DEVELOPMENTAL EMERGENCE OF JOINT VISUAL ATTENTION

by

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Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy

at

Dalhousie University
Halifax, Nova Scotia
August, 1996

ISBN 0-612-15957-4

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ABSTRACT

This work examines the development, in infants aged 6 through 19 months, of a specific type of attention called joint visual attention. In a series of four experiments, employing two different paradigms, three main issues are examined: age of emergence, cues employed, and origins of the response. Based on the pattern of findings conclusions are drawn regarding the nature of the infant's social understanding. With respect to age of emergence, the results indicate a somewhat later age of onset for joint visual attention than a number of previous investigators have concluded; 8-9 months as opposed to 6 months. With respect to the cues employed, the findings suggest that, with development, infants progress from relying exclusively on information about another's head orientation at about 8 months to a consideration of both head and eye orientation, to finally being able to align with changes in another's eye orientation alone sometime after 16 months. Finally, in terms of the origins of the joint visual attention response, while infants were able to learn to align with a model from about 8 months there seemed to be some constraints on the nature of the cues which could be associated with such a response. In particular, the head plus eyes cue was found to have inherent directional properties. Based on the collective findings of this work, it is concluded that: 1) early joint visual attention occurs in the absence of an understanding of directed visual attention in others, 2) nativist or empiricist roots can account for the development of joint visual attention, and 3) rather than requiring an understanding of other minds, it may be by way of engaging in joint visual attention that infants gain the experience they need to help them acquire an understanding of other minds.

ACKNOWLEDGEMENTS

I thank the parents and infants who graciously gave of their time to participate in this research. Without their interest and committment this work would not have been possible.

I thank Dr. Chris Moore for supervising me in a collegial, respectful fashion and for creating or supporting many academic opportunities. His intellectual excellence has served to challenge and inspire me.

I thank my committee members, Dr. John Barresi and Dr. Vincent LoLordo whose careful, thoughtful reading of this work has contributed significantly to the caliber of the final product.

I thank Dr. Philip Dunham who, as my honour's supervisor, ignited a spark of excitement for infancy research and taught me the basic skills I needed to pursue it.

I thank Paula Bennett, Kerri L'Esperance, Susan Pollack, David Rouse-McLaughlin, Sara Shepherd, and Carol Thompson for their diligent, careful work as research assistants.

I thank Nameera Akhtar, Nadine DeWolfe, and Isabel Smith who have been unwavering sources of support in both academic and personal spheres.

I thank my parents, who sometimes found it hard to understand what I was doing and why, but who loved me and encouraged me through it all.

Lastly, I thank Frank who, in many ways, has toiled as hard as I have to get through my graduate training.

Overview

This work examines the development, in infants, of a specific type of shared attention called joint visual attention. In a series of four experiments, with infants spanning the range from 6 to 19 months, three issues are explored: the age of emergence of joint visual attention, developmental differences in the cues used by infants for establishing joint visual attention, and the roles of learning vs. innate abilities in the development of the joint visual attention response. Based on the findings of these experiments conclusions are drawn regarding the nature of the infant's emerging social understanding.

Definition of Joint Attention

In the broadest sense, joint attention involves a shared focus of attention which may take many forms (see Tomasello, 1995; Baldwin, 1995). Both the manner in which the shared focus is demonstrated as well as the manner in which it is experienced can vary greatly depending upon the definition. For example, the action of sharing attention can be overtly manifested or covertly experienced, shared attention can be initiated by either partner in a dyadic interaction, and it can involve varying degrees of cognitive awareness of the shared focus by each partner. The various combinations of these variables yield forms of joint attention which are qualitatively very different. While many investigators have used the term joint attention in its broadest sense, in the present work a more narrowly focused approach has been taken. Before proceeding further the focus of the present work will be outlined, so that it is clear, from the outset, what was studied and why.

The present work focuses on the development of infant social understanding. Joint attention is of interest in this respect because of its connection to infants' emerging awareness of other people and their understanding of others' actions. In the present work, a form of joint attention called joint visual attention has been investigated. Joint visual attention involves, quite simply, "looking where someone else is looking" (Butterworth, 1991, p. 223). The present focus has been on infant rather than adult initiated bouts of joint visual attention (which emerge earlier, developmentally; Schaffer, 1984) because they provide more insight into the infant's social awareness. Joint visual attention has been studied rather than another form of shared attention, primarily because of its simplicity. Compared with other forms of joint attention, joint visual attention is overtly manifested in a set of simple behaviors (such as head orientation, eye orientation, and body posture) which makes it very easy both to define and to measure. Further, the fact that it is so simple suggests that joint visual attention may be one of the earliest forms of joint attention to appear, developmentally. Consequently, studying joint visual attention allows inferences to be drawn regarding later, more sophisticated, forms of joint involvement and, ultimately something of the nature of the infant's social understanding to be learned. To place joint attention in the broader context of emerging social awareness, some of the significant social developments in the first two years of life will be outlined.

Infant Social Development

The period of early infancy, including approximately the first eight months of life, is best characterized as one of dyadic interaction or "primary intersubjectivity" (Trevarthen, 1979). During this period, infants' attention and actions are directed either at objects or at people. Although adults frequently employ objects in their interactions with infants, at this point infants do not yet effectively coordinate their attention to both people and objects. Much research has focused on examination of mother-infant dyadic interaction during the period of early infancy and the factors which influence the nature and quality of this interaction. Changes in such variables as maternal facial expressions (e.g., Gusella, Muir & Tronick, 1988), vocal patterns (e.g., Werker & McLeod, 1989), and degree of social contingency (e.g., Dunham, Dunham, Hurshman, & Alexander, 1989) indicate not only infants' perceptual sensitivity to variations in these factors but also their preference for certain aspects which serve to promote further social interaction. In particular, infants prefer to look at faces over other complex stimuli, they focus on the eye area of the face more than any other region (Hainline, 1978; Haith, Bergman, & Moore, 1977), they prefer a pattern of contingent reciprocity (Dunham et al., 1989), and a variable high-pitched manner of speaking termed "infant-directed speech", which adults tend to naturally produce in their interactions with infants (Werker & McLeod, 1989).

The period of middle and late infancy, that is, from the ninth month of the first year into the second year of life, is best characterized as one of triadic interaction (Bakeman & Adamson, 1984). Infants still attend to, and act on objects and they still attend to, and interact with people; but, now they also have the capacity for attending to both objects and people at the same time. This new capacity has been termed "secondary intersubjectivity" (Trevarthen & Hubley, 1978) and it marks the infant's transition into a period of qualitatively different social awareness. Joint attention, as described earlier, is certainly one exemplar of triadic interaction in that it requires the infant to coordinate her attention toward both a social partner and an object of mutual interest. Other exemplars of triadic interaction include behaviors such as social referencing (e.g., Feinman, 1982; Sorce, Emde, Campos, & Klinnert, 1985; Hornik, Risenhoover, & Gunnar, 1987), and protocommunicative gestures (e.g., Bates, 1979; Bates, Camaioni, & Volterra, 1979). In the sections which follow, each of these behaviors will be described in turn and the main empirical findings which have particular relevance for the present work on joint attention will be reviewed.

Social Referencing. Broadly defined by Feinman (1982), social referencing refers to conditions under which an infant relies on another person for cognitive or emotional information in order to assist her in forming her own appraisal of a situation (whether the situation is a person, object, or event). According to Feinman's broad definition, the information that the infant obtains through social referencing can be actively solicited by her or can simply be casually observed. Further, the information obtained through social referencing can be emotional in nature (and consequently, can inform the infant about how to feel in a given situation) or it can be instrumental in nature (and can instruct the infant about how to behave in a given situation). Other investigators of social referencing (e.g., Campos, 1983; Klinnert, Campos, Sorce, Emde, & Svejda, 1983) have employed a narrower definition whereby the infant is required to actively seek another's input and the information conveyed by the adult is specifically emotional in nature. Despite differences in definition, for the present purposes, the commonalities among conceptualizations are that the process of social referencing involves a referer (the infant), a referee (the adult), and a referent (the ambiguous person, object or event) (Feinman ,1992). Further, in the act of social referencing, the referer (the infant) must coordinate her attention between the referee and the referent in order to obtain and make use of the new information. In so doing, the referer (the infant) is engaged in triadic interaction which clearly implicates joint attention, as described earlier.

In the prototypical social referencing paradigm, the infant, accompanied by a parent (usually the mother) encounters an unfamiliar situation. In most work, the unfamiliar situation has been a strange toy (e.g., Hornik et al., 1987) but other worl has included an unfamiliar person (e.g., Feinman & Lewis, 1983), or an ambiguous physical environment (i.e., the visual cliff; e.g., Sorce, et al., 1985). Further, some work has also been done in which infant referencing of a stranger, rather than the mother, has been examined (e.g., Klinnert, Emde, Butterfield, & Campos, 1986). Upon encountering the unfamiliar situation, the mother portrays some predesignated emotional expression (e.g., fear or joy) either at a predetermined time in the session or in response to a specific cue from the infant (such as a look to the mother). In most cases, the mother's gaze has been directed toward the unfamiliar toy. Work has varied in its inclusion of verbalizations to accompany the portrayed facial expression (see Feinman, 1992, for a review of various paradigms). Two aspects of infant behavior are typically measured: infant looking (i.e., alternating between toy and mother) and infant behavior toward the new toy (i.e., approach/touch, or avoid).

Feinman and Lewis (1983) investigated social referencing in 10-month-olds in response to encountering an unfamiliar stranger. Mothers provided either a positive or negative message about the stranger to their infant either directly (i.e., speaking to the infant) or indirectly (i.e., speaking to the stranger). Results indicated that infants' behavior toward the stranger was more likely to be affected when the message was direct. While some have interpreted this finding as evidence of a social referencing effect, unfortunately, it is open to other interpretations. Most notably, for the present purposes, it could indicate that the infant did not understand that the stranger was the referent of the mother's message and consequently, the infant's subsequent behavior was likely influenced by a general modification of her mood (i.e., mood contagion) which "appeared" to be directed at the stranger but only because other possible referents were not available in the set-up.

The occurrence of social referencing in response to the visual cliff has been investigated in 12-month-olds by Sorce, Emde, Campos, & Klinnert (1985). Sorce et al. had mothers enact an expression of fear or joy in response to their infants approaching the border between the shallow and deep sides of the cliff. Results indicated no social referencing effect (i.e., no infants crossed the border regardless of the mother's facial expression) when the drop-off was deep (3 1/2 feet). However, when the drop-off was reduced to 12 inches, a social referencing effect was found in that infants who observed their mothers enacting an expression of joy tended to cross the border, while those infants who observed their mother enacting an expression of fear did not. These findings suggest that infants are more likely to seek and employ information from others via social referencing when they are faced with a truly ambiguous situation (e.g., a moderate rather than a large drop-off). Further, while these findings provide stronger support for the infant's understanding of the referent of the mother's emotion, clearer evidence would come from work in which more than one referent is possible and infants demonstrate differential responses congruent with their mother's behavior.

Further progress on this issue can be found in the work of Hornik, Risenhoover, and Gunnar (1987) who present evidence to indicate that 12-month-old infants selectively avoid toys which previously received a negative appraisal from their mothers when these toys are encountered at a later time in a free play situation involving many toys. This finding does suggest a social referencing effect. However, since only one referent was present at the time of the mother's portrayal of emotion, again the infant does not have to possess an understanding of reference, she simply has to remember the toys which were presented during the initial portion of the session when mother expressed a negative appraisal.

Work which better addresses the issue of reference is reported by Baldwin and Moses (1994) who outline preliminary findings of a study with 12- and 14-month-olds. In the Baldwin and Moses study, infants were presented with pairs of toys, only one of which was the referent of the experimenter's gaze/affective reaction. During the affective labelling phase of the study, infants were presented simultaneously with pairs of toys, one of which was pushed forward for them to manipulate. The experimenter then portrayed either positive or negative affect, in one of two conditions: joint (whereby the experimenter focused her gaze on the same toy as the infant) or discrepant (whereby the experimenter focused her gaze on the toy to which the infant was not attending). During the test phase, both toys of a pair were placed equidistant from the infant and within her reach. The amount of looking towards the experimenter's face during labelling and the degree to which infants played with each toy during the test were noted. Results indicated a social referencing effect in both labelling conditions and both age groups, suggesting that, from 12 months, infants can determine the referent of another's attention and emotion, and can use this information to modify their subsequent behavior. Mumme, Won, and Fernald (1994) report a similar pattern of findings.

Gewirtz and Pelaez-Nogueras (1992) investigated a new issue for the social referencing literature: the possibility that social referencing may be acquired via a process of learning. Infants ranging in age from 9 to 12 months each participated in a series of 8 to 13 successive daily training sessions in which formerly meaningless gestures were paired with positive and negative consequences for the infant in an attempt to see if infants could learn to use neutral cues to signal emotional consequences (i.e., positive and negative). In the set-up, mother and infant were seated next to each other with the infant facing a puppet theater in which an unfamiliar toy would appear. On each trial, the infant was presented with a toy (which was covered) and was permitted a window of opportunity in which to reference her mother. When the infant looked at her mother, the mother enacted one of two facial expressive cues: fist to nose, or palms to cheeks. The linking of each of these cues with positive or negative consequences was counterbalanced for the two groups of infants tested. When the infant turned back to the theater after referencing her mother, the toy was uncovered and it was moved within the infant's reach. Consequences for infant reaching were delivered dependent upon cue condition. The negative consequence consisted of an aversive noise plus rapid movement of the toy, while the positive consequence consisted of pleasant music and gentle rocking of the toy. Results indicated that infants successfully learned the signal/predictive value of the formerly neutral cues and used this information to attain the toy under positive conditions, and to avoid the toy under aversive conditions. This pattern of findings suggests that the social referencing response may be acquired via a process of operant conditioning.

In summary, the work reviewed on social referencing indicates three main points which have relevance for the present work. First, the behavior of social referencing involves active coordination of the infant's attention to both an interactive partner and an unfamiliar situation, thereby implicating joint attention. Second, infants do not reliably demonstrate social referencing, including the ability to discriminate the referent of the emotional display, until near the end of the first year of life. Third, learning is one avenue by which infants can come to appreciate the significance of the social-emotional signals of another and to employ them to affect their own behavior.

Protocommunicative Gestures. Prior to the emergence of formal language, infants come to use gestures as a way of transmitting messages to others in their environment. Lock (1978) describes the emergence of formal language as a series of transitions from action to gesture to symbol. In this way, protocommunicative gestures can be seen to emerge as infants move from simple, direct motor actions on objects/people to use of some modified form of these motor actions to communicate a specific message to others. Two examples should help to illustrate this process. First, in the process of trying to obtain an object that is within reach the infant extends her arm with an outstretched hand and closes her grasp around the object. Later, developmentally, the infant can be seen to employ a similar gesture, involving an extended arm and an opening/closing hand to communicate her desire to obtain an object that is out of her reach. Similarly, in the process of being lifted up by a caregiver, the infant's arms get raised, somewhat, as a function of the pressure applied. The infant then later comes to use a gesture of arms held up to indicate, to her caregiver, her desire to be picked up. In this way, motor actions become ritualized and are employed for communicative purposes.

Elizabeth Bates and her colleagues (Bates, 1976; Bates, 1979; Bates, Camaioni, & Volterra, 1979) have researched, extensively, the place in communicative development of such protocommunicative acts. Bates and colleagues were the first to define two specific subtypes of protocommunicative gesture: the protoimperative and the protodeclarative. Protoimperatives have been defined, by Bates and colleagues, as the use of gestures for instrumental purposes (i.e., the attainment of some specific end-goal). In this way, the two scenarios described above (i.e., the infant indicating a desire to be picked up or a desire to secure an object which is out of reach) can be seen to be examples of protoimperatives. In contrast, protodeclaratives have been defined as the use of gestures for the purpose of directing another's attention toward some specific place in the environment. Examples of this type of protocommunicative gesture can be found in the infant's showing of an object to another by way of pointing toward it (with no instrumental goal intended). Because of the focus in the present work on shared attention as a line of insight into the nature of the infant's emerging social understanding, it is the latter of these two types of protocommunicative gestures, the protodeclarative, which is of particular importance.

Work on protodeclarative pointing has taken two directions, with investigations examining aspects of infants' comprehension as well as their production of such gestures. Investigation of the comprehension of protodeclarative points has involved studying the degree to which infants follow the points of others, and consequently, the degree to which they make use of others' pointing as a signal for directing their own attention. In general, the results of this research indicate that infants tend to follow others' points to nearby objects from approximately 9 months (Murphy & Messer, 1977) or 10 months of age (Leung & Rheingold, 1981; Butterworth, 1991), while points to more distant objects are followed by infants at about 14 months (Murphy & Messer, 1977) or 15 months of age (Morissette, Ricard, & Gouin-Decarie, 1995). It is cautioned that it is likely to be the case that it is easier for infants to find targets which are close in proximity to the pointing cue (in fact, it may not even be necessary for infants to actually follow this "cue" in order to "find" the target). In keeping with this notion, Morissette et al., in their longitudinal work with infants from 6 to 18 months of age, found that prior to 12 months of age, infants were significantly more likely to look at the adult's pointing hand than at the target of her point. It was not until 15 months of age (and older) that Morissette et al. found that infants successfully found the target of the point on a significant proportion of trials.

Investigations of the production of protodeclarative points has involved studying the extent to which infants produce points themselves as a way of directing the attention of the others in their environment. Work on the production of pointing has investigated both the age at which, as well as the conditions under which, infants produce points. In general, the work on age of appearance indicates that it is not until at least 12 months (Desrochers, Morissette, & Ricard, 1995; Franco & Butterworth, 1991; Lempers, Flavell, & Flavell, 1977; Lempers, 1979; Leung & Rheingold, 1981) or 14 months of age (Murphy & Messer, 1977) that infants are found to be reliably producing points of their own. In fact, in their longitudinal work on pointing, Desrochers et al. found that "communicative pointing" (which they defined as pointing accompanied by a look to the adult) emerged somewhat later, at 15 months, than "noncommunicative pointing" (which they defined as pointing without such an accompanying referent look). In terms of the conditions under which pointing was found to be produced, Franco and Butterworth (1991) found that 12- to 19-month-old infants were much less likely to produce points under conditions where they were alone, as compared with conditions under which they were accompanied by an adult (regardless of whether the adult was active and pointed toward the target herself, or passive and did no pointing). In more recent work by DeWolfe, Moore, and Bennett (1996), 10-15-month-old infants who had been observed by parents to be pointing frequently in the home environment were tested in the lab under one of three conditions in which the mother's attention to a target varied. In the match group the infant's mother attended to an activated target, in the mismatch group she attended to a static target, and lastly, in the unavailable group mother was present but engaged in an unrelated activity. In contrast with previous thinking regarding pointing as a signal for redirecting another's attention, DeWolfe et al. found that infants pointed more frequently in the match condition, where their mothers were already attending to the same target. The authors interpret their findings as suggestive of the infant's use of the protodeclarative not as a way of redirecting her mother's attention to the object but as a way of "commenting" on an object of shared interest and of prolonging an interaction.

So how does this information relate to the present work? The important points to be gleaned from this section on early social development are as follows. First, at the end of the first year of life and into the second year, the infant makes a shift in her way of interacting with people and acting on objects which is characterized by a capacity for coordinated attention to both. Second, this shift into triadic interaction makes possible a number of new, more complex behaviors such as social referencing and protocommunicative gestures. Third, these new behaviors implicate joint attention and they further, play a role in the development of the infant's social understanding.

Infant Social Understanding

How can the infant's behavior in triadic interactions be interpreted? What can it infer about her emerging social awareness? Interpretations of the nature of the infant's social understanding as indicated by her participation in various forms of triadic interaction (including joint attention, social referencing, and protocommunicative gestures) vary widely. In a recent review paper, Moore (1996) provides a thoughtful comparison of a variety of theories of infant social understanding. As outlined by Moore, models of infant social understanding attempt to account for a simpler set of features than the later emerging, more sophisticated, "theory of mind" characteristic of the late preschool period. As such, models of infant social understanding need address only the issues of: 1) coding of psychological relations including a variety of orientations and attitudes towards objects, events, or people in the environment, and 2) self-other equivalence including the notion that self and other have the capacity for both similarity (and difference) in their psychological relations with objects, events, and people in the environment. While Moore identifies each model reviewed as derivative of a particular school of thought, for the present purposes it is useful to think of the available models of infant social understanding as spanning a continuum from conservative through liberal interpretations of the infant's early social behavior. Rather than provide an exhaustive review of all of the models contrasted by Moore, the range of current interpretations regarding the nature of the infant's social understanding which have clear implications for the present work on joint visual attention will instead be illustrated by way of example.

On the liberal end of the continuum, Baron-Cohen (1994; 1995; Baron-Cohen & Ring, 1995) has proposed a Mindreading System to account for the emergence of the attribution of mental states to agents (self and others). Baron-Cohen's Mindreading System is comprised of three modular components (the Intentionality Detector, the Eye-Direction Detector, and the Shared Attention Mechanism) which are activated during infancy and which serve to trigger the functioning of a fourth module, the Theory of Mind Mechanism, during the preschool period. While Leslie (1987) originally proposed the Theory of Mind Mechanism (ToMM) as a modular entity, for the present purposes the main components of interest are the three components more recently developed by Baron-Cohen which are aimed at providing an account of social understanding during the period of infancy. The Intentionality Detector (ID) performs the function of coding stimuli as volitional, that is, in terms of goals and desires. The Eye Direction Detector (EDD) performs the functions of detecting eye-like stimuli and of coding their direction of gaze. Both ID and EDD are proposed by Baron-Cohen as coding dyadic representations between agents and objects (e.g., I see mother; mother wants the cup). While ID is proposed to be fully functioning by 6 months, EDD is proposed to be in place from as early as 4 months of age. In contrast, the Shared Attention Mechanism (SAM) performs the function of coding when self and other are attending to the same object. Unlike ID and EDD, the representations coded by SAM are triadic in nature (e.g., I see mother sees the cup). Further, these representations are built from dyadic inputs received from ID and EDD. Baron-Cohen proposes that SAM is fully functioning from about 9 months of age.

