ABSTRACT

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The Development of Directional Understanding in Three- to Five-year-old Children
(Under the Direction of DR. JANET FRICK)

Endogenous orienting occurs when a meaningful cue, such as an arrow, is used to direct attention toward a peripheral target. Adults and children as young as four years of age respond faster to a target that is cued by a central arrow than to an uncued target. However, the nature of the understanding of the arrow by young children is not well understood. Young children may look in the proper direction based on the “weighted” nature of the arrow, or the fact that an arrow is perceptually “heavier” on one side than the other. If this is the case, then young children do not necessarily need to understand the symbolic nature of an arrow in order to direct attention to a target. In this project, three- to five-year-old children were tested using various centrally located arrow cues to test the hypothesis that as development progresses, there is also a progression of understanding of arrow cues from a perceptual to a symbolic understanding. The results did not support the hypothesis, but future research must be done to investigate the understanding that young children have of important directional cues such as arrows.

INDEX WORDS: Symbolic Understanding, Arrows, Endogenous Orienting, Development, Weight, Directional Cues

THE DEVELOPMENT OF DIRECTIONAL UNDERSTANDING IN THREE- TO FIVE-YEAR-OLD CHILDREN

by

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A Thesis Submitted to the Honors Council of the University of Georgia
in Partial Fulfillment of the Requirements for the Degree

BACHELOR OF SCIENCE

in PSYCHOLOGY and BIOLOGY

with HIGHEST HONORS

and CURO SCHOLAR DISTINCTION

Athens, Georgia

2008

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ACKNOWLEDGEMENTS

I would like to thank my faculty advisor, Dr. Janet Frick, for her direction and guidance throughout this project. Additionally, completion of this thesis would not have been possible without the help of my reader, Krisztina Varga, who has taught me so much about the process of conducting research, and showed me that writing is not as scary as it seems! I would also like to thank all of the children and parents who participated in this research. Finally, I owe a huge thank you to my fellow research assistants in the UGA Infant Lab for spending countless hours calling families, running participants, and coding videos so that this project could be completed.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1
INTRODUCTION

Symbolic understanding is a universally important aspect of development. A symbol has been defined as "any entity that someone intends to stand for something other than itself" (DeLoache, 1995, p. 109). DeLoache (1995) discusses a model of development by which children learn to use and understand symbols. According to her theory, before the age of about two and a half years, children do not understand that one object can represent another object, an idea that is essential in symbolic understanding. One symbol that has been used in a large body of research is the arrow. Studies use the arrow as a cue in the study of an important process in visual attention known as endogenous (voluntary) orienting. The purpose of this study is to investigate how children begin to understand the symbolic meaning of an arrow specifically, and how this understanding develops throughout the early years of life.

Endogenous Orienting

The study of visual attention provides a means for better understanding the cognitive capabilities of young children and even infants. In addition, paradigms can easily be used with older children and adults, thus providing a way to examine the development of cognitive function throughout the lifespan. *Endogenous orienting* describes the controlled response to a centrally-cued peripheral target. Unlike *exogenous orienting*, which is an automatic and innate response to a target that is preceded by a cue in the periphery, endogenous orienting is considered to be under voluntary control (Jonides, 1981) and requires mental effort (Renner, Klinger, & Klinger, 2006). In the most widely used test of orienting (Posner 1980), participants are seated in front of a screen and asked to focus on a central fixation point. A central cue then appears, facilitating attention toward the left or the right periphery. The cue is followed by the appearance of a target on either side. In some cases, the cue is predictive (i.e., it gives an indication for which side the target will appear), in other cases it is nonpredictive and the cue does not indicate the target's location. Participants press a corresponding key when they detect the target, and the time that it takes to respond to the target in each case is calculated. If the cue serves to orient the participants' attention, then reaction time (RT) should be faster to valid cues (those in which cue and target are congruent) than to invalid ones (cue and target are incongruent).

In the current study, the spatial orienting paradigm was modified to allow for the study of attentional orienting in young children. Instead of a key press response, participants' eye movements were used to measure RTs. In this way, the orienting paradigm was used to investigate the development of symbolic understanding in 3- to 5-year-old children.

