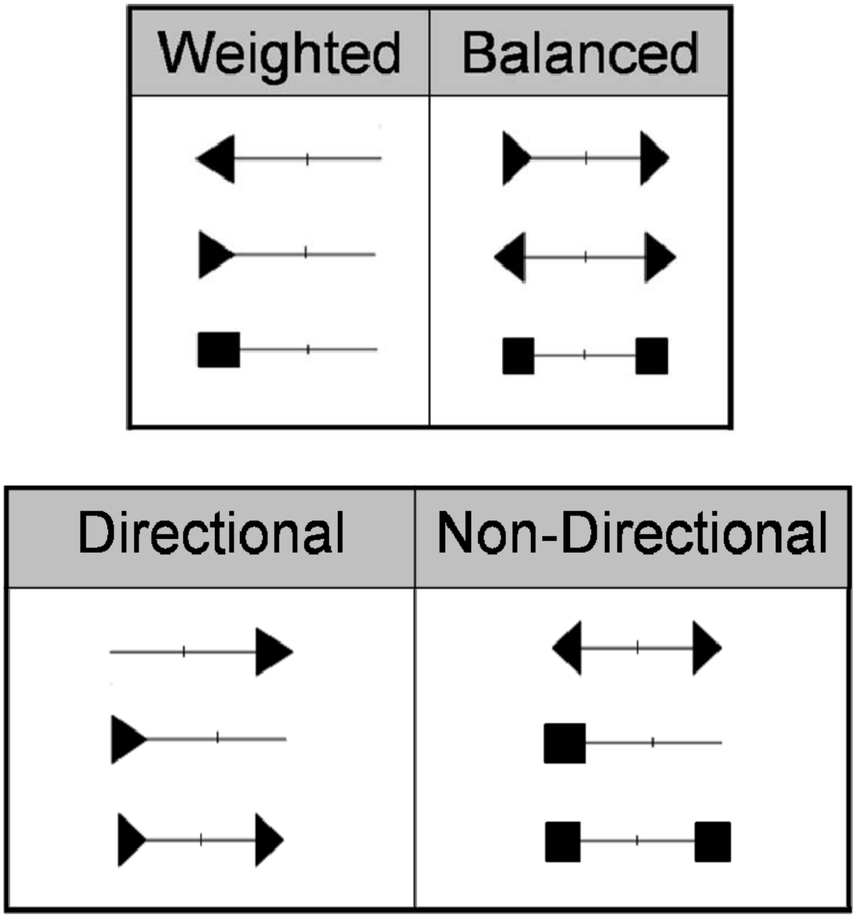

Figure 3. Cue conditions which contribute to weighted and directional results. (a) Cue conditions which present weighted information (left panel) were used to examine responses to valid and invalid weights. Cue conditions that provided no weighted information (right panel) were used as neutral (control) trials. (b) Cue conditions which present directional information (left panel) were used to examine responses to valid and invalid direction. Cue conditions that provided no clear directional information (right panel) were used as neutral (control) trials.

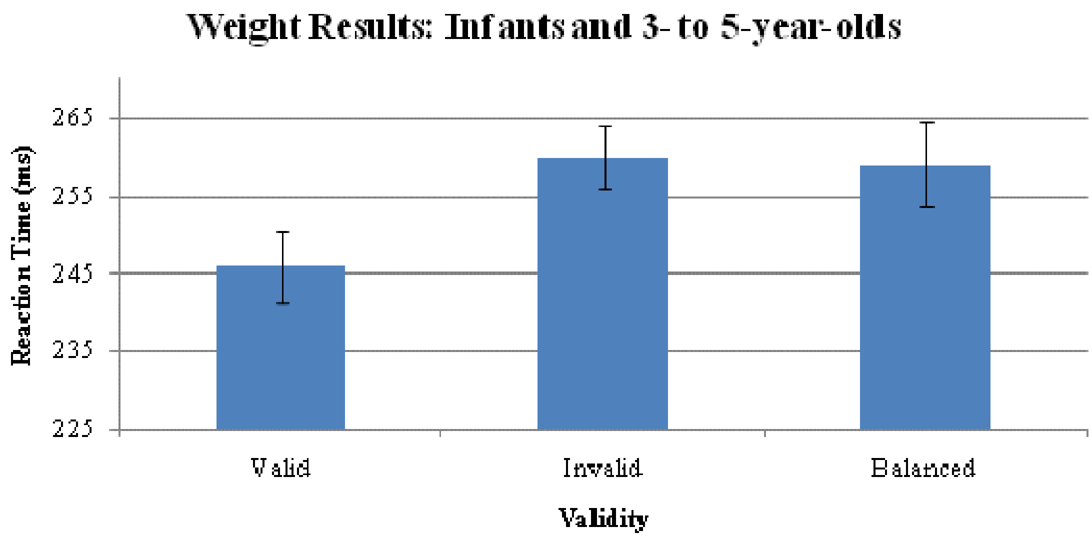

Figure 4. The results for the younger participants showed that they were cued by the weight of the stimuli. They were faster to respond to valid than invalid stimuli (*p* = .029), and also faster to respond to valid than balanced stimuli (*p* = .033). Error bars represent standard error of the mean, corrected for between-subject variability (Morey, 2008).