From the point of view of the present work, two of the features of Baron-Cohen's model are particularly salient. First, he identifies the infant, from very young ages, as both attending to and coding the direction of eye gaze of others. Second, he affords the infant, from very young ages, the capacity for representing agents (self and others) in psychological relations with aspects of the environment (people, objects, events). In the latter of these two points Baron-Cohen shares a stance with other investigators of infant social understanding. For example, Tomasello and colleagues (e.g., Tomasello, Kruger, & Ratner, 1993; Tomasello, 1995) refer to the infant as an "intentional agent" who not only enters into intentional relations with aspects of the environment but possesses an awareness of the intentional nature of these relationships. Further, Bretherton and colleagues (Bretherton, 1991; Bretherton, McNew, & Beeghly-Smith, 1981) on the basis of evidence of the young infant's communicative competence (specifically the aspects of gaze alternation, repair of failed messages, and ritualization of previously instrumental gestures, as identified by Bates, 1979) are willing to afford the infant a rudimentary "theory of mind", albeit implicit rather than explicit.

The common thread here is that each of these investigators affords the under 12 month infant considerable understanding of other's perspectives/intentions. These authors suggest that participation in triadic behaviors such as joint attention, social referencing, and protocommunicative gestures, requires an understanding that outward behavior (of self and others) is representative of underlying psychological states. For example, in the case of protocommunicative gestures and joint attention, infants are assumed, by simple virtue of their participation, to understand that cues such as a pointing finger or the orientation of an individual's head and eyes are actually signals for the direction of the individual's attention. Likewise, in the case of social referencing, infants are assumed to understand that the emotional expressions enacted by adults are not only directed at and carry meaningful information regarding specific objects in the environment but represent the adult's emotional appraisal of the object.

In contrast, on the other end of the continuum, authors such as Barresi and Moore (1993, 1996; Moore & Barresi, 1993) and Moore and Corkum (1994a) provide a simpler, more conservative account of triadic interaction which does not involve attributing to the infant knowledge of the psychological states of self and others. Barresi and Moore (1996) have outlined a four-level model of social understanding which accounts for the manner in which individuals develop a notion of an "intentional agent" which is applicable to self and others. They cite empirical evidence which provides support for their model from both a phylogenetic as well as an ontogenetic perspective. For the present purposes, clearly the ontogenetic stream is of most relevance. Barresi and Moore are clear in articulating the developmental problem of how it is that qualitatively very different information regarding intentional (or psychological) relations obtained from the first and third person perspectives of a person becomes integrated to provide a view of an intentional agent which is equally applicable to self and other. Their solution relies on both real and imagined components and assigns a central role to the infant's experience of triadic interaction (including joint attention, social referencing, and protocommunicative gestures). To be clear, Barresi and Moore suggest that the 9 month infant enters into shared intentional relations (for example by way of joint visual attention or social referencing) but that at this age the representations of the intentional relations are coded in terms of the interaction rather than in terms of either of the individual agents. In contrast, by 18 months Barresi and Moore propose that infants have developed an imaginational/representational capacity which permits them to code intentional relations in terms of an independent self and other, each with first and third person perspectives on an object/person/event of mutual interest. Similarly, Moore and Corkum (1994a) offer a conservative account of the infant's understanding of other's minds as implicated in their joint attention, social referencing and protocommunicative behavior, which is an alternative to the "common-sense" view that such behavior requires that the infant understand the psychological relations of self and others with respect to objects/events in the world.

In this way, Moore and colleagues argue that infants need not possess an understanding of psychological relations in order to engage in triadic behavior. Instead, they propose that in participating in triadic interaction the infant need understand only that behaviors, such as the direction of a pointing hand or the orientation of another's head and eyes (in the case of protocommunicative gestures and joint attention) are indicative of the direction of interesting sights but not that such sights are the focus of anyone's attention. Likewise, with respect to social referencing, Moore and colleagues believe that the infant need understand emotional expressions as simply valuable predictive information rather than indicators of the emotional disposition of the actor.

In addition to voicing skepticism regarding the infant's awareness/understanding of other's minds, the position put forward by Moore and colleagues offers a solution for the developmental problem of how infants come to acquire such an understanding. That is, Moore and colleagues suggest that it is the infant's participation in triadic relations, rather than requiring an understanding of psychological relations, that may instead actually serve to provide just the experience which is needed in order for the infant to acquire such an understanding.

In adopting this position, Moore and colleagues have expressed a view which has some commonalities with positions held by a number of other investigators. For example, Butterworth and colleagues (Butterworth, 1991, 1994; Butterworth & Jarrett, 1991) clearly identify the infant's joint attention behavior as not dependent upon or indicative of an awareness or understanding that others have minds which reflect a potential for sharing. Instead, changes in another's line of regard may simply be a good predictor of where an object might be located. Perner (1991) is also conservative in his interpretations of the infant's social behavior with reference to the development of a concept of minds. In much the same way that Moore and colleagues see the infant's understanding of other's behavior in predictive-value terms, Perner adopts a stance that infants may merely perceive/understand action sequences or contingencies rather than intentions per se. Hobson (1994), in his treatment of the period of triadic interaction, writes about the "relatedness triangle" whereby infants relate not only to the world (including objects and people) but relate to other's relatedness to the world. In line with Moore and colleagues, Hobson is quite explicit that the infant need not possess an understanding of other minds in order to participate in the relatedness triangle. Further, like Moore and colleagues, Hobson goes beyond simple skepticism regarding early abilities to pose a developmental role for interactive experience; he holds that it may be by way of participating in social interactions that the infant comes to appreciate "the concept of person as someone in whose place I can put myself" (Hobson, 1994, p. 526).

So, it can be seen that interpretations of the infant's social understanding vary considerably from the liberal model of Baron-Cohen which assumes an understanding of other's minds in order to account for the appearance of triadic behavior, to the more conservative account offered by Moore and colleagues which rationalizes the infant's role in triadic interaction without a need for such an understanding. This range of interpretations will be important to bear in mind as the present work unfolds and some of the notions put forth by these authors are tested in the context of the developmental emergence of joint visual attention. Attention will now be turned to a review of some of the developmental implications of joint or shared attention.

Developmental Implications

Joint or shared attention has been identified as playing a number of important roles in the social, emotional, and cognitive development of the infant (see Adamson & Bakeman, 1991; and Moore & Dunham, 1995, for surveys). Work on the functional implications of joint attention has focused on contributions to both typical and atypical development. Each of these will be addressed, in turn, in the following sections.

Typical Development. As outlined in the section on early social development, joint attention is clearly implicated in the phenomenon of social referencing whereby emotional information about an ambiguous object or event is conveyed from adult to infant (e.g., Feinman, 1982; Sorce et al., 1985; Hornik et al., 1987). Further, joint attention has been identified as an important marker of early social understanding and consequently as a necessary precursor to the development of a full-blown "theory of mind" (Bretherton, 1991; Baron-Cohen, 1991). By way of caution, as reviewed in the section on infant social understanding, while there is general agreement in the literature that joint attention plays a significant role in the development of infant social understanding, there is nonetheless considerable debate regarding the nature or degree of understanding which should be attributed to infants based on their joint attention behavior (see Moore & Corkum , 1994a for one account).

In terms of language and communicative development, joint attention serves an important function during the prelinguistic period, permitting basic information about objects of interest or desire to be conveyed both by the infant to her caregivers and by caregivers to the infant (Butterworth, 1991). Thus, as reviewed earlier, joint attention has been identified as playing an integral part in the protocommunicative gestures first identified by Bates and her colleagues (e.g., Bates et al., 1979). In terms of later communicative development, Bruner (1983) has suggested that joint attention provides the basis in shared experience necessary for the acquisition of language. In support of this notion, a number of researchers have examined the impact of joint attention on aspects of language acquisition.

Bakeman and Adamson (1986) conducted a longitudinal study of the social context in which early language emerges. These authors videotaped infants in their home environment as they engaged in play (with their mothers, with peers, and while alone) at 9, 12, and 15 months of age. Videotapes were scored for the demonstration, by the infant, of conventionalized acts (including referential and regulative words and gestures) as well as the infant's state of engagement (i.e., object, person, or joint). Results indicated that at all ages tested, involvement with a partner in a joint focus of attention greatly facilitated the infant's production of conventionalized acts.

A number of investigators have examined the influence of joint attentional focus on language development in older children. Tomasello and Farrar (1986) reported two studies which provide converging evidence for the facilitative effect of joint attention on language acquistion. The first project was a naturalistic study of mother-infant interaction at 15 and 21 months of age. In the context of naturalistic interaction, Tomasello and Farrar noted the occurrence of episodes of joint attention as well as the composition of mother's and child's language both inside and outside of these episodes. There were qualitative and quantitative differences in the language of both mother and child inside and outside of joint attention episodes. Further, mothers' behavior during episodes of joint attention at 15 and 21 months was positively correlated with infants' vocabulary size at 21 months (while behavior outside of joint attention episodes was not). In the second project reported by Tomasello and Farrar, 17-month-olds were found to be better able to learn novel words presented in the context of the experimenter joining the infant in her current attentional focus than when the experimenter attempted to redirect the infant's attention to a new focus.

In line with Tomasello and Farrar, more recent work by Dunham, Dunham, and Curwin (1993) reports a similar facilitory effect of joint attentional focus on novel word learning in 18-month-olds. In the Dunham et al. (1993) work, infants were found to better acquire a label for a novel toy when the experimenter used an attention-following rather than an attention-switching strategy. Work by Baldwin (1991) suggests that 16-19-month-olds were skilled enough in understanding and establishing joint attention with an adult to be able to infer (and learn) the referent of a novel label both when it matched the infant's current attentional focus (follow-in labelling) and when it did not (discrepant labelling).

Atypical Development. In addition to the documentation of important links between joint attention and aspects of typical development, several lines of research have emerged over the last decade which explore the functional significance of joint attention in the context of atypical development. These lines of research include investigations with premature, low-birthweight infants (e.g., Garner, Landry, & Richardson, 1991; Landry, 1995; Landry & Chapieski, 1988; Landry, Garner, Denson, Swank, & Baldwin, 1993), socioeconomically disadvantaged, adolescent mothers and their infants (e.g., Raver & Leadbeater, 1995), and individuals with autism (e.g., Baron-Cohen, 1989; Baron-Cohen, 1995; Mundy, Sigman, Ungerer, & Sherman, 1986; Sigman & Kasari, 1995), to name just a few. In the next section, the methods and findings of some of this work with atypical populations will be reviewed, in brief.

Much of the work on the development of joint attention in groups at risk for medical complications, such as premature and low birthweight infants, has been conducted by Landry and colleagues (Garner, Landry, & Richardson, 1991; Landry, 1995; Landry & Chapieski, 1988; Landry, Garner, Denson, Swank, & Baldwin, 1993). Garner, Landry, and Richardson (1991) examined the development of joint attention skills in very low birthweight infants in a longitudinal study spanning the first 2 years of life. The low birthweight infants were subdivided into high and low risk groups based on medical complications. A group of full-term infants was included for purposes of comparison. All infants were tested at 6, 12, and 24 months in toy-centered play with their mothers. Both high and low risk groups of low birthweight infants were found to demonstrate difficulties in communicative joint attention responses relative to the full-term group. Interestingly, Garner et al. found that mothers tended to develop specific strategies for engaging their infants which seemed to correlate with level of impairment (i.e., mothers of high risk infants took on a more active role).

In a similar vein, Raver & Leadbeater employed a longitudinal design in investigating the factors influencing joint attention in socioeconomically disadvantaged, adolescent mothers and their infants. All infants were videotaped at 12 and 20 months in play with their mothers. Measures of maternal affect and responsiveness were collected in addition to noting specific parameters regarding the joint attention episodes (e.g., duration). Results indicated that maternal depression and sensitivity were each related to differences in joint attention. Mothers who reported either intermittent or chronic depressive symptoms were found to engage with their infants in a higher proportion of nonreciprocal bid sequences than nondepressed mothers and their infants. In contrast, mothers judged to be highly sensitive were found to engage in significantly more reciprocal bidding sequences and to spend significantly more time in joint attention with their infants than mothers judged to be moderate or low in terms of sensitivity.

In terms of the work examining joint attention in children with autism, one of the earliest comparative studies was conducted by Mundy, Sigman, Ungerer, & Sherman (1986) who compared the nonverbal communicative abilities of autistic children with mentally retarded children and normally developing infants (all matched on mental age and mother's level of education). Children were tested on aspects of both dyadic social interaction (or affiliation) and triadic interaction (joint attention/indicating and behavior regulation/requesting). Social interaction/affiliation was defined as use of nonverbal acts to initiate or maintain face-to-face interaction. Behavior regulation/requesting was defined as use of nonverbal behavior to coordinate attention with a social partner and an object for the purpose of fulfilling some instrumental goal (e.g., retrieving an out of reach object). Finally, joint attention/indicating was defined as use of nonverbal behavior to coordinate attention with a social partner and an object with no instrumental goal intended. Mundy et al. found that while a variety of deficits were demonstrated by the autistic children relative to the control groups, the deficits which best distinguished the autistic children from the other groups were those in the joint attention/indicating category. Interestingly, the autistic children demonstrated no difficulty in nonverbal requesting relative to the other two groups, which indicates that the deficit is not one of more basic triadic interaction, but is specifically related to coordination of attention between self, object, and other with respect to noninstrumental goals.

More recent work by Leekam, Baron-Cohen, Perrett, Milders, and Brown (in press) has investigated both joint attention and perspective taking abilities in children with autism. Leekam et al. tested three subject groups: children with autism, children with Down syndrome, and a group of normal controls. The three groups were roughly matched on receptive verbal abilities. Joint attention abilities were evaluated in a gaze-monitoring task modelled after the work of Butterworth and colleagues (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991). This task involved changes in the experimenter's gaze direction to both sides as well as to a location behind the child; alignments of the child's gaze with the experimenter's were noted. The perspective-taking task was modelled after the work of Baron-Cohen (1989) and involved having the child identify, by way of verbal labelling, the target of the experimenter's gaze. In this task the movement of the experimenter's gaze to the target location was concealed from the child. Results indicated that both the normal controls and the children with Down syndrome passed both gaze-monitoring and perspective taking tasks while the children with autism passed only the perspective taking task. The authors interpret their findings as indicative of an impairment, in children with autism, of spontaneous gaze monitoring while the geometric abilities needed to determine direction of another's gaze seem to be intact.

Along with the Mundy et al. work and Leekam et al. work described above many authors have likewise documented the deficits in joint attention behavior of children with autism relative to other groups including: developmentally delayed (e.g., DiLavore & Lord, 1995) and language delayed or disordered (e.g., Loveland & Landry, 1986; McArthur & Adamson, 1995). This work has even spawned a number of models of autism which attempt to account for the autistic child's joint attention deficits (e.g., Baron-Cohen, 1991; Mundy & Sigman, 1989).

In summary, in each of these investigations of joint attention in atypical children the investigators have identified some disruption in the quality of joint attention and/or some delay in the emergence of joint attention associated with the child's exceptional status. The joint attention deficits seem to be most profound in autism, where the development of joint attention behavior is not simply delayed, but is actually absent. This work with atypical populations is valuable because it not only provides great insight into the core deficits which underlie particular disorders, but in so doing, it serves to highlight the fundamental contributions that joint attention makes to more typical development.

Empirical Work on Joint Visual Attention

The current body of work on joint visual attention focuses on a number of developmental changes in this important behavior including: age of onset (Scaife & Bruner, 1975), accuracy of target localization (Butterworth & Cochran, 1980; Butterworth & Grover, 1990; Butterworth & Jarrett, 1991), and the cues or behaviors important for establishing joint visual attention (Lempers, 1979; Butterworth & Jarrett, 1991; Hains, D'Entremont, & Muir, 1996).

Age of Emergence. Age of onset of joint visual attention is an important issue because it provides some insight into when infants begin to demonstrate social awareness which includes both social partners and their perspectives. The earliest investigators to explore the emergence of joint visual attention in infants were Scaife and Bruner (1975) who established the "prototypical" joint visual attention paradigm. In this paradigm, an experimenter engages in a face-to-face interaction with an infant. After establishing eye contact with the infant the experimenter delivers a cue for change in the direction of her attention and the infant's response is noted. Subsequent trials are conducted in the same manner with the experimenter first reestablishing eye contact with the infant and then delivering a cue for change in the direction of her attention. Cases in which the infant changes her direction of gaze to align with the experimenter's are recorded as episodes of joint visual attention. In the Scaife and Bruner work each experimental session consisted of just two trials of change in the experimenter's gaze direction - one to each side. On each trial the experimenter turned head and eyes together 90 degrees to fixate a target which was not visible to the infant. Scaife and Bruner judged infants as having established joint visual attention if they turned to look in the same direction as the experimenter on one out of the two trials. The results of this experiment indicate that 30% of infants as young as 2 months turned their heads to follow an adult's line of regard. The percentage of infants turning to follow the adult's head plus eye movement increased steadily with age, so that by 11-14 months of age 100% of the infants tested demonstrated head turning in the appropriate direction on at least one of the two experimental trials.

Butterworth and colleagues (Butterworth & Cochran, 1980; Butterworth & Grover, 1990; and Butterworth & Jarrett, 1991) employed the joint visual attention paradigm but included an important modification which involved having each infant's mother assume the role of the experimenter. Butterworth and colleagues were concerned with the issues of age of emergence as well as the accuracy with which infants of different ages could localize the targets of another's attention. As in the work by Scaife and Bruner, infant and adult participated in a face-to-face interaction, and periodically, the adult (mother) shifted her attention to fixate one of a number of targets. In the Butterworth work the targets, which were colored paper constructions mounted on sticks at eye level, were visible to both mother and infant. Each target was composed of a blue star on a bright yellow background. Pairs of targets were spaced equidistant from each other along the sides of the experimental cubicle so that one row of targets flanked the mother and infant on each of their right and left sides. The number of targets employed in the work by Butterworth and colleagues varied from two to ten. On each experimental trial, the mother turned in silence (and without pointing) to fixate, for 6 seconds a specific target. The sequence of targets fixated by the mother was randomized and signalled to her by the experimenter via a sequence of lights not visible to the infant. In this work, infant responses were scored as: no codable response, correct fixation, error-same side, or error-opposite side. Although incorrect responses which involved the infant turning in the direction opposite to the mother were coded, they were judged by Butterworth and colleagues to be infrequent and thus were omitted from their published reports. Results of the work by Butterworth and colleagues indicates an age of emergence of joint visual attention of 6 months. Further, Butterworth and colleagues have documented three age-specific mechanisms for joint visual attention between 6 and 18 months. At 6 months of age infants reliably turn their heads to the correct side of the room for targets within their own visual field but only locate the correct target if it is first within their path of scanning (ecological mechanism). At 12 months of age infants correctly pinpoint both the direction and location of targets regardless of positioning along the path of scanning (geometric mechanism); however, they fail to search for targets located behind them. Finally, at 18 months of age infants not only correctly pinpoint both the direction and location of targets regardless of positioning along the path of scanning, but now they search for targets which are located behind them; however, they only do so when their own visual field is empty of targets (spatial-representational mechanism).

Perceptual Cues Employed. Work on the cues or behaviors important for joint visual attention has been focused primarily on the relative importance of head and eye orientation in the establishment of the joint visual attention response. The majority of the research on joint visual attention, to date, has made use of a single signal, that is, congruent head and eye orientation, for indicating change in direction of another's attention. Functionally, head and eye orientation are often equally good predictors of direction of attention since they are frequently congruent (i.e., we usually turn our head and eyes together). However, there are cases when the two cues are in conflict; for example, the more subtle movement of turning our eyes but not our head. In these cases, eye orientation alone provides the most accurate information regarding direction of attention.

The age at which infants begin to employ eyes alone vs. head plus eyes cues for joint visual attention is an important issue in that it has implications for the nature of the infant's understanding of directed attention in others. More specifically, when infants establish joint visual attention based on changes in another's eye orientation, it suggests that they understand that visual attention is a function of visual fixation. This, in turn, implies a qualitatively different, that is, more advanced, form of infant social awareness. While some authors speculate that this awareness is in place from the time that infants begin to engage in joint visual attention (e.g., Baron-Cohen, 1994; 1995; Baron-Cohen & Ring, 1995) others suggest that it does not emerge until significantly later in development (e.g., Barresi & Moore, 1993, 1996; Moore & Corkum, 1994a).

Empirical work examining the cue issue has taken a number of forms. First, there is considerable evidence to indicate that infants as young as 2 months are interested in the eyes of others, in that they look longer at the eyes than at other facial features (Maurer, 1985; Haith, Bergman, & Moore, 1977; and Hainline, 1978). Further, there is also convincing evidence that infants are sensitive to changes in the direction of another's eye orientation; in particular, "eyes looking at me or not" (3-7 months, Caron, Caron, Mustelin, & Roberts, 1992; 3-5 months, Hains, Muir, & Franke, 1994; 5 months, Lasky & Klein, 1979; and Symons, Hains, Dawson, & Muir, 1996).

Caron et al. (1992) measured looking and smiling behavior of 3, 5, and 7 month infants in response to prerecorded video images of adult females who interacted with or without eye contact. The no eye contact condition consisted of one of three possibilities: eyes closed, head & eyes averted, or eyes only averted conditions. Caron et al. found that even 3-month-olds discriminated these eye contact and no eye contact conditions in that they looked more on eye contact than no eye contact trials. Interestingly, a developmental trend of increased looking time and decreased smiling time for no eye contact relative to eye contact trials was found, suggesting an increasing awareness of the social/communicative significance of the cues.

Lasky and Klein (1979) used live interactive partners rather than video displays to investigate 4 to 6 month infants' sensitivity to eye contact with mother versus a stranger. Lasky and Klein found that infants were sensitive to changes in the eye contact of both mother and stranger in that they smiled more during eye contact than during gaze-away periods. Unfortunately, Lasky and Klein may have confounded eye direction and contingency, since in the gaze away condition it would have been difficult for the adult behavior to remain contingent with the infant's behavior when the infant could not be seen.

Work by Hains, Muir, and Franke (1994) nicely addresses the issue of infant sensitivity to changes in another's eye gaze while keeping aspects of contingency constant. Hains et al. tested 4-6-month-olds and included two types of interactions, "live" and closed circuit TV. Further, within each interaction type they included periods of eye contact and averted eye gaze. The averted eye gaze conditions were of three possible types: head and eyes averted to the side, eyes only to the side, eyes only down (simulating eyes closed). Because Hains et al. had the adult view a monitor display of the infant during each of the no eye contact conditions, the adult was able to maintain contingency with the infant during these conditions. Results show that infants are sensitive to changes in another's eye gaze in that they smiled more during eye contact than averted eye gaze conditions. No differential responses were noted in terms of the infants' looking time, which showed a uniform decline across the session. Results for live and TV conditions were similar.