Development of Symbolic Understanding

Symbolic understanding is important in all aspects of life. Adults encounter hundreds of symbols every day; tasks such as following street signs while driving and reading a map would be much more complicated or even impossible if it were not for the luxury of a highly developed system of symbols. In addition, our writing and number systems rely on the idea that written letters and numbers carry special representative meanings (sounds and number concepts, respectively). The use of symbols is ubiquitous in modern society and is therefore an important topic to understand.

Adults become so familiar with symbols that they often assume that a new entity carries symbolic meaning. However, young children do not display the same expertise with symbols.

Recent research has shown that development of symbolic understanding takes place throughout infancy and childhood (DeLoache, 1987; 1991; DeLoache, Miller, & Rosengren, 1997). Infants and young children have not had as much experience with symbols as adults have, and therefore, do not recognize that an object could stand for something other than itself.

According to DeLoache (1987), symbolic understanding requires *dual representation*, or the knowledge that an object can be recognized in two ways: as itself, and as a representation of something else. Some of the earliest evidence of symbolic understanding occurs when young children discover the meanings of photographs and pictures. When shown a picture, 9-month-old infants attempt to interact with the objects in the picture as if they are real objects; but by 18-20 months they instead point to the objects in the picture (DeLoache, Pierroutsakos, Uttal, Rosengren, & Gottlieb, 1998). DeLoache and colleagues reason that between 9 and 18 months of age, infants acquire an understanding of the concept the dual nature of a picture (as an object and as a representation of other objects). However, recent research has opposed the results of this study by finding that 9-month-old infants interact with pictures as two-dimensional rather than 3-dimensional objects (Yonas, Granrud, Chov, & Alexander, 2005), showing that infants might begin to understand the function of pictures even earlier than previously thought.

Furthermore, 2-year-olds are not able to find an object in a room when they are first shown a picture of the room, but 2.5-year-olds are able to complete the task (DeLoache, 1987; 1991). These results suggest that in a very short time span children learn that pictures can represent other things, and thus, they begin to understand the nature of symbols.

Similar research shows that there is further development in symbolic understanding throughout toddlerhood. In one study, 2.5- and 3-year-old toddlers watched as a miniature toy was hidden in a to-scale model of a living room (DeLoache, 1987). Then, the toddlers were taken to the adjoining regular-sized living room and were asked to find the toy, after being told that the toy could be found in the same place as in the little room. The 2.5-year-olds were not successful in this task, but the 3-year-olds were. It was reasoned that the younger children had not yet achieved dual representation, and therefore could not understand that the small room was a representation of the large room. Another study (DeLoache et al., 1997) removed the symbolic aspect of the task by hiding a toy in the large room and then telling the children that a "shrinking machine" had made the entire room smaller. Two and a half-year-olds succeeded in finding the toy, presumably because they did not have to think about the small room as a symbol for the larger room, and thus the concept of dual representation was not necessary. That 2-year-old children do not succeed in the picture task or the model room task, while 2.5-year-olds succeed in the picture task only and 3-year-olds succeed in both, suggests that there is a progression of symbolic understanding throughout the early years of life. According to this research, children begin to understand the general concept of symbols around three years of age.

Arrow Cues

Arrows are directional cues that are commonly recognized by children and adults. Adults have been shown to respond faster to targets that are cued by an arrow than to uncued targets (Friesen, Ristic, & Kingstone, 2004; Brodeur & Enns, 1997; Goldberg, Maurer, & Lewis, 2001). In addition, children as young as four years of age respond faster to a target that is preceded by a valid arrow (direction of arrow and target location are congruent) than to a target that is preceded by an invalid arrow (direction of arrow and target location are incongruent; Ristic, Friesen, & Kingstone, 2002). However, no research has been done to investigate the nature of the understanding that young children have of arrow cues. Arrows have more perceptual "weight" on one side than the other; there is physically more stimulus on the side of the arrowhead. Because of this perceptual asymmetry, it is possible that the side that is more weighted is also more perceptually stimulating, and thus cues children to look in the direction of the arrow. If this is true, then children may be cued to look in the direction of the arrow even if they do not have a true understanding of its symbolic meaning. A few endogenous orienting studies using arrow cues have controlled for the effect of perceptual weight by removing the “tail” of the arrow (Tipples, 2002) or by making the arrow symmetrical (Friesen et al., 2004). However, no research has pursued the specific question of perceptual weight and whether or not it plays a role in the development of symbolic understanding.