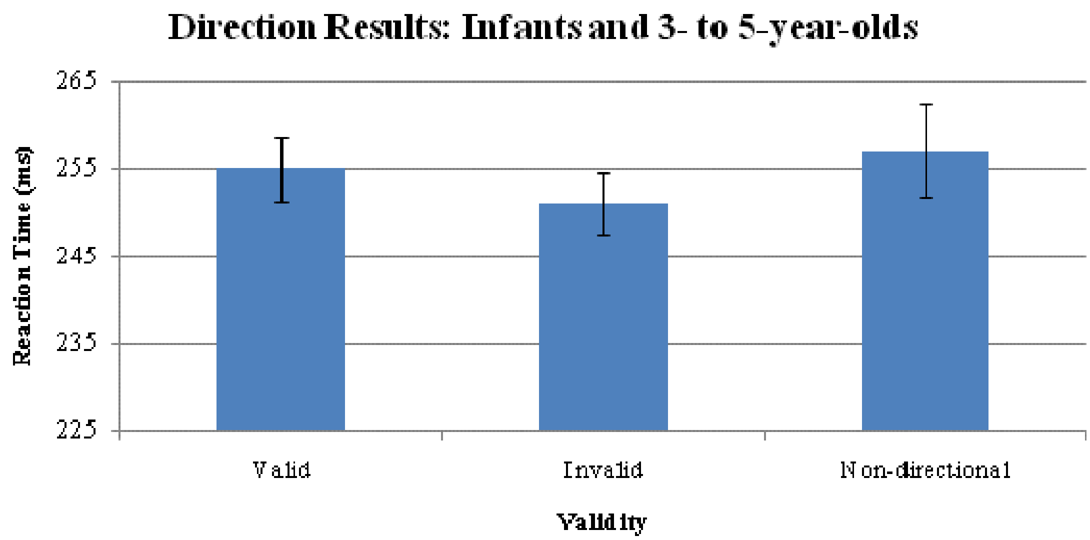

Figure 5. The younger participants showed no evidence of being cued by direction (*p*'s > .05). Error bars represent standard error of the mean, corrected for between-subject variability (Morey, 2008).

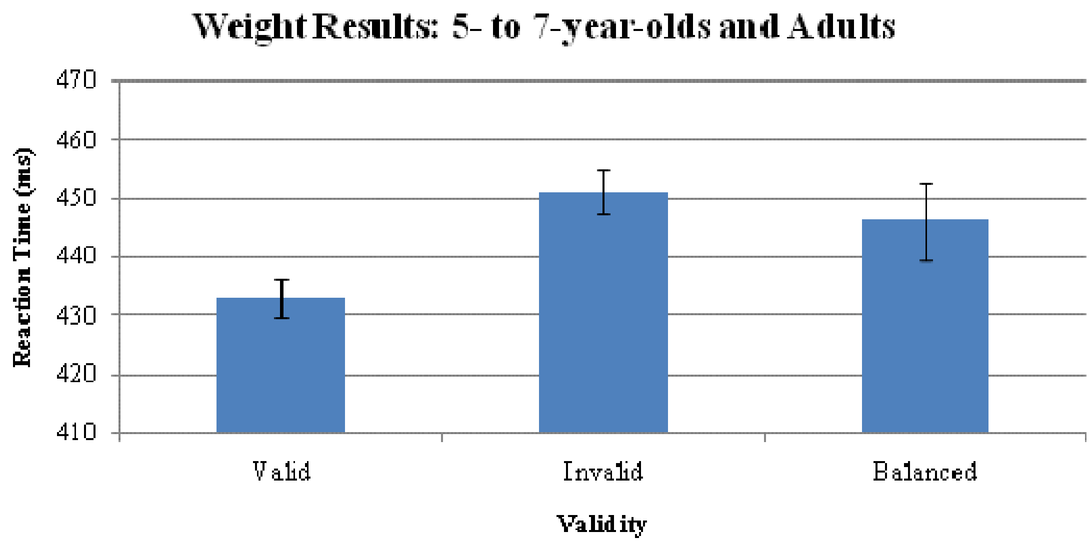

Figure 6. The older participants initially showed an effect of weight. It appeared that they were faster to respond in the valid than invalid condition (p = .001), and also faster to respond in the valid than balanced condition (p = .045). Error bars represent standard error of the mean, corrected for between-subject variability (Morey, 2008).