Symons, Hains, Dawson, & Muir (1996) expanded on the eye gaze issue by examining infants' sensitivity to small changes in adult eye direction. Symons et al. exposed 5-month-old infants to periods of contingent interaction in which the adult's gaze was directed at the infant's eyes (eye contact) or at the infant's ear (gaze-away). Results show that 5-month-olds are sensitive to small changes in eye direction in that infants smiled and looked less during the gaze-away than during the eye contact periods.

Whilc the work reviewed above provides clear evidence of the infant's ability to detect changes in another's eye orientation, few studies have gone beyond this to examine the infant's actual use of these changes for establishing joint visual attention. The issue of the relative effectiveness of changes in head plus eye orientation vs. changes in eye orientation alone as cues for joint visual attention has thus far been investigated in two studies; Lempers (1979) and Butterworth and Jarrett (1991, experiment two). Butterworth and Jarrett studied head turning to localize targets in 18-month-olds in response to changes in a model's eye orientation only, as well as in response to congruent changes in head and eye orientation. The work by Lempers examined the same basic issue as Butterworth and Jarrett but in a variety of ages (9-, 12-, & 14-month-olds), and included an additional condition in which the static head plus eye orientation directed at a target was viewed by the infant while the physical movement of the model to this new orientation was not. In general, the results of both studies indicate that a combined change in head and eye orientation is a somewhat more effective cue for joint visual attention than a change in eye orientation alone. In addition, Lempers found that the addition of movement enhanced the saliency of the head plus eyes cue. Finally, while Lempers found that no 9-month-olds engaged in joint visual attention based on the eyes alone cue, about 50% of the 14-month-olds did so. Likewise, Butterworth and Jarrett found that 18-month-olds successfully re-oriented their own gaze on 42% of the trials when the cue was change in the experimenter's eye orientation.

Operational Definition of Joint Visual Attention. In the early work on joint visual attention investigators have reported simply the frequency or percentage of correct responses (or matches with a model's direction of gaze) but have excluded the corresponding frequency of mismatches. In contrast, the position taken in the present work is that in order to conclude that infants are reliably engaging in joint visual attention, it must be clear that they are shifting their own attention to "match" a model's direction of gaze significantly more frequently than they shift it to the opposite direction or "mismatch" with the model. In this way, the pattern produced is systematic rather than random, with infants matching at levels greater than would be predicted based on chance alone. Because the previous work has taken only matches but not mismatches into consideration in the analyses, it would seem less possible to draw meaningful conclusions with respect to whether or not infants are actually engaging in joint visual attention at any particular age. In fact, it is hypothesized that this early work has likely underestimated the age at which infants begin to engage in joint visual attention, in a reliable fashion. Therefore, in order to more accurately examine the occurrence of joint visual attention, in the present work a more stringent operational definition of joint visual attention was employed in which matches with adult direction of gaze were compared with mismatches (Morissette et al., 1995 adopted a similar definition). According to this new operational definition, a difference score was created in which the number of infant head turns which mismatched the experimenter's direction of gaze was subtracted from the number of infant head turns which matched it and infants were required to match the experimenter's direction of gaze significantly more frequently than they mismatched it (i.e., show a difference score significantly greater than zero) in order for joint visual attention to be reliably demonstrated. In this way, it was believed that it would be possible to more accurately identify the occurrence of joint visual attention.

Present Focus

As stated earlier, the present work on joint visual attention has grown primarily out of an interest in learning more about the nature of emerging social understanding in infants. The burgeoning literature on young children's social understanding has rather neglected the developmental connections between the social-cognitive changes seen in the preschool period and earlier signs of social sensitivity in infancy (Moore & Frye, 1991). The present work summarizes a program of research designed to investigate the nature of infant social understanding over the first two years of life as demonstrated by their joint visual attention behavior (portions of it are described in Corkum & Moore, 1992; 1993; 1994; 1995; in press; Moore & Corkum, 1994a; 1994b; and Moore, Corkum, & MacLellan, 1995). The focus was essentially three-fold.

First, there was an interest in the age of emergence of joint visual attention. Although the appearance of social referencing (e.g., Feinman, 1982; Sorce et al., 1985; Hornik et al., 1987) and protocommunicative gestures (e.g., Bates, 1979; Bates et al., 1979) has not been documented until the end of the first year of life, there is substantial evidence (e.g., Scaife & Bruner, 1975; Butterworth & Cochran, 1980; Butterworth & Grover, 1990; and Butterworth & Jarrett, 1991) to suggest that joint visual attention, unlike these other types of triadic interaction, emerges much earlier, at around the 6 month mark. Given this curious developmental discrepancy, in the present work an attempt was made to identify, more clearly, the age of onset of joint visual attention.

Second, there was an interest in the perceptual cues employed for joint visual attention. In keeping with the interest in joint visual attention as a line of insight into the nature of the infant's social understanding there was a desire to explore what it is that infants know about other people that allows them to engage in joint visual attention. Of particular interest were the perceptual features that infants employ for determining another's direction of gaze and aligning with it. Therefore, in the present work a systematic examination of the developmental changes in the cues that infants rely on for establishing joint visual attention was undertaken.

Finally, there was an interest in the origins of joint visual attention. In light of the Gewirtz & Pelaez-Nogueras work on instrumental conditioning as a model for the acquisition of social referencing, there was curiosity about learning as a possible route of acquisition for the joint visual attention response. In particular, it was hypothesized that learning might be a possible mechanism by which the cues for joint visual attention acquire their signal value. In keeping with this notion, the present work examined the extent to which it was possible, with the provision of contingent reinforcement, to train infants to make a "joint visual attention-like" head turn to attention relevant vs. attention irrelevant cues.

In order to address these issues, a series of four experiments was conducted which employed two very different paradigms: the joint visual attention paradigm described earlier, with some modifications, and a conditioned head turn paradigm. Infants tested in this work ranged in age from 6 to 19 months. In Experiments 1 and 2 the age of onset issue is addressed. The issue of the cues employed by infants of different ages for establishing joint visual attention is investigated in Experiments 1 and 4. Finally, the origin of the joint visual attention response is investigated in Experiments 2 and 3. In the following sections, this program of research is outlined.

Experiment 1

In Experiment 1 two issues were examined: 1) the age of onset of joint visual attention, and 2) the perceptual cues that infants of different ages employ for determining the direction of another's gaze and aligning with it. To meet these ends, Experiment 1 incorporated a number of important features. First, a more stringent operational definition of joint visual attention was adopted which was reflected in the fact that the coding definition included both matches and mismatches with the experimenter's direction of gaze (as outlined in the general introduction). Second, targets were excluded from the experimental set-up in the interest of reducing the occurrence of false positive responses; that is, infant head turns which match adult direction of gaze but which are a function of visual search of the experimental cubicle rather than responses to cues from the experimenter. Although much of the early work on joint visual attention (e.g., work by Butterworth & colleagues) included targets for the infants to fixate, the absence of targets was certainly not without precedent (e.g., Scaife & Bruner, 1975) and further it was believed that it would be beneficial in the accurate identification of episodes of joint visual attention. Third, Experiment 1 extended the previous research on the perceptual cues employed for joint visual attention by systematically varying both head and eye orientation in isolation (i.e., head only and eyes only) as well as in combination (i.e., head & eyes move in the same direction and head & eyes move in opposite directions) in order to determine their relative importance as cues for establishing joint visual attention. Finally, in Experiment 1 infants ranging in age from 6 to 19 months were included in order to gain a more complete picture of the developmental changes in sensitivity to these different cues.

In summary, Experiment 1 employed the joint visual attention paradigm, with some added features, in order to identify: 1) the age of onset of joint visual attention, and 2) the perceptual cues that infants of different ages employ for establishing joint visual attention .

Method

Subjects. The participants were recruited from lists provided by the Grace Maternity Hospital and birth announcements in the local newspaper. A total of 89 infants who were between 6 and 19 months of age participated. All of the infants were full-term (> 37 weeks gestation), of normal birthweight (> 3200 gm), and had experienced no birth complications or major health problems. Twenty-nine infants were eliminated from the final sample; 16 infants did not complete testing because they became fussy or too active to remain seated on the parent's lap, while 13 infants failed to meet the age criteria for the discrete groups chosen. The final sample of 60 infants consisted of 12 infants at each of 6-7, 9-10, 12-13, 15-16, and 18-19 months. The mean age and age range for each of the groups were as follows: 6-7 months (M = 6 months-25 days, Range = 6-0 to 7-26), 9-10 month (M = 10-8, Range = 9-14 to 10-28), 12-13 months (M = 13-0, Range = 12-10 to 14-3), 15-16 months (M = 16-1, Range = 15-2 to 16-22), and 18-19 months (M = 18-22, Range = 17-28 to 19-26). Equal numbers of boys and girls were tested at each age.

Set-up & Procedure. The experimental sessions were conducted in a 3.19 m x 1.75 m cubicle enclosed with curtains to minimize distractions. The parent sat on a chair facing the experimenter (0.75 m away) with the infant seated on the parent's lap while the experimenter sat on a small stool so that her eyes were at approximately the same level as the infant's. The parent wore glasses with the lenses covered with black paper in order to obscure his/her view of the experimenter and to prevent cuing of the infant. All infants were tested in an alert state. Specific state changes were monitored by the experimenter over the course of the session. If infants became restless or fussy, the session was terminated.

During the session, the experimenter participated in a face-to-face interaction with the infant. The experimental session was comprised of 16 trials of change in either the experimenter's head orientation, eye orientation, or both. Each trial commenced with the experimenter's eyes and head oriented frontward, directly facing the infant. The trial began once the infant's head and eyes were, likewise, frontward, facing the experimenter. Both prior to and following each trial, the experimenter used a combination of vocalization and/or touch (e.g., calling the infant's name and/or tickling the infant's tummy) in order to engage the infant in a social interaction and re-establish eye contact at midline. After establishing eye contact with the infant the experimenter then changed the orientation of either her head or her eyes to suit one of the following four types of trials: H (head orientation changed but eyes remained fixated on the infant), E (head maintained a frontward orientation facing the infant but eyes changed their direction of orientation), H+E (both head and eyes changed orientation in the same direction) or H-E (both head and eyes changed orientation but in opposite directions). Because no targets were present, small fixation points were marked with tape on the curtain behind the mother and infant to ensure a uniform deviation on each cue presentation. For the H, E, and H+E trials, the deviation of gaze was 61 degrees from the midline, whereas for the H-E trials, the eye and head orientations deviated 31 degrees each to opposite sides of the midline. Each change in orientation was maintained for approximately 7 s. After 7 s had elapsed, the experimenter turned back to face the infant and reestablished eye contact in order to begin the next trial. During the trials, the experimenter did not vocalize or touch the infant. At the start of each trial the experimenter enacted an expression of surprise including raised eyebrows, open mouth, and a short, quick intake of air (e.g., silent "oh") in an attempt to convince the infant of the plausibility of an interesting sight appearing to the side.

Two trials of each of the four types were conducted to each side (right and left) for a total of sixteen trials. Within each session, the trials were presented in two randomized blocks so that each cue was presented once to each side in each half of the session. Each block was further subdivided into two segments comprised of one trial of each of the four trial types. Six randomized presentation orders were recorded on audiotape and played back via an earphone during the session to cue the experimenter. Equal numbers of infants in each age group were tested using each of the six presentation orders.

The entire session was recorded on videotape via two video cameras; one positioned behind the experimenter facing the infant and the other positioned behind the mother facing the experimenter. A full face view of the experimenter and a full body view of the infant were combined into a split screen display.

Scoring. A coder naive to the hypotheses of the experiment scored the videotapes for the direction of the first infant head turn in the horizontal plane to occur during each trial. This judgement did not involve measuring degrees of deviation from midline but rather relied on the subjective judgement of the coder that a detectable head turn to the side had occurred. In keeping with Butterworth and Cochran (1980), infant head turns in other than the horizontal plane were not scored (e.g., a look up or down would be ignored). The rationale for ignoring these head movements was that they did not seem to be purposeful responses to the cues generated by the experimenter but rather behavior in response to other elements in the set-up (such as the lights, the carpeting, the mother), and there was a wish to be generous in providing infants with an opportunity to demonstrate an organized joint attention response. Each infant head turn scored was then designated either a match or a mismatch with the criteria for this judgement differing depending upon trial type. In the case of the H, E, and H+E trials, a match was defined as an infant head turn in the same direction as the trial executed by the experimenter while a mismatch was defined as an infant head turn which was opposite in direction to the trial executed by the experimenter. However, in the case of the H-E trials, since head and eyes are oriented in opposite directions, a match was defined as an infant head turn which followed the direction of the experimenter's head orientation, while a mismatch was defined as an infant head turn which followed the direction of the experimenter's eye orientation. In this way, on the H-E trials, matches reflected the extent to which infants tended to follow the experimenter's head orientation in preference over her eye orientation. A difference score for each trial type was calculated by subtracting the frequency of mismatches demonstrated to a particular trial type from the frequency of matches demonstrated to that same trial type. Trials on which "no relevant response" occurred were not included in the calculation of the difference score. If the infants matched more often than they mismatched with the experimenter a difference score in the positive direction would be expected. Conversely, a negative difference score would be obtained if infants mismatched more often than they matched with the experimenter. Finally, if infants behaved in a 'random' fashion then a difference score on the order of zero would be expected. A sample of 25% of the videotapes (three subjects from each age group) was randomly selected for reliability coding by a second coder. Coefficient kappas calculated for each age group were as follows: 6-7 months, k

= .81; 9-10 months, k = .87; 12-13 months, k = .85; 15-16 months, k = .87; and 18-19 months, k = .76.

Results

The analytic strategy adopted in Experiment 1, and throughout this work, was to conduct an omnibus ANOVA followed up by post hoc t-tests rather than planned comparisons. This approach was adopted because it is a more conservative approach especially when multiple comparisons need to be undertaken (Tabachnick & Fidell, 1989). Because the a priori predictions for this work were general rather than specific, multiple comparisons would certainly have been needed. One potential problem with performing an omnibus ANOVA and then following up with multiple post hoc t-tests is the likelihood of inflating Type I error. This potential problem was addressed by selecting a t-test which employs a family-based error rate; the Scheffé method. As a result of adopting this general approach to analysis, it was felt that any conclusions drawn would be based on robust findings.

A three-way ANOVA was conducted with Age (five levels: 6-7, 9-10, 12-13, 15-16, and 18-19 months) as a between-subjects variable and Block (two levels: one and two) and Trial type (four levels: H, E, H+E, & H-E) as within-subjects variables. The match minus mismatch difference score described earlier was the dependent variable in all analyses.

In order to allow testing for possible performance differences early and late in the session, the Block variable was constructed by dividing the 16-trial session into two halves. No significant effects involving the Block variable were found. In order to analyze further for possible performance differences throughout the experimental session the Segment variable was constructed by subdividing each Block into two halves, yielding four, 4-trial Segments in each experimental session. The data were collapsed across Trial type and an Age by Segment ANOVA was performed. The results of this two-way ANOVA yielded no significant effects involving the Segment variable. Since the results of this second analysis confirmed the absence of overall performance differences across the experimental session, the data were collapsed across Block and a two-way ANOVA was conducted with Age as a between-subjects variable and Trial type as a within-subjects variable. Table 1 provides an overall summary of the mean number of trials on which infants of each age turned to match or mismatch each trial type. Figure 1 illustrates the mean difference score obtained for each trial type as a function of age.

Results of the Age by Trial type ANOVA indicated a significant Trial type effect ($F(3,165) = 5.86$, $p = .001$) such that infants showed higher match minus mismatch difference scores for the H+E trials than any of the others; H, $t(1,165) = 3.43$, $p < .001$; E, $t(1,165) = 3.75$, $p < .001$; H-E, $t(1,165) = 2.87$, $p < .01$; with no significant differences in the difference scores for the remaining three trial types (H, E, & H-E).

In addition, a significant Trial type by Age effect was found, $F(3,165) = 1.88$, $p = .04$. Post hoc testing indicated that at 6-7, 9-10 and 12-13 months of age there were neither significant differences among the difference scores for the four trial types nor were the difference scores for any of the trial types found to be significantly different from zero. For the purposes of further post hoc testing, the difference scores were pooled across H, H+E, and H-E trial types at each age in order to construct an overall difference score which would reflect the extent to which infants at each age tended to align (rather than misalign) with the experimenter's head orientation. The pooled difference scores at 6-7, 9-10, and 12-13 months were found to be 0, 0.361, and 0.583, respectively. In comparing the pooled difference scores with zero, at 12-13 months the pooled

Table 1. Mean frequency of experimental trials on which infants of each Age turned to match or mismatch each Trial type in Experiment 1.

Age (months)	Trial Type: H	E	H+E	H-E
		Matches		
6-7	0.917 (.793)	0.917 (.669)	0.833 (.718)	1.000 (.953)
9-10	1.167 (.835)	1.167 (.718)	1.500 (.905)	1.333 (.492)
12-13	0.833 (.835)	0.583 (.900)	1.250 (.866)	1.167 (1.267)
15-16	0.917 (.900)	0.833 (.835)	1.667 (1.231)	0.750 (.754)
18-19	0.417 (.515)	0.583 (.900)	2.000 (1.279)	0.500 (.674)
		Mismatches		
6-7	0.917 (.793)	1.333 (.888)	1.083 (.996)	0.750 (.965)
9-10	1.000 (.835)	0.917 (.793)	0.917 (.793)	1.000 (.603)
12-13	0.500 (.835)	0.417 (.515)	0.417 (.669)	0.583 (.996)
15-16	0.417 (.515)	0.750 (.965)	0.500 (.674)	0.750 (.866)
18-19	0.750 (.866)	0.333 (.492)	0.083 (.289)	0.417 (.669)

Note. Four trials of each type were presented in the session. Values in parentheses are SD.

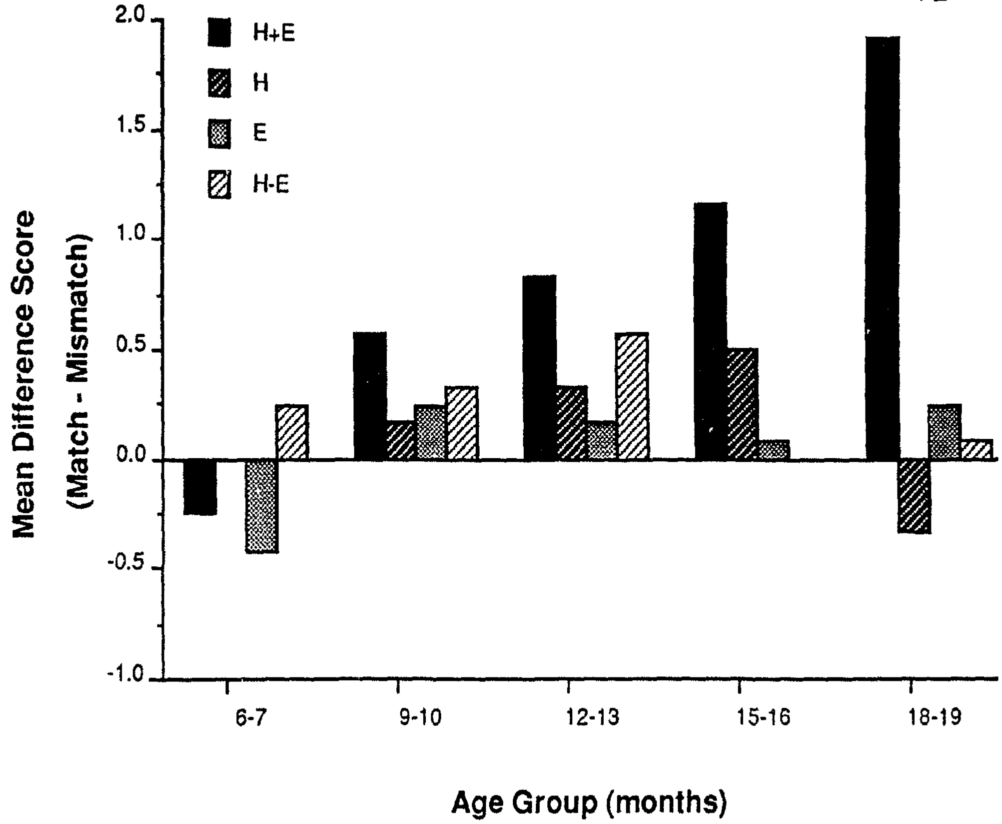

Figure 1. Mean match - mismatch difference score calculated for each Trial type as a funct' of Age in Experiment 1.

difference score was found to be significantly larger than zero; $t(1,165) = 2.49$, $p < .025$; while at 6-7 and 9-10 months it was not.

Further post hoc testing of the Trial type by Age effect revealed that 18-19 month infants showed higher difference scores for the H+E trials than any other trial type; H, $t(1,165) = 4.82$, $p < .001$; E, $t(1,165) = 3.57$, $p < .001$; H-E, $t(1,165) = 3.93$, $p < .01$; with no significant differences in the difference scores for the remaining three trial types (H, E, & H-E). In addition, the difference score for the H+E trial type at 18-19 months of age was found to be significantly greater than zero ($t(1,165) = 4.10$, $p < .001$). The 15-16-month-olds, like the 18-19 month group, showed higher difference scores for H+E than the E ($t(1,165) = 2.32$, $p < .025$) and H-E ($t(1,165) = 2.49$, $p < .025$) trial types. In addition, the 15-16 month-olds also have a difference score for the H+E trial type which is significantly greater than zero ($t(1,165) = 2.50$, $p < .025$) and they show no significant differences among the difference scores for the remaining three trial types (H, E, & H-E). However, unlike the 18-19 month group, the 15-16-month-olds show no significant difference in their difference scores for the H+E and H trial types.