Eye Gaze and Arrows

Another commonly studied cue used in endogenous orienting paradigms is eye gaze. Like arrows, eyes are perceptually weighted (i.e. the pupils are heavier on the side to which they are looking and thus possibly draw attention in the direction of the gaze). However, eye gaze cuing is considered to be more biologically relevant (more important to survival) than a non-social cue, such as an arrow. A large body of research has investigated whether there are attentional differences between biologically relevant and irrelevant cues. For example, there is evidence that cuing by eye gaze is special and is controlled by a different neural mechanism than cuing by other symbols, such as arrows (Friesen et al. 2004; Hood, Willen, & Driver, 1998; Ristic et al. 2002). Infants as young as eight weeks old watching a virtual adult human’s face respond faster to a probe when it is congruent with the adult’s eye movement than when the probe and gaze are incongruent (Hood et al. 1998;). Ristic et al. (2002) tested a split-brain patient to find a distinct pathway in the human brain for gaze cues; the results suggest that the biologically irrelevant arrows are linked to activity in both brain hemispheres, while gaze cues elicit activity only in the hemisphere responsible for face recognition. All of these studies suggest that orienting to eye gaze may be evolutionarily more important than orienting to other types of directional cues.

However, there is conflicting research showing that there may not be a difference between eye gaze and arrow cues (Tipples, 2002; Farroni, Johnson, Brockbank, & Simion, 2000). Farroni et al. (2000) found that it may be the movement of the eyes, rather than the final direction of gaze, that orients infants' attention. Tipples (2002) suggested that the previous differences between the two types of cues might have been due to differences in the nature of the cues: human faces had two cues (the two pupils), neither of which was at fixation, while for arrows there was typically only one cue which was located at fixation. After controlling for these differences, there was no significant difference in reaction times between the two types of cues, suggesting that eye gaze cues are in fact not unique.

Hypothesis

The purpose of this experiment was to investigate the development of understanding of symbolic cues such as arrows. Children from three to five years of age were selected because during that time children are learning about the nature of symbols. Three-year-olds do not have a great deal of experience with symbols; they are indeed just beginning to achieve dual representation when it comes to pictures and models (DeLoache, 1987; 1991). With such minimal experience, these children presumably do not understand the symbolic nature of cues such as arrows. Throughout the next two years, however, children begin to acquire skills with symbols as they learn to recognize specific letters and numbers and to apply their meanings.

The hypothesis of this project is that there will be development in the understanding of symbols during the age range tested. Three–year-olds, who have not been exposed to as wide a variety of symbols as adults, are predicted to respond to the "weight" of arrow cues (i.e. to respond faster to targets that appear on the side of the weight), regardless of which side the arrow actually indicates symbolically. This will be tested using non-arrow weighted cues (square cues, see methods) and ambiguous cues in addition to normal arrows. Older participants, on the other hand, have presumably had more experience with symbols and therefore are more likely to be cued by the arrow's symbolic direction rather than its weight. I therefore predict that five-year-olds will have faster reaction times to the target that is cued by the direction of the arrows than to those predicted by weight only. Thus, there will be a developmental shift in the aspect of the arrow that cues them, from a perceptual understanding to a symbolic understanding, between three and five years of age.

CHAPTER 2
METHODS

Participants

Fifty-one participants were recruited using local birth announcements and by word of mouth. Participants ranged in age from approximately 2 years, 4 months to 4 years, 9 months at the time of the test (mean age = 3 years, 8 months). Two children were excluded from analysis due to experimenter error. The final sample consisted of 49 participants (23 males and 26 females). The ages of these participants were as follows: 6 2- to 3-year-olds, 24 3- to 4-year-olds, and 19 4- to 5-year-olds.