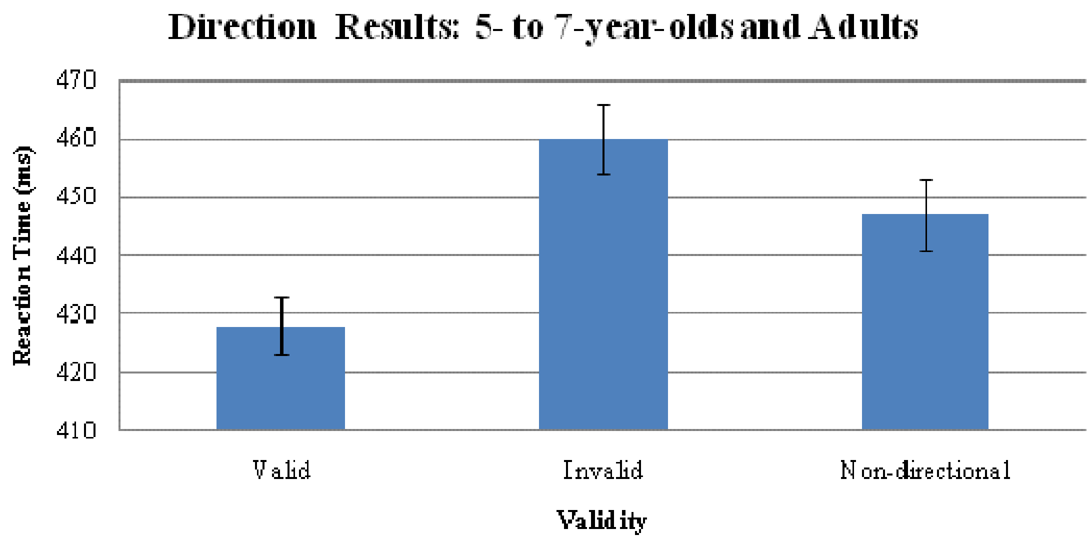

Figure 7. The older age groups initially showed an effect of direction. They had faster responses in valid than invalid trials (p < .001), and faster responses in valid than non-directional trials (p < .001). However, there was no difference responses in invalid and non-directional trials. Error bars represent standard error of the mean, corrected for between-subject variability (Morey, 2008).

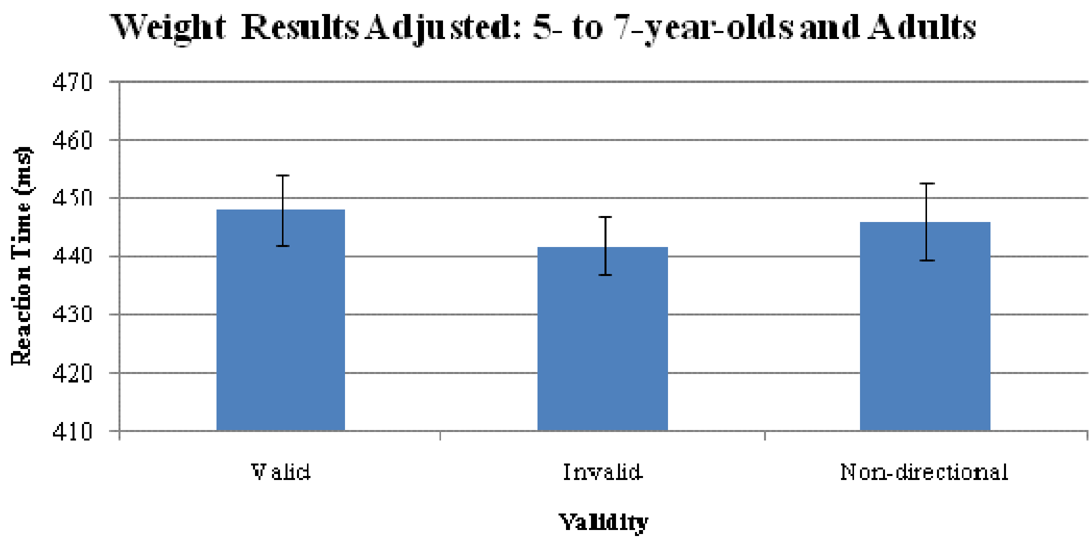

Figure 8. Following the removal of the typical arrow cue, the older age groups no longer showed a weight effect (*p*'s > .05). Error bars represent standard error of the mean, corrected for between-subject variability (Morey, 2008).