Discussion

Age of Emergence. The results of Experiment 1 provide a somewhat different picture of the age of onset of joint visual attention from the previous literature on the topic. Both Scaife and Bruner (1975) and Butterworth and colleagues (Butterworth & Cochran, 1980; Butterworth & Grover, 1990; and Butterworth & Jarrett, 1991) have reported that a significant proportion of infants engage in joint visual attention from 6 months of age. The results of Experiment 1 suggest that it is not until significantly later that joint visual attention is reliably demonstrated. In the strictest sense, it is not until 15 months of age that the infants in Experiment 1 demonstrate a joint visual attention response which is characterized by significantly more matches than mismatches with the experimenter's direction of gaze (i.e., a difference score which is significantly different from zero). However, evaluation of the pooled difference scores in the younger age groups indicates a developmental difference such that 12-13- but neither 6-7-nor 9-10-month-olds have pooled difference scores which are significantly greater than zero. This suggests that the rudiments of a reliable joint visual attention response may be evidenced as early as 12 months. This age of onset for joint visual attention is somewhat later than previous investigators have reported, and it is believed that the modifications in scoring and procedure adopted in Experiment 1 may well account for this difference. In more recent work, Hains, D'Entremont, and Muir (1996) found that infants as young as 3 months of age turned to align with a model's reorientation of gaze. It is cautioned that the Hains et al. study is less comparable to the present work because the targets used (two puppets) were present within the infant's field of vision rather than located to the side and because the researchers scored infant eye turns rather than head turns as in all of the other work.

One notable modification adopted in Experiment 1 was the exclusion of targets for the infants to fixate should they align with the experimenter's direction of gaze. While the bulk of studies on joint visual attention have included targets, the majority of them have been carried out by the same group of researchers (Butterworth and colleagues) for the purpose of examining the issue of target localization. Consequently, the inclusion of targets was a necessary part of their design. Although it was realized that the exclusion of targets from the set-up in Experiment 1 would compromise, somewhat, the ecological validity of the paradigm it was done in the interest of eliminating the occurrence of false positive responses due to visual search of the experimental cubicle rather than following of the experimenter's gaze to engage in joint visual attention. It was believed that the main risk of not having targets for the infants to fixate was an order effect which would have been manifested as extinction of infant looking (or some other change in response pattern) over the course of the experimental session. Since the data analyses showed no performance differences over the course of the experimental session (even when the session was broken down into four, 4-trial segments) this potential problem was not realized. Despite the fact that there were no targets for them to look at, infants maintained their age specific patterns of response throughout the lengthy experimental session.

In contrast with the view taken in the present work, Butterworth and colleagues might argue, based on their ecological mechanism for joint visual attention in 6-month-olds, that joint visual attention was not seen in this age group in Experiment 1 precisely because targets are an integral part of the context necessary for eliciting joint visual attention at this age so that by excluding the targets the possibility for joint visual attention was effectively removed. In defense of the present work, it could be answered, first, that the absence of targets in studies of joint visual attention is not without precedent (e.g., Scaife & Bruner, 1975), and second, that not all of the studies which included targets found an age of emergence for joint visual attention which is as early as that reported by Butterworth and colleagues. In fact, the weight of the empirical evidence suggests that age of onset of joint visual attention hinges more solidly on the criteria employed for scoring the joint visual attention response rather than on the presence or absence of targets in the experimental set-up. While Butterworth and colleagues did employ targets in their paradigm, Scaife and Bruner did not; yet, both groups report very early ages of onset for joint visual attention (i.e., from about 6 months). The critical similarity in the work of these two groups lies in the fact that both adopted joint visual attention scoring criteria which included matches or alignments with adult direction of gaze but excluded misalignments or mismatches.

In contrast with the present work, Morissette, Ricard, and Gouin-Decarie (1995) did include targets in their experimental set-up but they also adopted a more stringent operational definition of joint visual attention which compared matches, mismatches, and no responses. Instead of the early age of onset reported by Scaife and Bruner and Butterworth and colleagues, Morissette et al. (in keeping with the findings of Experiment 1) found that it was not until about 12 months of age that infants reliably engaged in joint visual attention. In a similar vein, Lempers (1979) tested 9-, 12-, and 14 month-olds in a paradigm which included targets but required infants to fixate the same target as a model on both experimental trials (one to each side) in order for them to be judged as correctly aligning with the model's gaze (i.e., if infants failed to look or misaligned on even one trial their performance was judged to be incorrect). In keeping with the findings of both Experiment 1 and Morissette et al. it was not until 12 months of age that Lempers found a majority of infants (83%) engaging in joint visual attention according to this more stringent definition. In light of this concordance between the findings of Experiment 1 and those of Lempers and Morissette et al. it is concluded that joint visual attention does not emerge until somewhat later than previous investigators have reported and that the most likely source of the discrepancy in findings between the findings of Experiment 1 and the bulk of previous studies which report a 6 month age of onset is the more stringent operational definition of joint visual attention.

Perceptual Cues Employed. Since the pattern of performance exhibited by 6-7- and 9-10-month-olds suggests that these infants are not reliably engaging in joint visual attention based on information from any of the cues (i.e., their difference scores were not found to be significantly greater than zero, indicating that they turned in the opposite direction or mismatched the direction of the experimenter's gaze as frequently as they matched it) this age group will not be considered with respect to the issue of the cues employed for joint visual attention.

In contrast to the two youngest age groups, the findings for the 15-month-olds indicate that these infants do reliably engage in joint visual attention, and they appear to do so based primarily on information about head position, because: 1) their difference score for the H+E trials (but no other trial type) was significantly greater than zero, indicating that they turned their heads to match the direction of the H+E trials significantly more frequently than they mismatched them; 2) their difference score was significantly higher for the H+E compared with the E trials; and, 3) there were no significant differences in the difference scores for the H and H+E trial types. However, because the 15-16 month-olds did have a significantly higher difference score for the H+E than the H-E trial types it appears that at least some awareness of eye orientation as a signal for direction of attention is present at this age.

In keeping with the findings for 15-16-month-olds, analysis of the pooled difference scores constructed for the 12-13 month age group indicates that these infants, like the 15-16-month-olds, seem to be making a joint visual attention response which is based primarily on information about the experimenter's head orientation (because pooled difference scores which reflect tendency to follow head position were significantly different from 0).

In contrast to the 12-16 month infants, the 18-19-month-olds seem to rely on congruent head and eye orientation for determining direction of gaze and establishing joint visual attention because: 1) their difference score for the H+E trials (but no other trial type) was significantly greater than zero, indicating that they turned their heads to match the H+E trials significantly more frequently than they mismatched them; 2) they matched the H+E trials significantly more frequently than they matched any of the other trial types; and, 3) there were no significant differences among the difference scores for the remaining three trial types.

Finally, at no age did the infants in Experiment 1 align with the direction of adult gaze based on information about eye orientation alone (whether presented in the context of the E or H-E cues). This finding is inconsistent with Lempers (1979) and Butterworth and Jarrett (1991), who found that a significant proportion of 14- and 18-month-olds, respectively, were able to employ changes in a model's eye orientation alone as a cue for establishing joint visual attention. Lempers found that 50% of 14-month-olds engaged in joint visual attention on the basis of change in a model's eye orientation alone while 90% of them did so when the cue was congruent change in head and eye orientation. Similarly, Butterworth and Jarrett report that 18-month-olds turned their heads in the same direction to a change in eye orientation alone on 42% of occasions compared to 50% of occasions when the cue was congruent head and eye orientation. In these two studies, therefore, it appears that both 14-month-olds and 18-month-olds were reasonably good at establishing joint attention on the basis of eye orientation alone.

How can these discrepant findings with respect to the use of eye orientation as a cue for joint visual attention be reconciled? Since research on infant vision (Mayer & Dobson, 1982) indicates, certainly from 2-3 months of age, visual acuity levels sufficient for resolution of the changes in eye orientation presented at the proximate distance employed in Experiment 1, the differing findings are clearly not the result of a problem in detecting the cues presented. Instead, a difference in procedure between Experiment 1 and the work of Lempers and Butterworth and Jarrett may well account for the apparent discrepancy. Both Lempers and Butterworth and Jarrett presented E and H+E trials separately; Butterworth and Jarrett presented them in separate blocks, while Lempers presented them as completely separate tasks. This procedural difference may have acted to enhance the saliency of the E trials in these two studies. By comparison, in Experiment 1, there were more types of trials and the different trial types were presented in random order, which may have made discrimination of the E trials more difficult.

Notwithstanding this difference, both Experiment 1 and those of Lempers (1979) and Butterworth and Jarrett (1991) found that for 18-month-olds H+E was a more salient cue for joint attention than E alone. By way of explanation, Butterworth and Jarrett have proposed that congruent eye and head movements may simply be a clearer signal for change in attention than eye movements alone. It should be added that it is also possible that congruent head and eye movements signal something about the target which is not signalled by eye movements alone (e.g., that it is more interesting or more enduring, and thus more worthy of a turn). Further, it is possible that the nature of infants' social understanding is qualitatively different at older ages, making it more likely that they understand the significance of changes in another's eye orientation, and consequently begin to employ cues regarding another's eye orientation for establishing joint visual attention. In any case, this issue of the cues employed for establishing joint visual attention shall be revisited in Experiment 4.

In summary, the results of Experiment 1 indicate that infants do not reliably engage in joint visual attention until about 12 months of age. Prior to this age not only do infants fail to distinguish between the four trial types but they mismatch, or turn in the opposite direction, as frequently as they match any of them. From about 12-16 months of age, infants seem to establish joint visual attention based primarily on head position alone while at 18 months head and eye congruence seems to be important. At no age did the infants in Experiment 1 establish joint visual attention based on information about eye orientation alone.

Experiment 2

In light of the somewhat cloudy findings of Experiment 1 with respect to the age of onset of joint visual attention, another test of this issue was undertaken in Experiment 2. In order to more adequately address the age question, in Experiment 2 only infants under 12 months of age, were tested (i.e., the age range in Experiment 1 in which infants did not demonstrate joint visual attention). Further, a much larger number of infants in this age range were tested; and finally, targets were included to provide a "fairer" assessment of joint visual attention with respect to the bulk of the previous literature (in particular, the work of Butterworth and colleagues).

The second aim in the design of Experiment 2 was to address, at least in part, the issue of the origins of the joint visual attention response. Overall, interests were clearly in weighing the relative contributions of innate and environmental influences (Moore & Corkum, 1994a). A logical starting point for Experiment 2 was the empiricist side of the issue. In light of the work by Gewirtz and Pelaez-Nogueras on instrumental learning as a model for social referencing, it was wondered, quite simply, if joint visual attention may also be acquired via a process of instrumental learning. In order to examine these two issues, in Experiment 2 a somewhat unconventional methodology for joint attention research was adopted: the conditioned head turn paradigm.

The conditioned head turn paradigm was particularly appropriate for the present purposes for a number of reasons. First, notwithstanding the earlier arguments against the absence of targets in Experiment 1 as a methodological problem, an empirical test of this notion remained to be completed. Because the conditioned head turn paradigm necessitates the addition of targets to act as reinforcers, it permitted an empirical examination of the possibility that the later emergence of joint visual attention in Experiment 1, compared with earlier research, was due to the absence of targets for the infants to fixate. Second, the nature of the conditioned head turn paradigm, with its inclusion of contingent feedback, allowed the hypothesis that joint visual attention might be acquired via a process of learning to be directly tested. Because developmental psychologists have successfully employed the conditioned head turn paradigm for decades to delimit the parameters of infant perception it was clear that infants younger than 12 months could be trained to make simple head turns in response to visual or auditory stimuli (e.g., Bower, 1966; Werker & Tees, 1984; respectively). However, what was not clear was whether infants in this age group could also learn to make differential head turn responses to more complex social stimuli differing in only one crucial aspect: orientation of gaze. By attempting, in Experiment 2, to train infants to make gaze-following head turns it was believed that something would be learned about not only the age of acquisition of joint visual attention but, perhaps more importantly, about the possible origins of the joint visual attention response.

Method

Subjects. The participants were seventy-seven infants who were between 6 and 11 months of age. All of the infants were full-term (> 37 weeks gestation), of normal birthweight (> 3200 gm), and had experienced no birth complications or major health problems. Testing was not completed with fourteen infants who became fussy or too active to remain seated on the parent's lap; four from the 6-7 month group, six from the 8-9 month group, and four from the 10-11 month group. The final sample of sixty-three infants was subdivided into three groups (6-7-, 8-9-, and 10-11-month-olds) each of which was comprised of 21 infants. The mean age and age range for each of the groups were as follows: 6-7 months (M = 6 months-27 days, Range = 6-1 to 7-29), 8-9 months (M = 9-3, Range = 8-6 to 9-29), 10-11 months (M = 10-23, Range = 10-3 to 11-27). At 8-9 months, 11 girls and 10 boys were tested while at 6-7 and 10-11 months the groups were comprised of 12 girls and 9 boys.

Set-up & Procedure. Sessions took place inside the same curtained cubicle described in Experiment 1; however, in this experiment, targets were included. The targets were identical black and white stuffed dogs with a height of approximately 22.5 cm (one located on each side of the cubicle). Each toy rested on a 32.5 cm diameter turntable located inside a 45 cm x 45 cm x 45 cm black box that was mounted on the far side of a black plywood wall approximately 77.5 cm from the floor and 1.35 m away from the chair on which the parent and infant sat. A 45 cm x 45 cm plexiglass window on the front of the box permitted viewing of the toy. When activated, a light (mounted on the ceiling of the box) better illuminated the toy while the turntable on which the toy rested rotated. An observer located in an adjacent room watched the proceedings of the session on a video monitor and was responsible for remote control of the toys. Both toys were visible to the infant at all times but activation was contingent upon the behavior of both the experimenter and infant as well as the particular phase of the session.

During the session, the experimenter participated in a face-to-face interaction with the infant while the infant was seated on the parent's lap. The distance between experimenter and infant was 0.60 m. All infants were tested in an alert state. Specific state changes were monitored by the experimenter during the course of the session. If infants became restless or fussy the session was terminated. Parents were asked to close their eyes for the duration of the testing in order to prevent cueing the infant. Both prior to and following each trial, the experimenter used a combination of vocalization and/or touch in order to engage the infant in a social interaction and reestablish eye contact at midline. Each session consisted of a maximum of 28 trials or changes in the experimenter's direction of gaze either to the right or left. The change in gaze direction was achieved by the experimenter reorienting her head and eyes approximately 90 degrees to fixate the toy located to the side. This reorientation of gaze was maintained for a duration of 7 s. During the trials the experimenter did not vocalize or touch the infant, nor did she point toward the target. The experimenter employed a signal light during the session (which was not visible to the infant but appeared on camera) to indicate the beginning and end of each trial. This signal permitted the coder to score the videotapes blind to the direction of the cue demonstrated by the experimenter.

Each session was comprised of three phases. Table 2 outlines the events which took place during each experimental phase. During Phase I (Baseline) there were four trials of a change in the experimenter's direction of gaze (two trials to each side) throughout which the targets remained inactive. This phase permitted assessment of a spontaneous joint visual attention response in the presence of targets. During Phase II (Shaping) there were also four trials (two to each side) but this time regardless of the infant's behavior the target to which the experimenter turned was activated approximately 2 s after the change in the experimenter's direction of gaze. This phase assisted in shaping the joint visual attention/gaze-following response. Finally, during Phase III (Test) there was a maximum of 20 trials (10 to each side) during which a toy was activated only if the infant made a head turn which matched the direction of the experimenter's gaze. This phase was subdivided into five, four-trial blocks within each of which there were two trials to each side. Phase III allowed for further shaping of the joint attention response and a test of learning.

Table 2. Outline of events in Experiment 2.

Phase	# Trials	Event
Baseline	4	both targets visible but inactive
Shaping	4	target of experimenter's gaze activated after 2 s delay
Test	20	target of experimenter's gaze activated contingent upon concurrent fixation by infant

Although a maximum of 20 Test trials was possible, the exact length of the Test phase varied as a function of individual performance. Based on pilot work, it was determined that infants who mastered the demands of the task early in the session subsequently became bored and fussy (with a concomitant deterioration in performance) prior to completing the session. Consequently, it was decided that for those infants who demonstrated a reliable joint visual attention response, the session would be terminated early. A criterion measure was employed by the observer on-line in each session such that the Test phase was terminated at the end of the four-trial block in which infants demonstrated a reliable joint visual attention response. In order to demonstrate a reliable joint visual attention response the infant was required to make five consecutive alignments with the experimenter's direction of gaze (with an estimate of the probability of an infant engaging in five consecutive matches at $p < .05$). If no such response was demonstrated, the Test phase continued to a maximum of 20 trials. In order to implement this criterion measure, during the Test phase the observer kept track of infant head turns which aligned with the experimenter's gaze. Once five consecutive alignments with the experimenter were demonstrated, the observer signalled the experimenter by activation of a signal light. The experimenter then proceeded to complete the remaining trials in the current block prior to terminating the session. In coding the videotapes the accuracy of the observer's judgement regarding the session termination criterion was checked. No errors were detected. Thirty-two infants were exposed to all 20 Test trials while 31 infants had an abbreviated session (18 infants had 8 trials, 8 infants had 12 trials, and 5 infants had 16 trials). A full face view of the experimenter and a full body view of the infant were recorded with separate videocameras and the two images were combined on a split screen. The session lasted approximately 6-8 min.

Scoring. A coder blind to the nature of the cues demonstrated by the experimenter and naive to the hypotheses of the study scored the videotapes for the direction of the first infant head turn in the horizontal plane to occur during each trial. As in Experiment 1, this judgement did not involve measuring degrees of deviation from midline but rather relied on the subjective judgement of the coder that a detectable head turn to the side had occurred. Each infant head turn was then designated either a match or a mismatch, respectively, depending upon whether the turn was aligned with (match) or in the direction opposite (mismatch) the orientation of the experimenter's gaze. A difference score was then calculated by subtracting the frequency of mismatches from the frequency of matches demonstrated in each four-trial block of the session. A sample of 30% of the videotapes (seven subjects from each age group) was randomly selected for reliability coding by a second coder. Coefficient kappas calculated for each age group were as follows: 6-7 months, $k = .95$; 8-9 months, $k = .95$; 10-11 months, $k = .97$.

Results

In order to evaluate the influence of the conditioning procedure on the incidence of joint visual attention, the session was broken down into four-trial blocks and performance during three critical blocks (Baseline, first four Test trials, last four Test trials) was compared. This subdivision of the session was necessary for the analysis since, as outlined earlier, the length of the Test phase varied as a function of individual performance. The mean numbers of Test trials completed at each age were (out of a possible total of 20 Test trials): 6-7-month-olds, 20 trials; 8-9-month-olds, 14.5 trials; 10-11-month-olds, 12 trials.

A two-way ANOVA was conducted with Age (three levels: 6-7, 8-9, and 10-11 months) as a between-subjects variable and Block (three levels: Baseline, first Test block, last Test block) as a within-subjects variable. As in Experiment 1, the match minus mismatch difference score was used as the dependent measure in the analysis. Table 3 outlines the mean difference scores calculated for each age group during each of the Baseline, First, and Last Test blocks.[1]

Results of the Age by Block ANOVA indicated a significant Age effect, $F(2, 60) = 14.04$, $p < .001$, such that 8-9-month-olds and 10-11-month-olds both had higher difference scores than 6-7-month-olds; 8-9 months, $t(1, 60) = 3.27$, $p < .01$; and 10-11 months, $t(1, 60) = 7.36$, $p < .001$. In addition, 10-11-month-olds were also found to have higher difference scores than 8-9-month-olds, $t(1, 60) = 4.09$, $p < .001$.

A significant Block effect was also found in which infants demonstrated greater difference scores in the Test blocks than in the Baseline portion of the session; first Test block, $t(1, 120) = 3.78$, $p < .001$; last Test block, $t(1, 120) = 3.78$, $p < .001$. The Age by Block interaction was not significant.

Although this analysis illustrates performance differences amongst Age groups and session Blocks, of equal importance is whether the patterns of performance demonstrated are at all systematic rather than random. If infants did turn their heads in a systematic rather than a random fashion in relation to the cues demonstrated by the model, then it would expected that the difference scores obtained would be significantly different from zero. In order to evaluate

[1] Since two aspects of the analyses were unprecedented in the area (i.e., the use of a difference score and the analysis of only a portion of the total trials conducted) two alternative analyses were undertaken: a) ANOVA employing % correct responses as the dependent measure in lieu of the difference score measure, and b) ANOVA comparing the first four Test trials and the second four Test trials in lieu of the first four and last four. The pattern of results obtained in these analyses was the same as that for the analyses presented in the text.

Table 3. Mean difference scores (and standard deviations) for each Age group during each Block of testing in Experiment 2.

	Block		
Age (months)	Baseline	First Test	Last Test
6-7	0.095 (0.889)	0.667* (1.317)	0.667 (1.494)
8-9	0.476 (1.436)	1.762*** (1.513)	1.619*** (1.717)
10-11	1.619*** (1.746)	2.571*** (1.938)	2.714*** (2.004)

Note. Probabilities represent M tested against 0: *p < .05; **p < .01; ***p < .001

the extent to which infants in each Age group were performing in a systematic way during each Block of the session a series of t-tests was conducted in which the difference scores obtained were compared with zero. Results of these post hoc tests indicated that during Baseline only the 10-11-month-olds showed a difference score that was significantly greater than zero; $t\ (1,19) = 4.25$, $p < .001$. In contrast, all three age groups obtained difference scores which were significantly greater than zero in the First Test block; 6-7 months, $t\ (1,19) = 2.30$, $p < .05$; 8-9 months, $t\ (1,19) = 5.34$, $p < .001$; and 10-11 months, $t\ (1,19) = 6.08$, $p < .001$. Finally, during the Last Test block only the two older age groups showed difference scores which were significantly greater than zero; 8-9 months, $t\ (1,19) = 4.32$, $p < .001$; and 10-11 months, $t\ (1,19) = 6.21$, $p < .001$.

Although the difference score analysis revealed both a significant age effect as well as a significant effect of the conditioning procedure, based on observations of infant performance it was realized that even in the narrow 6-11 month age range tested in Experiment 2 infants were demonstrating qualitatively different response patterns that were not captured by the quantitative difference score measure. Consequently, a second type of analysis, based on a categorization of individual infant performance across the entire session, was conducted. While this new categorical measure captured an additional dimension of infant performance, the foundation for the criteria adopted still rested firmly in the notion (as outlined in Experiment 1) that infants must demonstrate more matches than mismatches in order to be judged as reliably engaging in joint visual attention.