Apparatus and Stimuli

The children sat either in a parent's lap or in a chair by themselves 60 cm from a presentation screen (43 by 58 cm). A curtain surrounded the testing area to prevent distraction. A computer was connected to an InFocus projector (model LT755), which projected the stimuli onto the screen. Two Panasonic VHS cameras (model AG-188-Proline) were used to record each session. One camera was positioned above the participant, allowing the experimenter to monitor the participant's eye movements. Another camera was positioned behind the participant and recorded the stimuli appearing on the screen. The images were combined using a Videonics Digital Video Mixer (model MX-1). Behavior coding was done offline using the Noldus Observer 5.0.

A flashing bulls-eye (12º by 12º) was flashed in the center to initiate fixation. The bulls-eye was then replaced by one of 10 cues, measuring 10º by 3º. Figure 1 shows each of the cues used. *Weighted* cues have perceptual weight on only one side of the horizontal line, while *balanced* cues have weight on both sides. *Arrow* cues have a symbolic meaning (i.e. they “point” in one direction or the other), while *square* cues do not indicate direction symbolically. Finally, *ambiguous* cues would be interpreted in different ways depending on whether weight or symbolism was used for attention cuing. For example, if the ambiguous weighted arrow cued attention based on symbolic direction, participants would be cued to look in the opposite direction as if it cued based on perceptual weight.

Combinations of these traits (weight, balance, shape, and ambiguity) give six types of cues. Weighted arrow, ambiguous weighted arrow, balanced arrow and square cues are not completely symmetric and therefore can cue to either the right or left side no matter which type of cuing (symbolic or perceptual) is taking place. Ambiguous balanced arrow and balanced square cues are symmetric and thus only one form is possible for each (i.e. there are not left- and right-cuing forms).

Following the cue, a target appeared either to the right or to the left of the cue. A variety of targets was presented in order to maintain participants’ attention. Most targets were pictures of cartoon animals, although some were pictures of common objects such as modes of transportation. Each target was 12º by 10º.

Half of the trials were *valid*, while the other half were *invalid*. For weighted arrows and balanced arrows, valid trials were those in which the direction of the arrow’s point and the target were congruent, and invalid trials were those in which the direction of the arrow and the target were incongruent. For square cues, valid trials were those in which the target was congruent with the weight, while invalid trials were those in which the target was incongruent with the weight. Ambiguous weighted arrows were presented such that half of the targets were congruent with the arrow's direction and thus incongruent with the weight, while the remaining half of the target positions were incongruent with the direction but congruent with the weight. Ambiguous balanced arrows and balanced square cues are symmetric in terms of weight and direction and were therefore not associated with valid or invalid trials.

Design

Participants attempted up to five blocks of 20 trials each. Each block consisted of equiprobable combinations of type of cue (weighted, balanced, ambiguous weighted, ambiguous balanced, square weighted, or square balanced), cue variation (left, right or ambiguous), and target position (left or right).

Procedure

After obtaining the informed consent and assent, participants and their parents were led to the testing room, where they sat in a chair facing the screen. The experimenter gave the instructions to pay close attention to the middle of the screen because after the "colorful circles" (the bulls-eye) and the cue, a funny picture would come up on one of the sides. Participants were asked to name the target as soon as they saw it appear (e.g., to say "tiger" if the target was a tiger). The verbal response was not used as data; it simply promoted the eye movements that would later be coded for data analysis. Finally, participants were told that they could stop at any time they wished.

After all questions were answered, the experiment began. On the screen, a series of still-frame images was shown. An example of the display sequence is shown in Figure 2. When the experimenter determined that the participant was looking, she pressed a key to begin the first trial. The bulls-eye flashed on the screen for 1000 ms, followed by one of the cues for 1000 ms. Finally, the cue disappeared and a target appeared in the periphery until the participant made an eye movement and identified the target. The experimenter then initiated the next trial sequence with a key press. Up to 100 trials were presented based on the participant's interest and willingness to continue. After completing the experiment, participants chose a prize and received a certificate of completion.