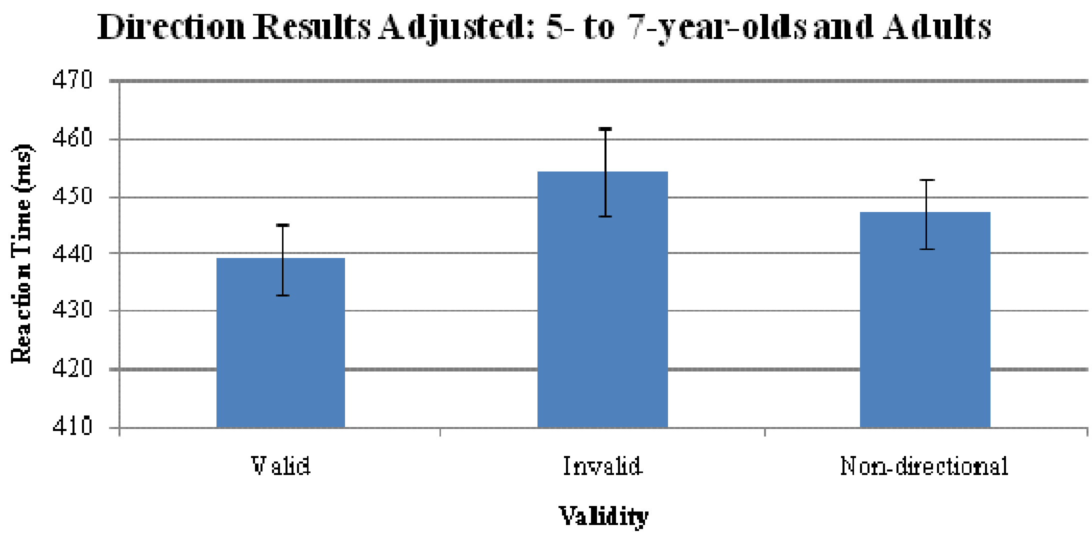

Figure 9. Following the removal of the typical arrow cue, the older age groups no longer showed a direction effect (p's $> .05$). Error bars represent standard error of the mean, corrected for between-subject variability (Morey, 2008).

TABLES

Table 1. Table of demographics information.

	Infants	**3- to 5-year-olds**	**5- to 7-year-olds**	**Adults**
Mean Age	38.7 weeks	3.89 years	5.91 years	19.89 years
Age Range	33-47 weeks	3.0-4.92 years	5.0-6.92 years	18-26 years
Males	37	42	16	24
Females	20	33	21	21

Table 2. Means (SD) for each age group by cue condition.

	Infants			3- to 5-year-olds		
	Valid	Invalid	Neutral	Valid	Invalid	Neutral
Weighted						
Weighted Arrow	309 (94)	320 (104)		205 (33)	202 (28)	
Ambiguous Weighted Arrow	295 (124)	320 (86)		198 (40)	205 (36)	
Weighted Square	296 (103)	331 (82)		200 (38)	211 (40)	
Balanced						
Balanced Arrow	300 (81)	324 (102)		213 (43)	211 (42)	
Ambiguous Balanced Arrow			304 (70)			211 (41)
Balanced Square			329 (75)			214 (33)
Directional						
Weighted Arrow	309 (94)	320 (104)		205 (33)	202 (28)	
Ambiguous Weighted Arrow	320 (124)	295 (124)		205 (36)	198 (40)	
Balanced Arrow	300 (81)	324 (102)		213 (43)	211 (42)	
Non-Directional						
Ambiguous Balanced Arrow			304 (70)			211 (41)
Weighted Square	296 (103)	331 (82)		200 (38)	211 (40)	
Balanced Square			329 (75)			214 (33)

	5- to 7-year-olds			Adults		
	Valid	Invalid	Neutral	Valid	Invalid	Neutral
Weighted						
Weighted Arrow	561 (135)	648 (147)		275 (46)	317 (40)	
Ambiguous Weighted Arrow	620 (184)	625 (154)		292 (40)	299 (40)	
Weighted Square	623 (152)	606 (139)		302 (39)	295 (39)	
Balanced						
Balanced Arrow	598 (166)	624 (132)		278 (40)	318 (38)	
Ambiguous Balanced Arrow			632 (162)			295 (37)
Balanced Square			617 (138)			304 (39)
Directional						
Weighted Arrow	561 (135)	648 (147)		275 (46)	317 (40)	
Ambiguous Weighted Arrow	625 (154)	620 (184)		299 (40)	292 (40)	
Balanced Arrow	598 (166)	624 (132)				
Non-Directional						
Ambiguous Balanced Arrow			632 (162)			295 (37)
Weighted Square	623 (152)	606 (139)		302 (39)	295 (39)	
Balanced Square			617 (138)			304 (39)