Performance observations suggested three primary patterns of response: Spontaneous Joint Visual Attention, Learning, and Perseveration. Table 4 outlines the criteria for these response patterns. In keeping with the basic logic of the operational definition adopted in Experiment 1, infants who demonstrated

Table 4. Criteria for each of the Response patterns identified in Experiment 2.

Response Type	Phase Criteria: Baseline	Phase Criteria: Test
Spontaneous JVA	match - mismatch difference score of 2 or greater	5 or more consecutive matches
Learning	failure to meet Baseline criterion for Spontaneous JVA	5 or more consecutive matches
Perseveration	failure to meet Baseline criterion for Spontaneous JVA	70% or more turns to one side OR 3 or more sequences of 3 or more turns to one side

a pattern of Spontaneous Joint Visual Attention engaged in more matches than mismatches during the Baseline phase; that is, there was a match minus mismatch difference score of two or greater in the four trial Baseline phase. In addition to satisfying this Baseline requirement, Spontaneous Joint Visual Attention infants went on to reach a criterion of five consecutive matches with the experimenter's direction of gaze during the Test Phase (with a conservative estimate of the probability of infants engaging in five consecutive matches at $p < .05$). In contrast, infants who demonstrated a pattern of Learning did not meet the Baseline criterion for Spontaneous Joint Visual Attention but did go on to meet the Test Phase criterion of five consecutive matches with the experimenter's direction of gaze. Finally, infants who demonstrated a pattern of Perseveration failed to reach either the Baseline or the Test Phase criterion outlined earlier. However, Perseverators did meet an alternative criterion during the Test Phase whereby they engaged in either a majority of head turns in one direction (70% or greater) or several sequences of turns in the same direction (three or more sequences of three or more consecutive turns in the same direction). Since these three response categories were not exclusive, decisions regarding categorization were made in a conservative fashion. That is, since it was possible for an infant to meet the criteria for both Learning and Perseveration such infants were assigned to the Perseveration category. In addition, it should be noted that the response categories were not exhaustive (i.e., 3 out of the 63 infants tested did not meet criteria for any of the patterns). However, all of the infants demonstrating an "other" response pattern fell into the youngest (6-7 month) age group.

A chi square test ($\chi^2(4, N = 60) = 26.66, p < .001$) performed on the data indicated clear developmental differences in the three primary response patterns. Figure 2 illustrates the number of infants in each age group exhibiting

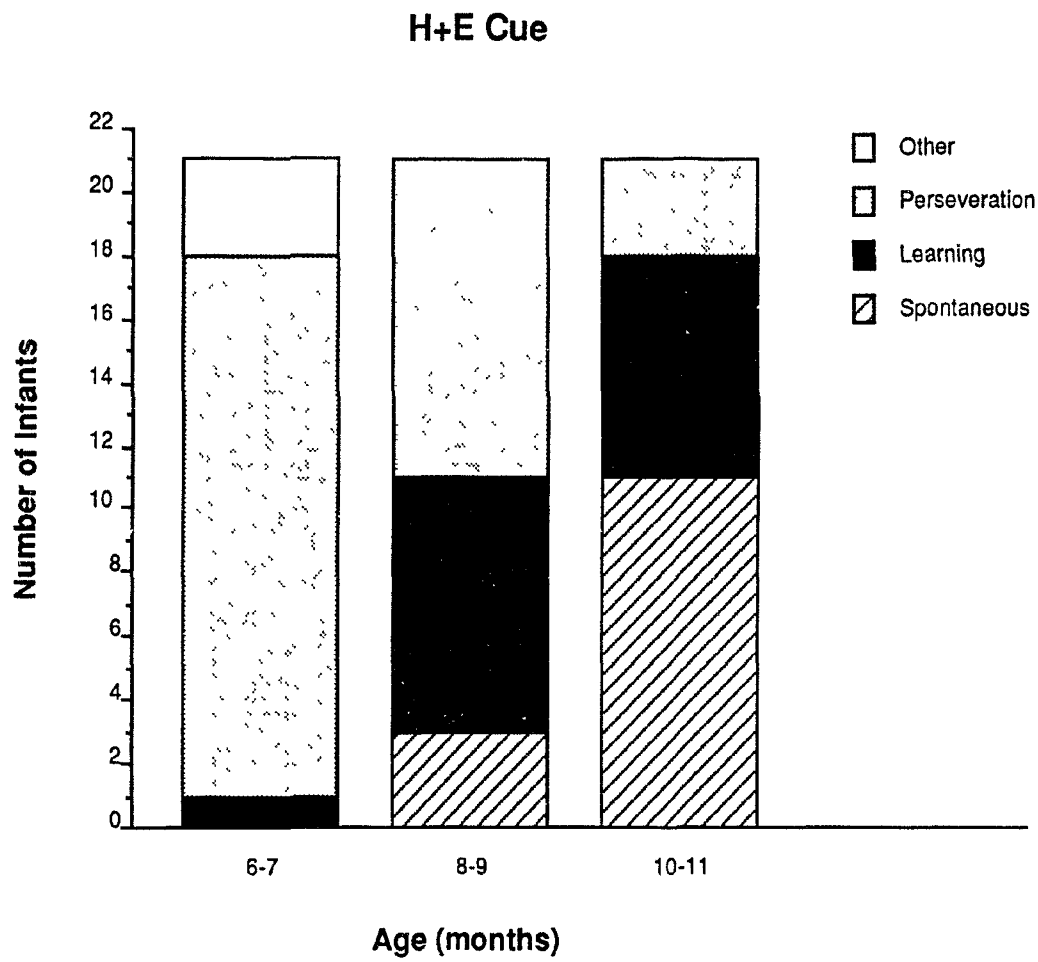

Figure 2. Number of infants demonstrating each Response pattern as a function of Age in Experiment 2.

each response pattern. In the 6-7 month age group the majority of infants (17 out of 21) engaged in a pattern of Perseveration. Only one infant in the 6-7 month group showed a pattern of Learning while none demonstrated Spontaneous Joint Visual Attention. In contrast, in the 8-9 month age group there were far fewer Perseverators (10 out of 21) and far more Learners (8 out of 21) than at 6-7 months. In addition, there were a few infants (3 out of 21) demonstrating Spontaneous Joint Visual Attention in the 8-9 month group. Finally, in the 10-11 month age group there were even fewer Perseverators (only 3 out of 21) than in the 8-9 month group, but roughly the same number of Learners (7 out of 21). However, the pattern demonstrated by the greatest number of infants in the 10-11 month group (11 out of 21) was one of Spontaneous Joint Visual Attention.[2]

Discussion

In line with the findings of Experiment 1 as well as those of Morissette et al., 1995, the pattern of results obtained in Experiment 2 clearly indicate that joint visual attention does not emerge until somewhat later than previous investigators have concluded (Scaife & Bruner ,1975; Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991). While the quantitative analysis revealed a significant overall effect of the conditioning procedure such that all infants tended to show higher difference scores during the Contingent compared with the Baseline phase, at the same time a significant Age effect indicated that older infants were still showing higher overall difference scores across the session. Only in the 10-11 month-old group were the infants more likely, even during

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[2] If a more liberal criterion is employed in examining the response patterns and those infants who meet criteria for both Learning and Perseveration are categorized as Learners instead of Perseverators the pattern of results for Experiment 2 changes very little. That is, 3 additional infants in each group demonstrate a pattern of Learning. Overall, the primary developmental trend remains essentially the same.

Baseline, to turn in the same direction as the adult than they were to turn in the opposite direction. However, infants at all ages studied did show some evidence of acquiring gaze-following over the course of the experimental session. Even the youngest infants were more likely to follow gaze in the Test trials than in the Baseline phase although only a very small proportion of them (less than 5%) followed the experimenter's gaze well enough across the Test trials to have reliably acquired gaze-following by the end of the session. Like the youngest group, the 8-9-month-olds did not show gaze-following in Baseline but did acquire gaze-following at above chance levels during the first block of Test trials. Unlike the youngest group, however, the 8-9-month-olds tended to maintain their above chance performance throughout the Test trials.

The categorical analysis of individual performance was consistent with the analysis of difference scores but added further information on how infants in each age group performed in the session. Based on this analysis, it was noted that even with the addition of targets in Experiment 2, there were no 6-7-month-olds who spontaneously engaged in joint visual attention and only a very small proportion (less than 5%) of them who were able to learn to align with the direction of another's gaze even with the assistance of contingent feedback. The large majority of infants in the 6-7-month-old group tended to turn for the most part in one direction only. Thus, even though the analysis of difference scores showed some ability to acquire gaze-following at 6-7 months, the effect cannot be considered to be particularly robust, since the pattern of head turns does not fully reflect the reliable link between the model's head turns and the appearance of the moving toy to the same side. While about half of the 8-9-month-olds showed a perseveration pattern, a considerable number (about 40%) were able to acquire gaze-following reliably given feedback. Of the 10-11-month-olds, a small majority showed spontaneous gaze-following and most of the rest were able to acquire gaze-following reliably during the session. Based on this pattern of findings, it is concluded that it is not until sometime around 10 months of age that joint visual attention becomes a reliable part of the infant's behavioral repertoire. However, given the high proportion of 8-9-month-olds who were able to learn to align with the direction of another's gaze, infants appear ready to acquire gaze-following from about 8-9 months of age.[3]

Clearly, it is appropriate to allow for developmental variability in the age of emergence of specific skills. The time-table for the emergence of joint attention is no exception. Consequently, rather than focusing on absolute ages of emergence, perhaps the most important information to be gleaned from Experiment 2 is the notion of a definite developmental progression in the emergence of gaze-following behavior. Initially, infants seem to show a basic awareness of: 1) the changes in behavior that accompany the re-orientation of the model's attention and, 2) the movement of the targets. This is demonstrated in an increase in infant head turning during the Shaping and Test phases (when targets were activated) compared with the Baseline phase (when the targets were inactive). However, at this stage infants seem unable to use the information provided by the model's behavior in order to produce differential responding (even with the assistance of feedback). Later developmentally, infants are able to respond differentially to the model's cues for change in gaze orientation. However, at this point feedback seems necessary in scaffolding the

[3] In an attempt to interpret more carefully the pattern of perseveration, responses were reviewed so as to determine whether there was anything systematic about the particular side to which these infants turned. Differences in lighting and other aspects of the set-up were ruled out after careful examination of the physical environment. The data themselves were then examined carefully to determine whether infants tended to show an overall side bias (e.g., most infants turning to the right side) or even whether individual infants tended to turn to a predetermined or "cued" side (e.g., the side on which the first target was activated). Both of these alternatives were ruled out. Although infants designated as perseverators shared in common the fact that they tended to turn primarily to one side, the side to which each of them did turn seemed to be "randomly" determined.

integration of model and target information. That is, infants fail to respond differentially when targets are inactive but do demonstrate differential responding when targets are contingently activated. They seem to need feedback in order to "learn" the connection between the model's cues and the appearance of the targets. Finally, the oldest infants seem able to spontaneously generate differential responses to the model's cues for change in gaze orientation without the need for specific feedback. That is, even during Baseline the oldest infants followed the model's changes in attention. These results suggest that the onset of joint visual attention, in line with general sensorimotor development, may be tied to infants' emerging ability to respond flexibly to two separate spatial locations on the basis of different cues.

In summary, the findings of Experiment 2 indicate that even when targets are present, joint visual attention is not spontaneously demonstrated by infants until about 10 months of age. However, given the appropriate feedback, infants seem to be able to acquire a joint visual attention-like response from about 8 months on. This pattern of findings suggests that learning or operant conditioning is a possible mode of acquisition of the joint visual attention response.

Experiment 3

In Experiment 2 one aspect of the issue of the origins of joint visual attention was addressed by assessing whether a joint visual attention response might be acquired via a process of operant conditioning. In Experiment 3 attention was turned to another aspect of the origins issue which also remained unaddressed in the joint visual attention literature; that is, the origin of the signal value of the most salient cue for joint visual attention (i.e., congruent head and eye orientation).

The results of Experiment 2 are clearly consistent with the view that joint visual attention might be acquired through learning in that some infants who did not show joint visual attention at the start of the experimental session were showing it by the end of the session. It is possible that in the natural world, infants learn that adult head turns happen reliably to predict the appearance of interesting sights. If the acquisition of joint visual attention amounts simply to learning that interesting sights will reliably appear after certain adult actions, then it should be the case that the particular cues provided by the adult are essentially unimportant. If so, the only important factor would be the association between the adult cues (in the case of this work, left and right head turns) and the appearance of an interesting sight in a distinct location. In other words, all that would be required is that one head turn predicts the appearance of the moving target in one location reliably and the other head turn predicts the appearance of the moving target in the other location reliably. While the results of the first experiment are certainly consistent with this sort of explanation, this first study alone cannot establish the extent to which joint visual attention is purely a learned phenomenon of this kind. It is equally possible that the characteristics of the cues for gaze reorientation are quite important. In fact, the actual physical form of the cues may be critical for the response associations that are possible. In this way, nature may have placed some constraints on the contingencies which may be learned.

One way to test this question of the importance of the cue characteristics is to examine the relative ease of training an infant head turn in response to a cue that is a natural signal for the direction of another's gaze versus another cue that is not such a natural signal. If it is the case that the characteristics of the cues for joint visual attention are unimportant for the acquisition of the head turn response then one would predict that it would be just as easy for infants to learn to make a head turn response when the stimulus is an unnatural cue as when it is a natural one. Conversely, if the actual form of the adult's behavior is important, then it may be more difficult to train a head turn response to an unnatural cue than to a natural one.

One practical problem in conducting Experiment 3 was the identification of an unnatural cue that would be similar enough perceptually to the natural one so that any differences in ease of training that might be obtained would not be due to a difference in the ease of detectability or perceptability of the cues. Since the plan was to employ the same cue as in Experiment 2 (i.e., a 90-degree head and eyes turn toward a moving target) for the natural cue then the logical choice for the unnatural cue was a head and eyes turn in the direction opposite to the moving target. The latter cue seemed appropriate because a head and eyes turn in the direction opposite to the moving target is equivalent in overall physical form to the natural cue so it would be just as easy for infants to detect. However, this cue would differ from the natural cue in one critical aspect: the direction of movement relative to the targets would be reversed. In this way, any differences in ease of training which resulted would be attributable to a difference in the ease of learning the predictive relationship between the cues and the targets rather than to a difference in the ease of detection of the cues.

Based on the selection of these cues, two conditions were created. Infants assigned to the Natural group were presented with a condition in which head turn cues predicted the appearance of moving targets on the side to which the model's head turn was made (just like the infants in Experiment 2). Infants assigned to the Unnatural group were presented with a condition in which head turn cues predicted the appearance of moving targets on the opposite side to which the model's head turn was made. If no significant differences were found between the Natural and Unnatural groups in terms of the ease with which they learned to turn toward the moving targets then it could be concluded that the form of the adult's behavior is not important and that the relation between the head turn cue and the infants' own head turns is an essentially arbitrary one and likely the product of learning. If, on the other hand, infants in the Natural group acquire their target response more easily than those in the Unnatural group, then it could be concluded that infants' acquisition of joint visual attention is facilitated by physical characteristics, in this case movement direction, of the model's gaze behavior.

Method

Subjects. The participants were fifty-nine infants who were between 8 and 9 months of age. All of the infants were full-term (> 37 weeks gestation), had normal birthweights (> 3200 gm), and had experienced no birth complications or major health problems. Twenty-seven infants were excluded from participation in this study because they demonstrated Spontaneous Joint Visual Attention in the first part of the session (see Procedure section for description of criteria used for making a designation of Spontaneous Joint Visual Attention). Due to an error in the application of the Baseline exclusion criterion, one infant who demonstrated spontaneous joint visual attention was tested but was subsequently excluded from the final sample. An additional three infants, one assigned to the Natural condition and two assigned to the Unnatural condition, did not complete testing because they became fussy or too active to remain seated on the parent's lap. The final sample consisted of twenty-eight infants, fourteen assigned to each condition: Natural (M age = 9 months - 4 days, Range = 8-4 to 9-26) and Unnatural (M age = 9-6, Range = 8-15 to 9-28). Equal numbers of boys and girls were tested in each condition.

Set-up & Procedure. The basic set-up and procedure described for Experiment 2 was employed for both groups of infants (Natural and Unnatural) in Experiment 3 as well. As in Experiment 2, the session contained a maximum of twenty-eight trials of change in the experimenter's direction of gaze with each session being comprised of three experimental phases (Baseline, Shaping, and Test phases). The primary procedural modification made in Experiment 3 was exclusively related to experimental condition. Infants assigned to the Natural group experienced an exact replication of the conditions presented in Experiment 2. Infants assigned to the Unnatural group, however, were exposed to a condition in which the toy that was activated was on the side opposite to the model's head turn in both Shaping and Test phases.

The only other modification incorporated into the Experiment 3 procedure (which applied to both experimental conditions) was the addition of an on-line evaluation of infant performance during the Baseline phase in order to exclude from the study infants who were spontaneously engaging in joint ual attention. Because, in this experiment, the interest was in the conditions for the acquisition of the joint visual attention response, infants who had already acquired the response were not included. Therefore an evaluation of infant performance during Baseline was conducted by the observer who watched the proceedings of the session on a video monitor from an adjacent room. During the Baseline phase the observer was responsible for noting the direction of the first infant head turn to occur during each trial and subsequently computing a target minus nontarget response difference score for the four-trial Baseline phase. It was on the basis of this difference score that infants were then judged to be demonstrating or not demonstrating Spontaneous Joint Visual Attention. In keeping with the Baseline criterion for a designation of Spontaneous Joint Visual Attention employed in Experiment 2, infants who demonstrated a difference score of two or greater during Baseline were judged to be demonstrating Spontaneous Joint Visual Attention and were excluded from the present study. After the completion of the Baseline phase, but prior to entering the Shaping phase, the observer indicated to the experimenter the nature of the infant's Baseline performance through activation of a signal light. This permitted the experimenter (on-line) to continue the session as planned if the infant met the inclusion criterion. Those infants not meeting the inclusion criterion were exposed to a different procedure (not described here). Further, as in Experiment 2, the Test phase was terminated at the end of the four-trial block in which the infant demonstrated five consecutive target responses. This judgement was made by the observer in the same manner described for Experiment 2. The accuracy of the observer's judgements concerning the Baseline and Test phase criteria were checked when the videotapes were scored. One error was detected in the application of the Baseline criterion and this infant was excluded from the final sample.

Scoring. Videotapes were coded in the same manner as in Experiment 2 with infant head turns first being scored for direction, then designated as target responses or nontarget responses, and finally, a difference score calculated by subtracting the nontarget responses from the target responses demonstrated in each four-trial block of the session. In light of the differences between Experiments 2 and 3 some further explanation of the criteria employed for designation of infant head turns as target or nontarget responses is in order. As in Experiment 2, a target response was scored during the Test phase if the infant's first head turn was toward the activated target, while a nontarget response was scored if the infant's first head turn was away from the activated target. Such a scoring procedure meant that for infants in the Natural group, target responses also followed the model's gaze; whereas for infants in the Unnatural group, target responses were in the opposite direction to the model's head turn.[4] In addition, in order for an analysis of performance during Baseline to be carried out, infant head turns during this phase were also coded. In the Baseline period, for both Natural and Unnatural groups, targets were present but not activated so target and nontarget responses were determined by looking at alignments with the model's gaze. This meant that for both groups, during Baseline, infant head turns that aligned with the model's were scored as target responses and infant head turns in the opposite direction to the model's were scored as nontarget responses.

A sample of 30% of the videotapes (five subjects from each group) was randomly selected for reliability coding by a second coder. Coefficient kappas calculated for each group were as follows: Natural, $\underline{k} = .94$; Unnatural, $\underline{k} = .96$.

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[4] This technique for scoring of responses evaluates the degree to which infants learn their respective contingencies and successfully find the targets. Of course, an alternative scoring technique is also possible whereby infants are evaluated in terms of the degree to which they tend to follow the model's cues. The first of these strategies was initially adopted because the main interest was in the role of learning in the acquisition of the joint attention response. Either technique would have adequately addressed the research questions. However, the technique adopted was more in line, than the alternative, with the manner in which the research questions were generated.

Results

In order to evaluate the influence of the training procedure on the incidence of producing a head turn response in each group, the session was broken down into four-trial blocks and the performance of each group during three critical blocks (Baseline, first four Test trials, and last four Test trials) was examined. As with Experiments 2 and 4, this subdivision of the session was necessary for the analysis because the length of the Test phase varied as a function of individual performance. The mean number of Test trials completed as a function of group were (out of a possible total of 20 Test trials): Natural, 18; Unnatural, 20. Since the criteria for target and nontarget responses differed during the Baseline and Test phases of the session (as outlined above) two separate analyses were conducted: one to examine performance differences between groups during Baseline, and the other to examine the same issue during the Test phase. Table 5 outlines the mean difference scores calculated for each group during each of the Baseline, First and Last Test Blocks.

First, a one-way ANOVA was conducted on the difference scores for the two groups (Natural and Unnatural) during the Baseline phase. Results of this analysis indicated no significant effects ($F(1, 26) = .85$, n.s.).

Second, a two-way ANOVA was conducted with Group (two levels: Natural and Unnatural) as a between-subjects variable and Block (two levels: first Test block, and last Test block) as a within-subjects variable. The difference score was also used as the dependent measure in this analysis. Results of this analysis indicated a significant Group effect, $F(1, 26) = 19.88$, $p < .001$, such that infants in the Natural group demonstrated greater difference scores than infants in the Unnatural group. Further, a significant Block effect was found such that infants demonstrated higher difference scores during the last compared with the

Table 5. Mean difference scores for each Training group during each Bloc.. of testing in Experiment 3.

Group	Block: Baseline	First Test	Last Test
Natural	0.071 (0.475)	0.714 (1.541)	1.714** (1.939)
Unnatural	0.286 (0.726)	-1.643* (2.170)	-0.929 (1.685)

Note. Criteria for target and nontarget responses differed in Baseline and Test Blocks. See Scoring section for details. Values in parentheses are SD. Probabilities represent M tested against 0: *p < .05; **p < .01; ***p < .001

first Test Block, $F(1, 26) = 4.22$, $p < .05$. The Group by Block interaction was not significant.