Data Analysis

Videotape of participants' eye movements was analyzed frame-by-frame (30 frames per second) following completion of the experimental session. Reliability between coders was high for the usability of each trial (Cohen's Kappa = .92). One coder measured the onset of the cue and the target and determined whether or not each trial could be used for analysis. In order for a trial to be usable, participants were required to fixate the central cue for the entire 1000 ms that it was present, and to make an eye movement directly from the cue to one of the possible target locations. Any trial in which the participant failed to fixate the cue or made an eye movement away from the cue before the target was presented was considered unusable for data analysis. In addition, any trial in which the participant looked in the direction of one of the two possible target locations while the cue was still present was not used in analysis; these were considered to be anticipated looks. Finally, any trial in which an eye movement was made in more than 2000 ms was excluded.

A second coder measured the onset and direction of the first eye movement made by the participant after the target was presented during each usable trial (Cohen's Kappa = .92). The reaction time was defined as the time between the first frame of the target's appearance and the onset of the first eye movement.

Predictions

It is predicted that there will be significant differences in RTs to different types of cues between younger children (3 years old) and older children (5 years old). Younger children are expected to respond to the weight of the cues, rather than to the symbol. Thus, the younger children in the study should not display different RTs to any cues containing weight on both sides (balanced square, ambiguous balanced arrow, or balanced arrows). However, for all other cues (ambiguous arrows, weighted arrows, and square cues), the younger participants should have faster RTs to targets on the weighted side than to those on the non-weighted side of the cue, regardless of the symbolic meaning of the cue. Therefore, for ambiguous arrow cues, they should have faster RTs to the target when it is congruent with the weight but incongruent with the direction of the arrow's point. Younger participants should have faster RTs to valid trials than to invalid ones when cued by a weighted arrow. Finally, when square cues are presented, they should have faster RTs to targets on the side of the weight than to those on the non-weighted side.

Older children in this study are expected to have an understanding of the symbolic meaning of an arrow cue. Older participants, like younger ones, should not be cued in either direction for balanced square or ambiguous balanced arrow cues (i.e., there should be no difference in RTs to targets presented to either side of the cue). However, unlike the younger participants, older children should show faster RTs on valid trials than to invalid ones when a balanced arrow precedes the target. For ambiguous weighted arrows, older participants should be cued in the direction of the arrow's point if they are cued by the symbolic nature of the arrow. Thus, they should have faster RTs to targets that are congruent with the point, but not the weight, of the arrow. Older participants should have faster RTs to valid trials than invalid ones when a weighted arrow is used. Finally, square cues may or may not cue the older participants. Because the square cue does not carry any value as a symbol, it may not cue participants at all; however given this lack of symbolic meaning participants may be cued by the weight and thus show faster RTs to targets that are congruent with the weight of the cue.

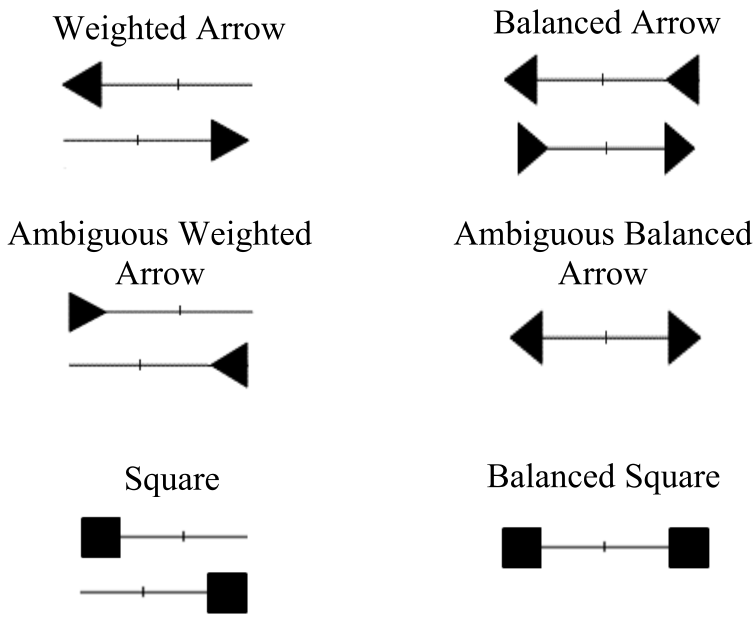


Figure 1. Terminology of cues used. There are six types of cues, giving a total of ten unique cues. Weighted arrows are cues in which the perceptual weight of the arrowhead is congruent with its symbolic direction. Ambiguous weighted arrows, however, point in the opposite direction as the weight. Square cues have weight on one side, but do not have a symbolic direction. Balanced arrows have equal weight on both sides, each pointing in the same direction. The ambiguous balanced arrow points in both directions (equal weight on both sides), and the balanced square contains equal weight on both sides but does not carry a symbolic meaning. Each cue is displayed for 1000 ms before either a valid or an invalid target is presented.

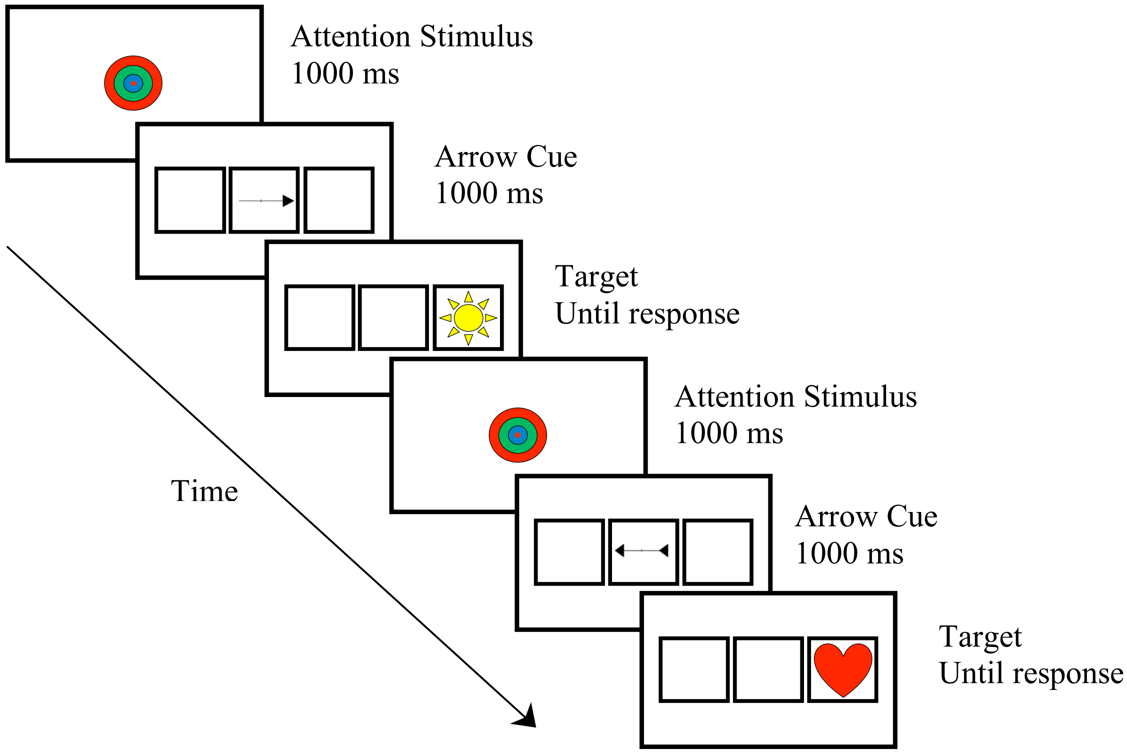


Figure 2. An example of two consecutive trials. Each trial began with a flashing bulls-eye to promote fixation, after which an arrow cue and then a target appeared. The first trial shown uses a right-pointing arrow cue, and the target appears on the side of the symbolic direction of the arrow, and is thus a valid trial. The second trial shown uses a balanced arrow which points in the direction opposite the target's location and is thus invalid (see text).

Table 1. Summary of the hypotheses of the current study. "Presymbolic" indicates the younger children tested (i.e. 3-year-olds), who are expected to be cued by the weighted nature rather than the symbolic nature of the cues. "Symbolic" indicates older children (5-year-olds), who are expected to have an understanding of the symbolic meaning of arrow cues.