Third, as in Experiments 2 and 4, post hoc tests were conducted to compare, against zero, the difference scores obtained by each Age group in each Block of the session. Results of these post hoc tests indicated that neither group was performing in a systematic fashion during the Baseline portion of the session. In contrast, during the First Test block only the Unnatural Group demonstrated a difference score which was significantly different from zero, $t(1,13) = 2.83$, $p < .05$; while only the Natural group demonstrated a difference score that was significantly different from zero during the Last Test block, $t(1,13) = 3.30$, $p < .01$.

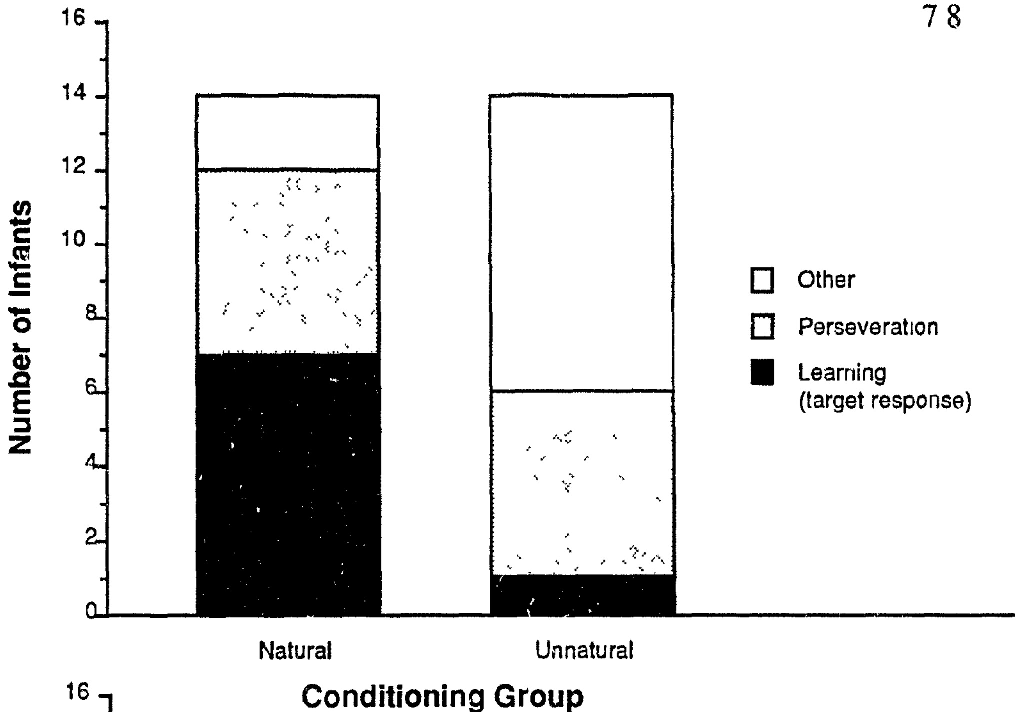
In keeping with the categorical analysis conducted for Experiment 2, performance of infants in the present study was also evaluated with respect to the response types identified in Experiment 2. The criteria employed for examining the response patterns in Experiment 3 were parallel to those outlined in Experiment 2; however, since infants demonstrating Spontaneous Joint Visual Attention were necessarily excluded from participation in Experiment 3 only the incidence of the Learning, Perseveration, and Other response patterns in each of the experimental conditions was compared. For the purposes of Experiment 3, the criteria for Perseveration were the same as those employed in Experiment 2 (i.e., during the Test phase, either 70% or more head turns to one side or three or more sequences of three or more turns to the same side). Likewise, as in Experiment 2, infants who demonstrated a pattern of Learning (i.e., acquisition of their target response) in Experiment 3 demonstrated five or more consecutive head turns which resulted in activation of the target during the Test phase of the session. Finally, as was the case in

Experiment 2, these response patterns were not exhaustive in that a number of infants did not meet criteria for any of them.

A chi square test ($\underline{X}^2$ (3, $\underline{N}$ = 28) = 10.24, $\underline{p}$ < .01) performed on the data indicated significant group differences in these three response patterns. The top panel of Figure 3 illustrates the number of infants in each conditioning group exhibiting each response pattern. Exactly half of the infants in the Natural group (7 out of 14) demonstrated a pattern of Learning to align with the experimenter's orientation of gaze. The other half of the infants in the Natural group were split between demonstrating a pattern of Perseveration (5 out of 14) and an Other response pattern (2 out of 14). In contrast, while only one of the infants in the Unnatural group demonstrated a pattern of Learning to misalign with the experimenter's orientation of gaze, five of them showed a pattern of Perseveration, and the remainder showed an Other response pattern (8 out of 14).[5]

The above pattern of results is seen when the numbers of infants who successfully located the contingently moving target is examined. If instead the frequency with which infants in both groups actually aligned with the experimenter's orientation of gaze is examined, a different pattern of results emerges. Now target responses in both groups are those for which the infant followed the model's head turn, whereas nontarget responses are those for which the infant turned in the direction opposite the model's turn. The bottom panel of Figure 3 illustrates the distribution of performance patterns in each group assuming such a common target response. The results for the Natural group, of course, remain unchanged because turning to the contingently

[5] If a more liberal criterion is employed in examining the response patterns and those infants who meet criteria for both Learning and Perseveration are categorized as Learners rather than Perseverators the pattern of results for Experiment 3 does not change at all.



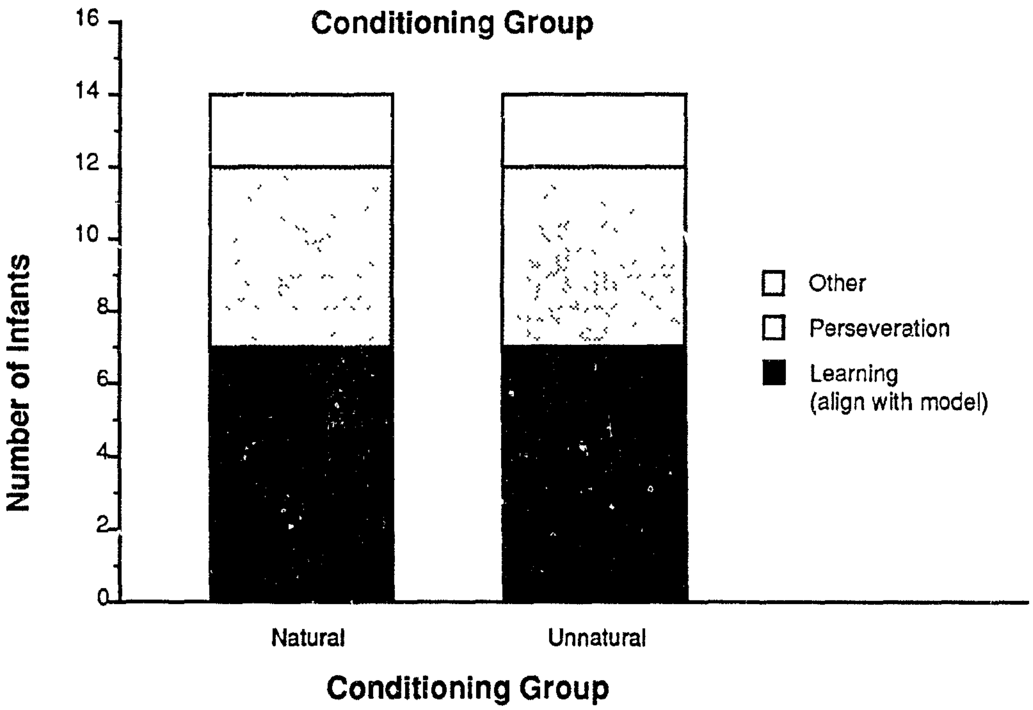


Figure 3. Number of infants demonstrating each Response pattern as a function of Conditioning group in Experiment 3. Top panel illustrates distribution of performance patterns in light of the target response designated for each Conditioning group. Bottom panel illustrates distribution of performance patterns assuming a common target response (align with model) for each Conditioning group.

moving target is the same as aligning with the experimenter's direction of gaze. In contrast, those for the Unnatural group are quite different. While the same number of Perseverators (5 out of 14) is evident in the Unnatural group using this new criterion, there are far fewer infants who demonstrate Other response patterns (only 2 out of 14 rather than 9 out of 14). Instead, 7 of the 14 Unnatural group infants, who formerly demonstrated Other response patterns, now reach the criterion set for Learning to align with the experimenter's gaze (in that they engaged in 5 or more consecutive matches during the Test Phase). This is exactly the same number of infants who demonstrated a pattern of Learning in the Natural group.

Given this result, a one-way ANOVA was conducted with Group as a between-subjects variable (2 levels: Natural and Unnatural) and number of trials to reach criterion for Learning to align with the experimenter's gaze as the dependent measure. This analysis revealed no significant effects ($F(1, 26) = 0.87$, n.s.).

Discussion

The results from the Natural condition in this experiment replicate those from the 8-9-month-old group of Experiment 2. Half of the infants exposed to a model's head turn followed by the appearance of the moving target on the same side learned to turn to find the target after seeing the head turn. Allowing, of course, for individual variability, both experiments suggest, that given the appropriate experience, a large proportion of 8-9-month-olds are able to acquire a joint visual attention response.

Comparing performance in the two experimental conditions showed that the two groups demonstrated difference scores that were equivalent during the Baseline phase, with neither group showing reliable joint visual attention prior to conditioning. However, during the Test phase, the infants exposed to activation of the target on the same side as the model's head turn were able to locate the target significantly more easily than the infants exposed to activation of the target on the side opposite to the model's head turn. This result implies that the particular cues provided by the adult are quite important. Infants' acquisition of joint visual attention seems to be facilitated by physical characteristics, in this case movement direction, of the model's gaze behavior.

Not only was the target response assigned to the Unnatural group significantly more difficult for infants to acquire, they did not acquire to criterion levels. However, these infants did acquire something during the session. When performance in relation to the model's head turns was examined, it was found that as many of the infants in the Unnatural group as in the Natural group followed the model's gaze by the end of the session. Therefore, despite completely opposite patterns of in-session experience, infants in the two groups were equally likely to acquire a joint visual attention response during the experimental session. Furthermore, the analysis of trials to criterion for matching with the experimenter's orientation of gaze showed that the infants in the Unnatural group acquired the joint visual attention response as efficiently as those in the Natural group. Together these results show that the movement direction of the cues is a very important factor in the acquisition of joint visual attention.

Before moving on to discuss more fully the findings from Experiment 3, it is important to consider explanations that would render the pattern of results obtained relatively trivial. One possible explanation is that the subjects could follow gaze correctly all along; they just didn't show it during the Baseline phase. This criticism amounts to saying that the exclusion criterion was too weak. Perhaps these infants just needed time to "warm up" to the laboratory environment and the strange experimenter in order to demonstrate joint visual attention. Or, perhaps after seeing the interesting sights of the toys being activated, the infants were motivated to employ skills that were dormant during Baseline. In either case, it would then be no surprise that there was no difference between the groups in their joint visual attention responses during the Test phase. An empirical test which would help to rule out this simplistic interpretation would involve presenting infants, of the same age, with a longer Baseline phase to determine whether a simple warm-up period leads to an increase in the proportion of 8-9 month infants who demonstrate joint visual attention by session end. While it is impossible, based on the present data alone, to rule out these kinds of explanations three facts question their plausibility. First, in both groups there were a number of infants who showed a Perseveration pattern. These infants too showed no sign of reliable joint visual attention in Baseline and were motivated to find the target after seeing the toys being activated in the Shaping phase. Yet they did not acquire joint visual attention during the session; instead they tended to look only to one side. Therefore, for these infants it cannot simply be the case that a warm-up period or activation of the targets stimulated an interest in gaze-following that was absent while the targets were inactive during Baseline. Second, the results from Experiment 2 showed that whether or not infants showed joint visual attention during Baseline was dependent on age. Older infants (10-11 months) were more likely than younger infants (6-9 months) to show the Spontaneous Joint Visual Attention pattern, implying that the Baseline phase was suitable for eliciting gaze-following but that this ability tends to develop after about 9 months. Third, a comparison of the proportion of infants who met the Baseline criterion for Spontaneous Joint Visual Attention in Experiments 2 and 3 suggests that the screening procedure adopted in Experiment 3 was more likely to be stringent than lenient. Only 14% of the infants (3 out of 21) tested at 8-9 months in Experiment 2 met the Baseline criterion for Spontaneous Joint Visual Attention and went on to also fulfill the Test phase criterion for this designation as well. By comparison, the proportion of 8-9-month-olds excluded from participation in Experiment 3 as a result of meeting the Baseline criterion was much higher at 47% (27 out of 59).

With respect to the issue of the origins of joint visual attention, the pattern of findings obtained in Experiment 3 discounts the learning of a purely contingent association as the mechanism by which the joint visual attention response is acquired. Two facets of the results are of particular importance. First, while a significant proportion of infants in Experiment 3 were successfully trained to align with the direction of a head turn demonstrated by an experimenter, attempts to train infants to misalign with this same cue were quite unsuccessful. Second, despite the presence of reinforcement for misaligning with the direction of the experimenter's gaze (as well as the absence of reinforcement for aligning with it), the infants in the Unnatural group were just as likely as those in the Natural group to align with the experimenter's head turn even at the end of the session. Taken together, these two findings indicate that the characteristics of the cues that are associated with a gaze-following response are critical. They imply that there is some information contained in the head reorientation cue that conveys powerful information about target location. This issue will be revisited in the General Discussion.[6]

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[6] As in Experiment 2, the response patterns of infants demonstrating perseveration were examined carefully to determine whether specific systematic differences could better account for their in-session behavior. As in Experiment 2, no specific trends were found.

Experiment 4

In Experiment 4 the focus came back to documenting developmental differences in the cues employed by infants of different ages for establishing joint visual attention. In light of the findings of Experiment 1 a number of features were incorporated into the design of Experiment 4. First, consistent with Experiments 2, and 3 targets were included in the set-up. Second, because it seemed, in Experiment 1, that multiple cues presented, in a randomized fashion, in the same session may have decreased the salience of more subtle cues such as changes in eye orientation, only one cue type was included in Experiment 4: E cues. Third, since helpful information about joint visual attention in response to head plus eyes cues was obtained in Experiments 2 and 3 via the employment of a training paradigm, the same approach was adopted in Experiment 4.

In Experiment 4 the issues of interest were: 1) the age at which infants employ changes in another's eye orientation as cues for establishing joint visual attention, and 2) whether it is possible to train infants in this age range to align with the orientation of another's eyes. Based on work by Lempers and Butterworth and Jarrett it would be expected that infants would not be making use of eye orientation information as a cue for joint visual attention until well into the second year of life. In contrast, the model proposed by Baron-Cohen suggests that infants have an innate propensity to be sensitive of the orientation of others' eyes. In keeping with this model, it would be expected that infants would be employing eye orientation cues for establishing joint visual attention from the onset of the joint attention response. In Experiment 4 infants ranging in age from 8 to 19 months of age were tested in order to determine the age at which infants naturally employ (and may learn to employ) eye orientation cues for establishing joint visual attention. In this way, it was hoped that some insight would be gained into the infant's understanding of directed visual attention in others.

Method

Subjects. The participants were 70 infants who were between 8 and 19 months of age. All of the infants were full-term (> 37 weeks gestation), of normal birthweight (> 3200 gm), and had experienced no birth complications or major health problems. Testing was not completed with seven infants who became fussy or too active to remain seated on the parent's lap. The final sample of 63 infants was subdivided into five groups: 8-9-, 10-11-, 12-13-, 15-16-, and 18-19-month-olds. Fourteen infants were tested at 8-9 months, 13 infants at 15-16 months, and 12 infants in each of the remaining three groups. The mean age and age range for each of the groups were as follows: 8-9 months (M = 9 months-8 days, Range, 8-14 to 9-26), 10-11 months (M = 10-25, Range = 10-1 to 11-21), 12-13 months (M = 13-6, Range = 12-4 to 13-29), 15-16 months (M = 15-27, Range = 14-20 to 16-29), and 18-19 months (M = 18-24, Range = 17-25 to 19-27).

Set-up, Procedure & Scoring. The same set-up, procedure and scoring criteria described for Experiment 2 were employed in Experiment 4 with the exception that in shifting her attention on each trial the experimenter moved only her eyes (E cue) rather than her head and eyes (H+E cue). A sample of 30% of the videotapes (five from each each age group) were randomly selected for reliability coding by a second rater. Coefficient kappas calculated for each age group were as follows: 8-9 months, k = .97, 10-11 months, k = .95, 12-13 months, k = .95 15-16 month, k = .97, 18-19 months, k = .96.

Results

In keeping with Experiment 2, the influence of the training procedure on the incidence of joint visual attention was evaluated by subdividing the session into four-trial blocks and comparing infant performance during three critical blocks: Baseline, the first Test block and the last Test block. A two-way ANOVA was conducted with Age (five levels: 8-9, 10-11, 12-13, 15-16, 18-19 months) as a between-subjects variable and Block (three levels: baseline, first Test block, last Test block) as a within-subjects variable. The dependent measure for this analysis was the match minus mismatch difference score. Table 6 outlines the mean difference scores calculated for each Age group during each of the Baseline, First and Last Test Blocks.

Results of the Age by Block ANOVA indicated a significant Age effect, $F(4, 58) = 3.30$, $p < .05$. Post hoc tests revealed that 18-19-month-olds had higher overall difference scores than all of other groups tested: 8-9-month-olds, $t(1, 58) = 3.23$, $p < .01$; 10-11-month-olds, $t(1, 58) = 2.89$, $p < .01$; 12-13-month-olds, $t(1, 58) = 2.40$, $p < .02$; 15-16-month-olds, $t(1, 58) = 2.78$, $p < .01$. However, other age comparisons were not significant. Further, the Block effect and the Age by Block interaction were not significant.

As in the previous experiments, in order to determine the extent to which infants in each Age group were performing in a systematic rather than a random way across the session, a series of t-tests was conducted in which the difference scores obtained were compared with zero. The results of these post hoc tests indicated that only the 18-19-month-olds showed difference scores which were significantly greater than zero, $t(1, 11) = 4.93$, $p < .01$.

In line with the qualitative analyses conducted for Experiments 2 and 3 the performance of infants in the present experiment was also classified in terms of the response types: Spontaneous Joint Visual Attention, Learning,

Table 6. Mean difference scores (and standard deviations) for each Age group during each Block of testing in Experiment 4.

	Block		
Age (months)	Baseline	First Test	Last Test
8-9	0.000 (1.754)	0.000 (1.468)	0.571 (1.604)
10-11	0.333 (1.231)	-0.167 (1.801)	0.750(2.491)
12-13	0.667 (1.231)	1.000 (1.758)	0.000 (2.132)
15-16	0.462 (1.050)	-0.077 (1.801)	0.769 (1.536)
18-19	1.833 (1.337)	1.583 (2.275)	1.917 (2.503)

Perseveration, or Other. A chi square test ($\underline{X}^2$ (3, $\underline{N}$ = 63) = 45.62, $\underline{p}$ < .001) performed on the data indicated developmental differences in these response patterns. Figure 4 illustrates the number of infants in each age group exhibiting each response pattern. As can be seen from Figure 4, by far the majority of infants in the 8 to 16 month range (including the 8-9, 10-11, 12-13, and 15-16 month groups) demonstrated a pattern of Perseveration. Of all of the groups tested, it is only the 18-19 month group in which a large proportion of infants demonstrated patterns of Spontaneous Joint Visual Attention and Learning (seven and three infants, respectively).[7]

Discussion

The results of Experiment 4 clearly indicate that infants from 8-16 months do not spontaneously employ changes in another's eye orientation as a cue for establishing joint visual attention. The quantitative analysis of the match minus mismatch difference scores revealed that only infants in the 18-19 month group demonstrated more joint visual attention across the session than any of the younger infants tested. Further, only infants in the 18-19 month group followed the direction of the model's eye orientation at a rate which was significantly greater than chance; thus, indicating reliable gaze-following.

The categorical analysis of response patterns was consistent with the analysis of difference scores. The categorical analysis indicated that infants from 8 to 16 months responded in an unsystematic fashion; their predominant response pattern was one of Perseveration. In contrast, in Experiment 4 the majority of the infants in the 18-19 month group showed a systematic pattern of

[7] If a more liberal criterion is employed in examining the response patterns and infants who meet criteria for both Learning and Perseveration are categorized as Learners rather than Perseverators, the pattern of results for Experiment 4 changes very little. That is, 1 additional infant in each of the 15-16 month and 8-9 month groups is found to demonstrate a pattern of Learning. No changes are noted in the 10-11, 12-13 and 18-19 month groups.