STIMULUS	**PRESYMBOLIC**	**SYMBOLIC**
	Should not be cued at all	Should not be cued at all
	Should not be cued at all	Should be cued in arrow direction (due to symbol)
	Should be cued to "weighted side" (due to weight)	Should be cued in arrow direction (due to symbol)
	Should be cued in arrow direction (but due to weight)	Should be cued in arrow direction (due to symbol)
	Should be cued to "weighted side" (due to weight)	May be cued to "weighted side" (due to weight), or may not be cued at all (due to lack of symbolic meaning)

CHAPTER 3
RESULTS

A total of 1039 usable trials were observed across all participants. Of these, 126 trials (12.1%) were incorrect (i.e. the participant's initial glance was in the direction opposite the target) and were thus removed before analysis. Three additional trials (<.01%) were removed due to having response times (RTs) greater than 2000ms. The remaining 901 trials were used for analysis.

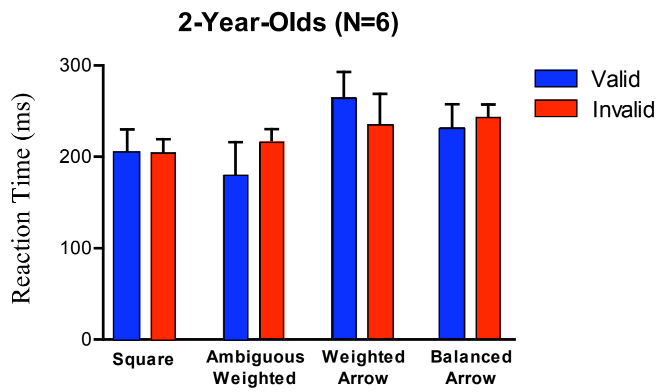
First, block effects were examined to determine if there was a difference between RTs in the first and second blocks. No other block effects were tested because the majority of participants (34 out of 49) completed two or fewer blocks. The mean RT of participants in the first block of trials (M = 213ms, SD = 25) was significantly slower than the mean RT in the second block (M = 198ms, SD = 41), F (1, 33) = 7.233, p = .011. This indicates that participants became faster at responding to the targets as they completed more trials.

Prior to analyses, a paired-samples t-test was used to examine whether there were RT differences between trials in which the target appeared to the right and the left of the cue. There were no significant differences across conditions (p > .1), and thus, right and left target conditions for corresponding cues were averaged for the remaining analyses.

The mean correct RTs for participants who contributed to all conditions were analyzed with a repeated measures analysis of variance (ANOVA) with validity (valid and invalid) and cue condition (ambiguous weighted, weighted arrow, square, and balanced arrow) as within-subject variables and age (2, 3, and 4 years) as the between-subjects variable (see Figure 3).

There were no significant main effects of validity (F (1, 15) = 1.002, p = .333) or cue condition (F (3, 45) = 1.160, p =.335). There were also no interactions between the variables (cue condition and age: F (6, 45) = 1.766, p = .128; validity and age: F (2, 15) = .006, p = .994; cue condition and validity: F (3, 45) = 1.135, p = .345; cue condition, validity and age: F (6, 45) = 1.120, p = .366).

A.



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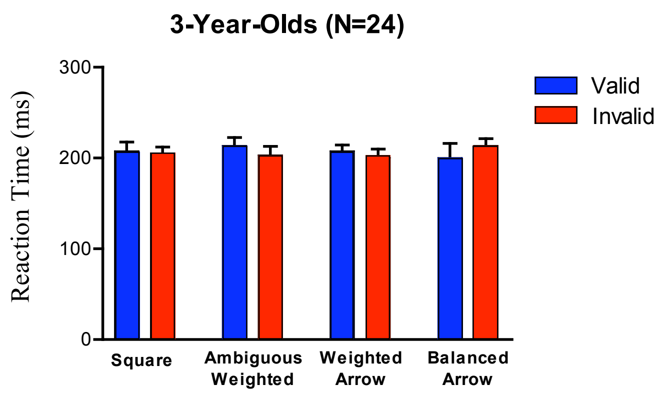

C.

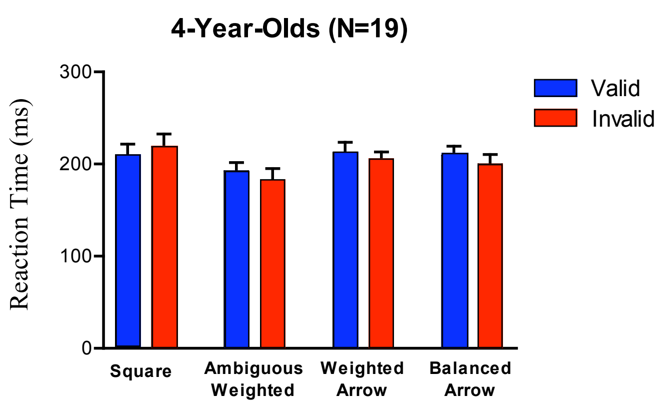

Figure 3. Mean RTs for each condition, for A) 2- to 3-year-olds, B) 3- to 4-year-olds, and C) 4- to 5-year-olds. There were no significant differences between valid and invalid trials for any age group in any condition.

CHAPTER 4
DISCUSSION

The purpose of this experiment was to examine the development of the understanding of arrow cues. An orienting task was used to determine whether 3- to 5- year old children were cued by the symbolic nature of arrows, or if they were rather cued by a different, more perceptual aspect of arrows (weight). It was hypothesized that younger children might be cued to the side of the arrow head due to the weight on that side (and not its symbolic meaning), while older children would respond to the directional meaning of the arrow rather than the weight).

The results of the experiment did not support the hypotheses. Participants did not respond differently in the various cue conditions, suggesting that neither the perceptual weight nor the symbolic meaning of an arrow cued their attention. In addition, no age differences were found using this paradigm.

Although the theory proposed in this paper was not upheld, the results still give a glimpse into the symbolic development that takes place in young children. It is possible that children between the ages of 3 and 5 years do not yet understand the directionality of an arrow, but are also not cued by the arrow's weight. In adults, an understanding of directionality prevails over the role that weight plays in cueing by arrows (Tipples, 2002), but the point at which this understanding develops is not established and may not occur during the age range tested. Similarly, this age might be a transitional stage at which some children understand what an arrow symbolizes, while others do not, resulting in the concealment of a significant effect. A clearer picture of directional understanding may be found by testing children of different ages. Proposed future study includes testing infants in a similar paradigm to determine if weight plays a role early in life, when symbolic understanding is unlikely to have any influence on cuing. Also, older children will be tested to establish if the transition period extends to children older than those tested in the current study.

Additionally, it is possible that there were small differences in RTs to the different cues, but that we did not have enough power to detect them. If this was the case, then the sample size would need to be increased to increase the the number of usable trials for analysis. An increase in power may reveal differences that support the hypotheses of this study.

Finally, the results may be different than expected because of an inability of the orienting paradigm to detect differences in symbolic understanding. If this is so, then differences may have been present but the RT analysis was not able to show them. A simple assessment using non-RT behaviors has been proposed to search for these differences in young children. The study will present 3-year-olds with two identical buckets on either side of a sign containing the weighted arrow cues used in the current study. The children will simply be asked in which bucket they expect to find a hidden toy. If the participants take into account the presence of the arrow in deciding which bucket to choose, then the various types of cues may influence their decisions in different ways. For example, presymbolic children may choose the bucket that corresponds to the weight of the arrow, while those who have an understanding of the arrow as a symbol would be expected to choose the bucket that the arrow points to. Thus, different responses to the various cues may reveal that non-symbolic factors such as weight indeed play a role in young children's understanding of arrows.

The current study sought to investigate how the perceptual weight of an arrow influences how young children interpret and are cued by the arrow. Based on the results of the experiment performed here, there is no evidence that weight plays a role in the understanding of three- to five-year-old children. However, the study also failed to show that symbolic understanding plays such a role, making it difficult to understand exactly how children are cued directionally. Continued research is needed to examine other possible factors that influence how young children respond to arrow cues.

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