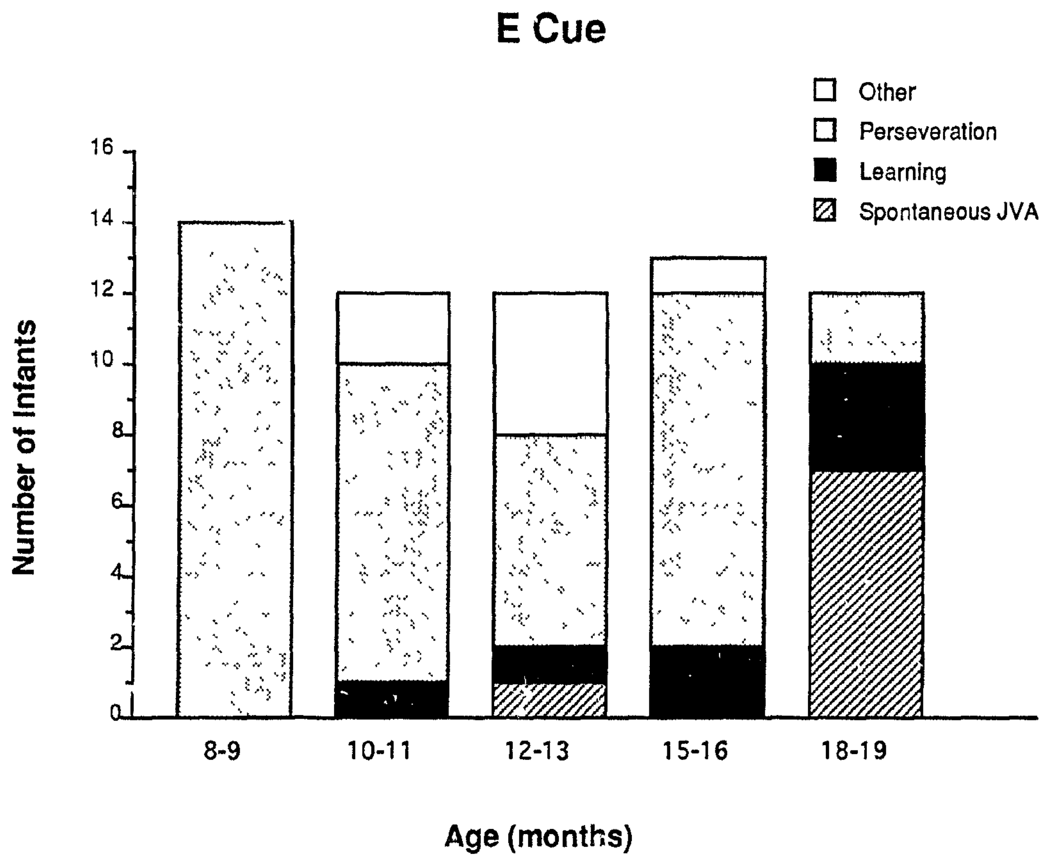

Figure 4. Number of infants demonstrating each Response pattern as a function of Age in Experiment 4.

reliably aligning with the experimenter, with most infants doing so from the beginning of the session (i.e., Spontaneous Joint Visual Attention) and only a minority of infants (2 out of 12) in this oldest group showing an unorganized response pattern (i.e., Perseveration). Curiously, very few of the infants tested in Experiment 4, even in the older groups, benefitted from participating in the training procedure by learning, over the course of the session, to align with the model's eye gaze.[8]

This overall pattern of findings is certainly in keeping with the results of Experiment 1 in that infants younger than 16 months did not establish joint visual attention based on changes in another's eye orientation. However, in contrast with the present results, in Experiment 1, none of the infants, not even those in the 18-19 month group, used the eye orientation cue for following the experimenter's gaze and establishing joint visual attention. Why might this be? It is suspected that the procedural modifications which were incorporated into the design of Experiment 4 may have contributed to the demonstration of joint visual attention by the 18-19 month group in this study. To be specific, in Experiment 4 infants were presented with eye cues, exclusively; that is, the experimenter demonstrated no other cue type. In contrast, the infants in Experiment 1 were exposed to four different trial types presented in a randomized fashion. The presentation manner adopted in Experiment 4 is likely to have enhanced these infants' sensitivity and attention to the experimenter's eyes. Further, while Experiment 1 did not incorporate targets in the design, Experiment 4 included contingently moving targets for the infants to see if they aligned with the experimenter's gaze. The inclusion of interesting

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[8] As in Experiments 2 and 3, the response patterns of infants demonstrating perseveration were examined carefully to determine whether specific differences could better account for their in-session behavior. As in Experiments 2 and 3, no specific trends were found.

sights to see may have provided the infants in Experiment 4 with an extra incentive for following the Experimenter's eye gaze which was not available to infants in Experiment 1.

In comparing the results of Experiment 4 with those of Experiment 2 several things are noteworthy. First, while the infants in Experiment 2 demonstrated joint visual attention based on head plus eye changes from about 10 months of age, those tested in Experiment 4 did not establish joint visual attention based on changes in eye orientation alone until substantially later, after 16 months of age. This pattern of results suggests that infants do not appreciate the significance of eye orientation as a cue for joint visual attention until well after joint attention based on head and eye cues is firmly established. Second, while a significant proportion of infants who were not demonstrating joint visual attention at the beginning of the session in Experiment 2 were able to learn to align reliably with model by the end of the session, few of the infants tested in Experiment 4 benefitted from the training procedure. Why? By way of explanation, it may be helpful to look at the composition of the groups tested in each experiment in terms of both age range and response pattern. In Experiment 2, a large number of infants were tested along a continuous range from 8 through 11 months. The infants who were most likely to benefit from training in Experiment 2 were those who were only slightly younger (8-9 months) than the infants demonstrating Spontaneous Joint Visual Attention (i.e., 10-11 months). In contrast, In Experiment 4, the groups of infants tested spanned a wider range and were in more discrete groups on the upper end of this range; most notably, no infants were tested at either 14 months or 17 months. Since a significant proportion of infants tested at 18-19 months demonstrated joint visual attention reliably from the beginning of the session, it is likely that the critical age at which infants were "ready to learn" to align with the model's eye changes was at approximately 17 months. Since no infants were tested at this age, this is likely the reason for the relative absence of the Learning pattern in the Experiment 4 data.

Finally, the pattern of findings obtained in Experiment 4 is entirely consistent with previous work on the cue issue by Butterworth and Jarrett (1991). While Butterworth and Jarrett did not test infants as young as 8 to 16 months in their paradigm, the modest proportion of trials on which even their 18-month-olds aligned with the orientation of the experimenter's eyes is certainly in line with the findings of Experiment 4. It seems, then, that both the present findings and those of Butterworth and Jarrett are at odds with the predictions of Baron-Cohen's (1994, 1995; Baron-Cohen & Ring, 1994) Mindreading Model whereby the sensitivity to another's eye orientation provided by EDD is the mechanism by which SAM enables joint visual attention. In contrast, the evidence from the present work (Experiments 1 and 4) and that of Butterworth and Jarrett, clearly indicates that joint visual attention occurs, initially in response to changes in another's head orientation. Only significantly later, developmentally, does the infant come to appreciate the significance of eye orientation as a signal of the direction of another's attention.

General Discussion

In the preceding sections the methods and results of four experiments examining the development of joint visual attention in infants have been outlined. In this section the task will be to integrate these findings and to draw some conclusions regarding the three main issues of interest with respect to joint visual attention: the age of emergence, the cues employed by infants of differing ages, and the origins of the response. This section will conclude with some inferences being drawn regarding the nature of the infant's social understanding as well as targeting some directions for future research on joint visual attention.

Age of Emergence

Experiments 1 and 2 examined the issue of age of emergence of joint visual attention using two different paradigms: the more traditional joint attention paradigm and a training procedure akin to the conditioned head-turn paradigm. Strictly speaking, the results of Experiment 1, which employed the joint attention paradigm, indicate that infants do not reliably engage in joint visual attention until about 15 months of age; however, the rudiments of a joint visual attention response seem to be present from about 12 months. Experiment 2, which employed a training procedure, shed some further light on the age of emergence issue in that it allowed observation not only of the age from which joint visual attention seems to be reliably demonstrated, but also the age from which infants are able to benefit from the training procedure, to acquire in the course of the session, a joint visual attention response. The results of Experiment 2 indicate that a significant proportion of infants spontaneously aligned with the model's direction of gaze from as early as 10-11 months of age. At this age, infants did not seem to need the contingent feedback to assist them in aligning with the model. In contrast, the majority of infants tested at 6-7 months of age did not reliably align with the model's gaze even with the additional support of the training procedure. Based on the findings of these two experiments it is concluded that it is not until sometime around the end of the first year that joint visual attention is reliably demonstrated.

This age of onset for joint visual attention is considerably later than that reported by Scaife and Bruner (1975) and Butterworth and colleagues (Butterworth & Cochran, 1980; Butterworth & Grover, 1990; and Butterworth & Jarrett, 1991) who suggest that even 6-month-olds engage in joint visual attention. What is the source of this discrepancy? Two differences between the present work and that of earlier researchers are potential sources of the discrepancy in findings: the more stringent operational definition of joint visual attention adopted throughout this work and the exclusion of targets in Experiment 1.

In the discussion section for Experiment 1 the rationale for concluding that the more stringent operational definition and not the absence of targets is the more likely source of the discrepant findings has been outlined in considerable detail. However, it will be reiterated here, in brief. The research which cites an early age of onset (e.g., Scaife and Bruner; Butterworth and colleagues) has varied in the inclusion/exclusion of targets but has shared in common an operational definition of joint visual attention which includes matches but not mismatches. In contrast, work by Lempers, and Morissette et al., in addition to the present work, has also varied in terms of inclusion/exclusion of targets but has shared in common the consideration of both matches and mismatches in defining joint visual attention. This work cites a later age of emergence of joint visual attention, implying that the operational definition, and not the presence/absence of the targets, is at the root of the discrepancy in findings. Despite this argument, the very recent findings of Caron, Krakowski, Liu, and Brooks (1996) bear on this discussion of the importance of targets and cannot be discounted. Caron et al. (1996) found that the inclusion or exclusion of targets in the set-up significantly influenced infant gaze-following behavior such that infants tended to turn less under target absent conditions. Although this work by Caron et al. was conducted with older (i.e., 12 and 14 month) infants, it clearly illustrates that the exclusion of targets can significantly affect the demonstration of joint visual attention. In this way, it must be concluded that both target and definition factors may have contributed to the very late age of onset of joint visual attention identified in Experiment 1.

In addition to clarifying the role of targets in the demonstration of joint visual attention, this finding by Caron et al. (1996), in conjunction with the results of Experiments 1 and 2, serves to highlight the importance of the multi-paradigmatic approach that has been taken in the present work on joint visual attention. By employing two very different, yet complementary, paradigms it has been possible to document, via the cross-experiment pattern of findings obtained, a more precise estimate of the age of appearance of joint visual attention. Based on consideration of the present own work, and related work by others, it is confidently concluded that joint visual attention does not appear prior to 8 months of age and is not a reliable part of the infant's repertoire until 10 months of age or later.

This age of onset for joint visual attention is certainly much more in keeping with the emergence of other types of triadic interaction such as social referencing (e.g., Feinman, 1982; Sorce et al., 1985; Hornik et al., 1987) as well as protoimperative and protodeclarative gestures (e.g., Bates, 1979; Bates et al., 1979) at around the end of the first year. In this way, the present findings suggest that there is a greater degree of consistency in the nature of the infant's social understanding in the first year of life than the previous work on joint visual attention. The issue of social understanding shall be addressed more fully in a subsequent section.

Perceptual Cues Employed

Experiments 1, 2 and 4 examined the issue of the cues employed by infants of different ages for establishing joint visual attention. In Experiment 1, the relative sensitivity of infants of different ages to a variety of combinations/permutations of a model's head and eye orientation as cues for joint visual attention was examined. In Experiments 2 and 4, the infant's ability to use, or to learn to use, head plus eyes and eyes alone cues, respectively, for establishing joint visual attention was examined within the context of a training paradigm. The findings of each of these experiments will be reviewed, in turn, and some conclusions drawn regarding the perceptual cues employed by infants of different ages for establishing joint visual attention.

The results of Experiment 1 suggest that 6-7-and 9-10-month-olds do not spontaneously engage in joint visual attention based on information from any of the cues because they mismatched as frequently as they matched any of them. In contrast, at 15 months of age infants appear to be engaging in joint visual attention based primarily on information about head orientation; these infants showed more matches than mismatches to the head plus eyes cue type but did not distinguish the head plus eyes and head alone cues. Similarly, the pooled difference score for the 12-13-month-old group in Experiment 1 indicates some evidence of joint visual attention based on head orientation. Finally, for infants in the 18-19 month group in Experiment 1, head and eye congruence seemed to be the most important factor since these infants aligned significantly more than they misaligned with the head plus eyes cue but also aligned with the head plus eyes cue significantly more frequently than with any of the head alone, head and eyes in opposite directions, or eyes alone cues. At no age, however, did the infants in Experiment 1 demonstrate joint visual attention in response to changes in the model's eye orientation alone.

Experiment 4 further investigated the infant's use of eye orientation as a cue for joint visual attention. The results of Experiment 4 show that it is not until after 16 months of age that infants employ changes in another's eye orientation alone as a cue for establishing joint visual attention. Of the infants tested in Experiment 4, only the oldest, 18-19-month-olds, matched more than they mismatched with the direction of the experimenter's eye gaze. Further, it was only this oldest group who matched the model's eye gaze at a frequency which was significantly greater than chance. At none of the ages tested did a majority of infants benefit from the training procedure in assisting them to align with the model's eye orientation. Although modest, the largest proportion of infants who did so benefit from the training procedure in Experiment 4 was certainly in the older age groups tested (i.e., 15-16 and 18-19 months).

Experiment 2 investigated the ability of infants to align with a model's head plus eye orientation within the context of the same training procedure employed in Experiment 4. The results of Experiment 2 are in contrast with those of Experiment 4 since in the former infants were found to establish joint visual attention based on changes in a model's head plus eye orientation from much younger ages, at around 10-11 months. Further, the findings of Experiment 2 illustrate that infants seem able to benefit from contingent feedback to assist them in aligning with the model's head plus eye orientation from about 8-9 months.

Collectively, the results of Experiments 1, 2, and 4 indicate definite developmental differences in the perceptual cues employed by infants for the establishment of joint visual attention. In the early stages of joint visual attention (from about 8 months) infants seem to rely on information about another's head orientation alone. This is consistent with the idea that joint attention has its origins in a response that makes use of another's head orientation as a stimulus to make a head turn in the same direction (Moore & Corkum, 1994a). Such an orienting response would work well in many instances because eye and head orientation are frequently congruent, and thus, in normal circumstances, one would expect the proportion of hits to misses yielded by such a response to be high. As development progresses, infants begin to employ information about both head and eye orientation in establishing joint visual attention. Finally, after about 16 months infants are quite responsive to subtle changes in eye orientation alone and reliably engage in joint visual attention based on the eyes alone cue.

This pattern of findings is fairly consistent, in a number of respects, with previous work on the cue issue by both Butterworth and Jarrett (1991) and Lempers (1979). First, as in the present work, both Butterworth and Jarrett as well as Lempers report that regardless of age of testing, head plus eye orientation is found to be a more salient cue for joint visual attention than eye orientation alone. Further, while Butterworth and Jarrett tested only one age group of infants (18-month-olds), their findings are consistent with the present ones in that they report a substantial proportion of 18-month-olds to be using eye orientation cues for establishing joint visual attention. Finally, as in the present work, Lempers, who tested a range of ages (9 to 14 months) reported a developmental increase in the tendency of infants to align with the experimenter's eye orientation. Unlike the present work, however, Lempers concluded that a significant proportion of even 14-month-olds align with the model based on changes in eye orientation alone. The discrepancy between the present findings and Lempers' is likely due to Lempers' procedure and criteria being somewhat more lenient than those used in the present work. For example, Lempers conducted only two trials with each infant. Further, the proportion of infants at 14 months who were found to be aligning with the model's eye orientation was somewhat modest at 50%. Finally, the notion that infants rely only on head orientation in the early stages of joint visual attention has been confirmed by Moore, Corkum, & MacLellan (1995) in a recent study in which 12-14 month infants were equally likely to follow a model's head plus eyes turn as they were a head turn with eyes closed. None of the 12-14 month infants tested by Moore at al. followed changes in the model's eye gaze alone.

Why are there age differences in the use of these cues for joint visual attention? A number of alternative explanations are possible. First the simplest explanation might rest on the infant's developing visual acuity. That is, it may be that infants only begin to use eye orientation as a cue for joint visual attention after their visual acuity has developed sufficiently for changes in other's eye orientation to be resolved. This alternative can be ruled out as there is evidence to indicate that infants have, from as early as 2-3 month of age, visual acuity sufficient for resolving changes in another's eye orientation (Mayer & Dobson, 1982). A second alternative might rest on the assumption that infants are inattentive to or uninterested in the eye region of the faces of others. This alternative too, can be ruled out as there is a large body of work to indicate that from very young ages infants are very interested in the eye region of the face; they sp d more time scanning it than any other region (e.g., Maurer, 1985; Haith, Bergman, & Moore, 1977; and Hainline, 1978). A third alternative that is proposed out of the present work assumes that the root of the difference is more likely a core difference in the nature of the social understanding of infants of different ages. The hypothesis is that young infants do not use changes in another's eye orientation as a cue for establishing joint visual attention primarily because they do not understand eye orientation as an indicator of the direction of the other's attention. This issue shall be explored in more detail in a subsequent section.

Origins of Joint Visual Attention

Experiments 2 and 3 addressed the issue of the origins of joint visual attention from two different perspectives. While Experiment 2 addressed the origins of the joint visual attention response, Experiment 3 explored the origins of the signal value of the most salient joint visual attention cue: head plus eyes orientation. The results of Experiment 2 indicate clear age-related differences in infants' abilities to spontaneously engage in joint visual attention or even acquire a joint visual attention-like head turn response. While the most frequent response generated by 10-11-month-olds was spontaneous joint visual attention, no 6-7-month-olds and only a very small number of 8-9-month-olds showed this pattern. In contrast, a considerable number of 8-11-month-olds but only one 6-7-month-old was able to learn to make head turns which reliably aligned with the experimenter's direction of gaze.

In light of the findings of Experiment 2 that illustrated that learning could be involved in the acquisition of joint visual attention, it was wondered whether the acquisition of joint visual attention might depend purely on observed contingencies or if the characteristics of the cues might play an important role. The pattern of findings produced in Experiment 3 discounts the learning of a purely contingent association as the mechanism through which joint visual attention is acquired. Two facets of the results are of particular importance.

First, while a significant proportion of infants in Experiment 3 were successfully trained to align with the direction of a head turn demonstrated by an experimenter, attempts to train infants to misalign with this same cue were quite unsuccessful. Second, despite the presence of reinforcement for misaligning with the direction of the experimenter's gaze (as well as the absence of reinforcement for aligning with it), the infants in the Unnatural group were just as likely as those in the Natural group to align with the experimenter's head turn even by the end of the session. Taken together, these two findings indicate that the characteristics of the cues that are associated with a joint visual attention response are critical. They imply that there is some information contained in the head reorientation cue that conveys powerful information about target location.

The mechanism by which the infants are able to acquire joint visual attention is still left open, however. One possibility is that the infants are learning the associations between the adult's cue and the head turn response but that the possible associations that can be learned are constrained such that only a head turn in the same direction as the adult's is "allowed". An alternative possibility is that once the infant has discovered during the Shaping phase that there are interesting sights to be seen, she attempts to predict where the interesting sight will appear next. In the latter case, the joint visual attention scenario becomes a kind of attentional cueing paradigm in that a central stimulus can be used to predict the appearance of a target to one or the other side. If the central stimulus has directional properties, then it will serve to cue attention in the specified direction. Under this description, one could think of the Natural and Unnatural conditions in Experiment 2 as providing "valid" and "invalid" cues, respectively based on prior history.

Work reported by Corkum and Moore (in press) represents a first attempt to discriminate between these two type of mechanisms. In this work, a group of

15 8-9-month-old infants were tested using the training procedure. None of these infants demonstrated Spontaneous Gaze Following during the Baseline portion of the session. For these infants during the Shaping phase, the targets were activated, twice on each side, but no adult head turns were provided. In this way, the infant discovered that there were interesting sights to be seen to each side but these sights were not presented in conjunction with the adult head turn. In the Test phase, the adult produced head turns and, as in the previous experiments, the targets were activated only if the infant made the appropriate response, in this case, a head turn in the same direction as the adult. Scoring of the infants' performance in the same way as in the previous experiments resulted in 9 of the 15 reaching criterion for "learning". Thus, even without observing the relation between the adult's head turn and the target during the Shaping phase, the infants still started to use the direction of the adult's turn to predict the location of the target. These results speak against the learning of a simple association between the adult cue and the infant's head turn but are consistent with the idea that the adult's head turn cues the infant's attention in the direction of the turn.

The question that is raised by these results is what is the nature of the information that cues the infant's attention? There are a number of plausible alternatives. First, it is possible that the static physical form of the cue indicates general target location in much the same way that an arrow might for an adult. Second, it is possible that the salient feature of the cue is the dynamic component. Thus, infants may be drawn to follow the direction of the model's head turn but the fact that this cue involves a head and eyes may be quite unimportant. Third, it is possible that a combination of static form and dynamic components is required. Thus, perhaps moving body parts (such as head and eyes) are particularly effective in eliciting the response. An empirical test of this analysis would involve employing a training paradigm and exposing infants separately to the various component features outlined above. Such a study would allow the effects of the various features of the head and eyes turn cue to be effectively isolated and the important information to be identified. In any case, what has been demonstrated in Experiments 2 and 3 is that at about 8-9 months, infants are able to take advantage of available social cues in order to gather information about the location of events in the world. Further, these social cues have natural properties that allow infants more easily to pick up such information.

Infant Social Understanding

Collectively, the four experiments described herein carefully document the developmental emergence of joint visual attention. Yet, they do more than that. These careful observations enable inferences to be drawn regarding the nature of the infant's social understanding in the first two years of life. In this section aspects of the present findings which have specific bearing on this issue of infant social understanding will be highlighted and the findings will be related to some of the available models of infants' social understanding.

In terms of the cues employed for establishing joint visual attention, in Experiments 1, 2, and 4 a definite developmental progression in infants from 8 to 19 months of age has been documented.[9] This progression seems to proceed from an initial reliance on another's head orientation without regard for eye direction, to consideration of both head and eye orientation, to, ultimately an ability to follow changes in another's eye orientation alone. Although it is

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[9] Infants younger than 8 months of age have not been included here because they have not been found to be reliably establishing joint visual attention, based on the present coding definition, in response to any of the cues.

difficult (and perhaps not completely desirable) to tag specific ages to these milestones, based on the present work some broad estimates are possible. Generally, infants seem to establish joint visual attention based on head alone cues from about 8 months of age but eyes alone cues are not used for establishing joint visual attention until sometime after 16 months of age. The advance to consideration of both head and eye orientation as cues for establishing joint visual attention clearly occurs sometime between 8 and 16 months of age. While based on the present work, it is not possible to pinpoint the time-frame more precisely, it is speculated (based on observations and the findings of others such as Caron, Krakowski, Liu, & Brooks, 1996) that it does not occur until after 12 months of age.

So what, if anything, does this say about the infant's social understanding? Assuming that the consideration of eye orientation in the establishment of joint visual attention is an indicator that the infant understands directed visual attention in others, the present findings indicate two things with respect to the infant's social understanding. First, early joint visual attention emerges in the absence of an understanding of directed visual attention in others. Second, this understanding does not emerge until well into the second year of life, sometime after 16 months of age.

These findings are certainly not in keeping with the more liberal interpretation of infants' social understanding put forth by such authors as Baron-Cohen (e.g., 1991; 1995; Baron-Cohen & Ring, 1994), Bretherton (e.g., 1991; Bretherton, McNew, & Beeghly-Smith, 1981) and Tomasello, (e.g., Tomasello, Kruger, & Ratner, 1993; Tomasello, 1995). In general, these authors have taken the infant's joint visual attention behavior as evidence of her understanding of other's minds. More specifically, they have assumed that understanding of other's psychological relations with the environment is a necessary condition for the appearance of joint visual attention. In contrast, the present results illustrate clearly that infants engage in reliable joint visual attention substantially prior to the development of an understanding of directed visual attention in others.

While the present findings are generally contradictory to the spirit of infant social understanding put forth by those in the more liberal camp, they propose perhaps the most difficulty for Baron-Cohen and his model of the infant's Mindreading System. As outlined earlier, this model includes the Intentionality Detector (ID) which codes stimuli in terms of goals and desires; the Eye Direction Detector (EDD) which detects eye-like stimuli and codes their direction of gaze, and the Shared Attention Mechanism (SAM) which codes when self and other are attending to the same object. Both ID and EDD are proposed by Baron-Cohen as coding dyadic representations between agents and objects and are believed to be in place from 6 months and 4 months, respectively. SAM is proposed to code triadic representations based upon dyadic inputs received from ID and EDD. SAM is said to be fully functioning from about 9 months of age. It is difficult to reconcile the present findings within the context of Baron-Cohen's model. It is not the case, as Baron-Cohen's model would have it, that infants are engaging in joint (or shared) attention based on eye orientation cues from 9 months. Consequently, there is no need for a mechanism (i.e., EDD & SAM) to explain how infants engage in joint attention based on eye orientation when they simply do not do it. Along with EDD and SAM the idea that ID is coding intentional relations is dismissed because a simpler explanation of the infant's early joint attention will do. Such a simpler account is offered by authors such as Barresi and Moore (1996) and Moore and Corkum (1994a). As reviewed earlier, their simpler alternative has it that infants need not understand others' minds in order to engage in joint visual attention. Instead, infants must merely find cues (such as a change in gaze direction) to be valuable predictive information. Further, these authors offer that instead of requiring understanding of other's minds, behaviors such as joint attention may represent the avenue via which infant's come to develop an understanding of other's minds.

If joint visual attention does not evolve/emerge out of an understanding that others have minds, then where does it come from? As outlined in Corkum and Moore (in press), both nativist and empiricist accounts of the origins of joint visual attention have plausibility. The possibilities will be illustrated, by way of example. First, proponents of the nativist side might propose the existence of an innate orienting response whereby infants, cued by the head turn of another, would be compelled to align with the other's gaze in the absence of any prior experience with it or any understanding of its significance. Given the universality of the joint visual attention response and its developmental importance, such a mechanism might make sense. In contrast, proponents of the nurture or learning side might suggest that joint visual attention comes about simply through the experience of repeated exposures to cues (such as the head turns of others) followed by reinforcers (such as seeing interesting sights). Note that this also may occur in the absence of any particular understanding of the significance of the cues or the events. Experiments 2 and 3 represent an attempt to document the relative contributions of nature and nurture to the development of the joint visual attention response. The results of Experiment 2 lend some support to the empiricist side of the debate in that infants were found to be able to learn to align with a model's direction of gaze (head plus eyes cue) from about 8 months of age. In contrast, the results of Experiment 3 suggest a strong nativist component which imposes constraints on the nature of the associations which may be learned by way of the directional information which is conveyed by the cues. Overall, with respect to the origins issue, the present findings are most consistent with the notion that nativist influences play a strong role in early joint visual attention by way of the directional information encoded in the head orientation cue. Later on, it may be that empiricist influences come in to play for example, possibly in the acquisition of sensitivity to eye orientation as a cue for the direction of another's attention.

If social understanding is not in place when infants begin to engage in joint visual attention then when and how does social understanding emerge? It has been speculated that triadic interaction (including joint attention, protocommunicative gestures, and social referencing) rather than requiring an understanding of psychological relations on the part of the infant may actually play a role in the development of such an understanding. Before proceeding further, a working definition of social understanding should be offered. As outlined earlier, Barresi and Moore (1996) recognize social understanding as involving two important components: 1) knowledge that psychological activity is relational, and 2) understanding that self and other are equivalent with respect to their ability to be in psychological relations with the world. Based on this working definition, the nature of the developmental role assigned to triadic behaviors such as joint visual attention remains to be explained. In keeping with Barresi and Moore (1996) and Moore and Corkum (1994a), it is proposed that understanding of psychological relations is an end-product of first sharing psychological relations with others. This could occur in the following manner. First, *in the absence of an understanding of psychological relations* infants come, by some means, to be in matched psychological relations with others.[10]

[10] In understanding this process the exact means by which infants come to be in matched psychological relations with others is incidental; nonetheless, earlier on some tenable alternatives which derive from nativist and empiricist roots were described.

This process of being in a matched psychological relation with another serves the important function of making available to the infant both first and third person information about the same event/relation. It is herein that the developmental role lies, for it is in the experiencing of both first and third person perspectives about an event, and across many events, that the infant is able to acquire an understanding of: 1) the relational nature of psychological activity, and 2) the similarity of self and other with respect to the capacity for such psychological relations.

So, how does this relate to the present work on joint visual attention? As one exemplar of triadic interaction joint visual attention provides one such opportunity for infants to be engaged in a matched psychological relation with another. It is clear from the present pattern of findings that infants do engage in joint visual attention prior to the development of an understanding of the attentional nature of this relation. It is proposed that it is through the participation in bouts of joint visual attention (and other forms of triadic interaction) that infants come first to appreciate the attentional nature of the interaction. Later, through accumulation of experiences across contexts they gain a broader understanding of the psychological nature of relationships, and ultimately, they develop a concept of a person (self or other) as a psychological agent.

Future Research

Based on the pattern of findings obtained in the present work some directions for future research will be proposed. Although many possibilities exist those described in this section are organized around the following issues: information conveyed by cues, atypical development, general approaches.

Information Conveyed by Cues. The findings of Experiment 3 suggest that the head plus eyes reorientation cue conveys powerful information regarding target location. To explore the nature of the information contained in the head plus eyes turn that serves to cue the infant's attention, a number of possibilities exist. First, the static physical form of the cue might indicate direction much the way that an arrow does. To test this possibility, one could conceal the head plus eyes movement from view and simply expose the infant to the static head plus eyes cue. Comparison of the relative effectiveness of this cue to the dynamic form would yield useful information. Based on previous work by Lempers (1979) and more recent work by Moore and Angelopoulos (1995) the static cue is likely to be less effective. Alternatively, it may be that the dynamic features of the head plus eyes cue carry the directional information; that is, the direction of movement of the head plus eyes may cue the infant as to which direction to look, and the fact that the stimulus consists of a head plus eyes may be irrelevant. In order to test this possibility one could employ moving objects (e.g., balls or blocks) to see if they are effective cues for infant attention. Other possibilities which could be tested include other body parts such as hands and other types of movement. Ultimately, it is hypothesized that some combination of static and dynamic features is likely to be critical. Infants are tuned in, from birth, to attend to particular aspects of the environment, such as human faces, likely because they convey important information that is critical to survival/fitness. For this reason it is likely to be the case that dynamic features are important but that movement of certain types of stimuli - such as heads/eyes, and hands are the most effective combinations for cuing infant attention.

Atypical Development. Although the present work was strictly a developmental project, the findings have clear implications for the study and understanding of atypical populations. The training paradigm developed in the present work represents an interesting approach for the study of atypical groups such as individuals with autism. The joint attention deficit in autism has been well documented in the clinical literature (e.g., Baron-Cohen, 1989; Baron-Cohen, 1995; Mundy, Sigman, Ungerer, & Sherman, 1986; Sigman & Kasari, 1995). Further, it is well-known, by clinicians and researchers alike that individuals with autism both spontaneously make use of/can learn to make use of associative contingencies which accomplish instrumental ends (for example, leading someone by the hand to an out of reach object of interest, or squealing/vocalizing to obtain an object of interest). In light of this, it would be interesting to see whether individuals with autism could benefit from a training procedure to learn to align with another's gaze. It is possible that first training individuals with autism to use social cues (such as gaze direction) in an instrumental context, such as in the present work, may provide them with the necessary/sufficient first step to learning to employ these same cues in purely social contexts.

A related issue of interest, with respect to clinical implications, would involve the examination of the patterns of response of individuals with autism to the set of conditions presented in Experiment 3 whereby an attempt is made to train subjects to misalign with the experimenter's direction of gaze. If individuals with autism are not naturally employing, as social cues, others' direction of gaze, it would be expected that they may have little difficulty learning such an "unnatural" association. If this proves to be the case then the unnatural training paradigm may represent a possible technique for early screening of infants for the possible prediction of developmental problems of a social/communicative nature. One clue that exists, from the present work, that such an application could be beneficial lies in an incidental observation regarding one of the subjects who participated in Experiment 3. In the data it is reported only one infant tested was able to "learn" to criterion the unnatural target response. This child, now almost 3 year of age, has been subsequently identified has having some developmental difficulties around speech/language and communication. The observation of his "exceptional" performance at 8-9 months in the present experimental paradigm seems to have been predictive, in at least some way, of more fundamental social/communicative difficulties. This highlights the possibility that this research paradigm may have more specific clinical uses.

General Approaches. In the course of conducting the present work a number of general issues became apparent which may serve as "food for thought" for subsequent investigations. First, in line with other work on joint visual attention, the data reported in the present work includes a core, but very restricted, repertoire of infant behavior. That is, like many other researchers the coding and analyses were restricted to the first infant head turn in response to the experimenter's cue. Scoring and analysis of other infant behaviors is certainly desirable. Some of the infant behaviors which are likely to be informative include: infant eye gaze (in particular, in the case of eye orientation cues delivered by the experimenter), and infant emotional expressions (in particular, emotional "reactions" to the experimental context such as the "unusual" cues presented in Experiment 1, and the "unnatural" cue delivered in Experiment 3). Because the equipment set-up, in the present work, did not permit a close shot of the infant's face, coding of more subtle features such as infant eye gaze and emotional expressions was not possible. Coding of a broader range of infant behaviors in such an experimental context is desirable as it would yield a much richer picture of the infant's processing of the experimenter's cues and the related experimental context, and consequently, it would allow the compilation of a much more informed/complete estimate of the nature of the infant's social understanding. For example, in the case of the conditions presented in Experiment 3, an infant who seems surprised or amused that the target appears in an "unnatural/unexpected" location most certainly has processed the experimenter's cues in a different way than one who turns without such a reaction. Likewise, in the case of the conditions presented in Experiment 1, infants demonstrating similar emotional reactions to the experimenter's unusual cues (such as head alone or head and eyes in opposite directions) have certainly gleaned something more from the experimental context than those who do not. As a consequence of such reactions, it is likely that these infants would be attributed with a different, more advanced, form of social awareness than is presented in the current interpretation.

Second, in light of the incidental observation that one of the subjects tested went on to experience developmental difficulties, it would have been wise to have included some basic developmental screening as part of an exclusionary criterion for participation. Although basic information was collected regarding the birth and relative health of the infants who participated no other developmental information was collected. In retrospect, inclusion of some basic parent report questionnaire such as the Child Development Inventory (Ireton, 1992) would have been a relatively simple, effective way of ensuring that the participants were, indeed, typically developing. That said, let it be clear that the practice in the present work is not at all out of line with the general practices adopted by infancy researchers with respect to subject screening. Further, with respect to the integrity of the present data, there is a high level of confidence in the patterns of findings reported as it would be expected, based on random selection, that infants who may not have been quite typically developing would have appeared, with roughly equal frequency, in each of the groups tested (within each experiment).

A final point of consideration concerns the multiparadigmatic approach that was taken within the present series of experiments. Future researchers would do well to take a multiparadigmatic approach in the study of the infant's developing social understanding; complementary approaches investigating the same domain of behavior can permit firmer conclusions to be drawn. The cross-paradigm cross-experiment pattern of findings obtained in the present work afforded a better insight into the developing nature of joint visual attention and the infant's social understanding. Other infant research paradigms such as habituation/dishabituation offer possibilities for future researchers. Further, multiple tasks investigating related aspects of behavior could help to provide a more comprehensive developmental picture. For example, investigations of different types of triadic interaction including social referencing, protocommunicative gestures, and joint attention within the same group of infants, perhaps in the context of a longitudinal study, would yield a very rich picture of a critical developmental period and would consequently serve greatly to expand knowledge of the development of infant social understanding.

Conclusion

The present set of experiments provides empirical support for a somewhat later age of emergence for joint visual attention than a number of previous investigators have concluded; 8-9 months as opposed to 6 months. With respect to the cues employed, the findings suggest that with development infants progress from relying exclusively information about another's head orientation at about 8 months to a consideration of both head and eye orientation, to finally being able to align with changes in another's eye orientation alone sometime after 16 months. In terms of the origins of the joint attention response, while infants were able to learn to align with a model from about 8 months there seemed to be some constraints on the nature of the cues which could be associated with such a response. In particular, the head plus eyes cue was found to have inherent directional properties. It is concluded that: 1) early joint visual attention occurs in the absence of an understanding of directed attention in others, 2) nativist or empiricist roots can account for the development of joint visual attention, and 3) rather than requiring an understanding of other minds, it may be by way of engaging in joint visual attention that infants gain the experience they need to help them acquire an understanding of other minds.

References

Adamson, L. B., & Bakeman, R. (1991). The development of shared attention during infancy. Annals of Child Development, 8, 1-41.

Bakeman, R., & Adamson, L.B. (1984). Coordinating attention to people and objects in mother-infant and peer-infant interaction. Child Development, 55, 1278-1289.

Bakeman, R., & Adamson, L. B. (1986). Infants' conventionalized acts: Gestures and words with mothers and peers. Infant Behavior & Development, 9, 215-230.

Baldwin, D.A. (1991). Infants' contribution to the achievement of joint reference. Child Development, 62, 875-890.

Baldwin, D.A. (1995). Understanding the link between joint attention and language. In C. Moore & P.J. Dunham (Eds.), Joint attention: Its origins and role in development. Hillsdale, NJ: Erlbaum.

Baldwin, D.A., & Moses, L.J. (1994). Early understanding of referential intent and attentional focus: Evidence from language and emotion. In C. Lewis & P. Mitchell (Eds.), Children's early understanding of mind: Origins and development. Hillsdale, NJ: Erlbaum.

Baron-Cohen, S. (1989). Joint attention deficits in autism: Towards a cognitive analysis. Development and Psychopathology, 1, 185-189.

Baron-Cohen, S. (1991). Precursors to a theory of mind: Understanding attention in others. In A. Whiten (Ed.), Natural theories of mind. Evolution, development, and simulation of everyday mindreading. Oxford: Blackwell.

Baron-Cohen, S. (1994). How to build a baby that can read minds: Cognitive mechanisms in mind-reading. Cahiers de Psychologie Cognitive, 13, 513-552.

Baron-Cohen, S. (1995). EDD and SAM: Two cases for evolutionary psychology. In C. Moore & P. Dunham (Eds.), Joint attention: Its origin and role in development. Hillsdale, NJ: Erlbaum.

Baron-Cohen, S., & Ring, H. (1994). A model of the Mindreading System: Neuropsychological and neurobiological perspectives. In P. Mitchell & C. Lewis (Eds.), Origins of an understanding of mind. Hillsdale, NJ: Erlbaum.

Barresi, J., & Moore, C. (1993). Sharing a perspective precedes the understanding of that perspective. Behavioral and Brain Sciences, 16, 513-514.

Barresi, J., & Moore, C. (1996). Intentional relations and social understanding. Behavioral and Brain Sciences, 19, 107-122.

Bates, E. (1976). Language and context: The acquisition of pragmatics. New York: Academic Press.

Bates, E. (1979). Intention, conventions, and symbols. In E. Bates, L. Benigni, I. Bretherton, L. Camaioni, & V. Volterra (Eds.), The emergence of symbols. New York: Academic Press.

Bates, E., Camaioni, L., & Volterra, V. (1979). The acquisition of performatives prior to speech. In E. Ochs & B. Schieffelin (Eds.), Developmental pragmatics. New York: Academic Press.

Bower, T.G.R. (1966). The visual world of infants. Scientific American, 215, 80-92.

Bretherton, I., McNew, S., & Beeghly-Smith, M. (1981). Early person knowledge as expressed in gestural and verbal communication: When do infants acquire a 'theory of mind'? In M. Lamb & L. Sherrod (Eds.), Infant social cognition. Hillsdale, NJ: Erlbaum.

Bretherton, I. (1991). Intentional communication and the development of mind. In D. Frye & C. Moore (Eds.), Children's theories of mind: Mental states and social understanding. Hillsdale, NJ: Erlbaum.

Bruner, J. (1983). Child's talk. Learning to use language. New York: Norton.

Butterworth, G. (1991). The ontogeny and phylogeny of joint visual attention. In A. Whiten (Ed.), Natural theories of mind. Evolution, development, and simulation of everyday mindreading. Oxford: Blackwell.

Butterworth, G. (1994). Theory of mind and the facts of embodiment. In C. Lewis & P. Mitchell (Eds.), Children's early understanding of mind: Origins and development. Hillsdale, NJ: Erlbaum.

Butterworth, G. & Cochran, E. (1980). Towards a mechanism of joint visual attention in human infancy. International Journal of Behavioral Development, 3, 253-272.

Butterworth, G. & Grover, L. (1990). Joint visual attention, manual pointing, and preverbal communication in human infancy. In M. Jeannerod (Ed.), Attention and performance XIII. Hillsdale, NJ: Erlbaum.

Butterworth, G. & Jarrett, N. (1991). What minds have in common is space: Spatial mechanisms serving joint visual attention in infancy. British Journal of Developmental Psychology, 9, 55-72.

Campos, J.J. (1983). The importance of affective communication in social referencing: A commentary on Feinman. Merrill-Palmer Quarterly, 28, 445-470.

Caron, A., Caron, R., Mustelin, C., & Roberts, J. (1992). Infant responding to aberrant social stimuli. Poster presented at the International Conference on Infant Studies, Miami, FL.

Caron, A., Krakowski, O., Liu, A., & Brooks, R. (1996). Infant joint attention: Cued orienting or implicit theory of mind? Poster presented at the International Conference on Infant Studies, Miami, FL.

Churcher, J., & Scaife, M. (1982). How infants see the point. In G. Butterworth & P. Light (Eds.), Social cognition: Studies of the development of understanding. Chicago: University of Chicago Press.

Corkum, V.L., & Moore, C. (1992). Cues for joint visual attention in infants. Poster presented at the International Conference on Infant Studies, Miami, FL USA.

Corkum, V.L., & Moore, C. (1993). Origins of joint visual attention. Paper presented at the Society for Research in Child Development meeting, New Orleans, LA USA.

Corkum V.L., & Moore, C. (1994). Conditioning of a joint attention response to two different cues. Poster presented at the International Conference on Infant Studies, Paris, France.

Corkum, V.L., & Moore, C. (1995). Development of joint visual attention in infants. In C. Moore & P.J. Dunham (Eds.), Joint attention: Its origins and role in development. Hillsdale, NJ: Erlbaum.

Corkum, V.L., & Moore, C. (in press). The origins of joint visual attention. Developmental Psychology.

Desrochers, S., Morissette, P., & Ricard, M. (1995). Two perspectives on pointing. In C. Moore & P.J. Dunham (Eds.), Joint attention: Its origins and role in development. Hillsdale, NJ: Erlbaum.

DeWolfe, N., Moore, C., & Bennett, P. (1996). The function of pointing in infancy. Manuscript in preparation.

DiLavore, P., & Lord, C. (1995). Do you see what I see? Requesting and joint attention in young autistic children. Poster presented at the Society for Research in Child Development meeting, Indianapolis, IN.

Dunham, P.J., Dunham, F., & Curwin, A. (1993). Joint-attentional states and lexical acquisition at 18 months. Developmental Psychology, 29(5), 827-831.

Dunham, P.J., Dunham, F., Hurshman, A., & Alexander, T. (1989). Social contingency effects on subsequent perceptual-cognitive tasks in young infants. Child Development, 60, 1486-1496.

Feinman, S. (1982). Social referencing in infancy. Merrill-Palmer Quarterly, 28, 445-470.

Feinman, S. (1992). Social referencing and the social construction of reality in infancy. New York: Plenum.

Feinman, S., & Lewis, M. (1983). Social referencing at 10 months: A second-order effect on infants responses to strangers. Child Development, 54, 878-887.

Franco, F., & Butterworth, G. (1991). Infant pointing: Prelinguistic reference and co-reference. Paper presented at the Society for Research in Child Development Meeting, Seattle, WA.

Gewirtz, J.L., & Pelaez-Nogueras, M. (1992). Social referencing as a learned process. In S. Feinman (Ed.), Social referencing and the social construction of reality. New York: Plenum.

Gusella, J., Muir, D., & Tronick, E.Z. (1988). The effect of manipulating maternal behavior on 3- and 6-month-olds affect and attention. Child Development, 59, 1111-1124.

Hainline, L. (1978). Developmental changes in visual scanning of face and nonface patterns by infants. Journal of Experimental Child Psychology, 25, 90-115.

Hains, S.M.J., D'Entremont, B., & Muir, D.W. (1996). Precursors of shared attention in young infants. Poster presented at the International Conference on Infant Studies, Providence, RI.

Hains, S.M.J., Muir, D.W., & Franke, D. (1994). Eye contact modulates infant affect during infant-adult interactions. Poster presented at the International Conference on Infant Studies, Paris, France.

Haith, M. M., Bergman, T., & Moore, M. J. (1977). Eye contact and face scanning in early infancy. Science, 198, 853-855.

Hobson, R.P. (1994). Perceiving attitudes, conceiving minds. In C. Lewis & P. Mitchell (Eds.), Children's early understanding of mind: Origins and development. Hillsdale, NJ: Erlbaum.

Hornik, R., Risenhoover, N., & Gunnar, M. (1987). The effects of maternal positive, neutral, and negative affective communications on infant responses to new toys. Child Development, 58, 937-944.

Ireton, H.R. (1992). Child Development Inventory manual. Minneapolis, MN: Behavior Science Systems.

Klinnert, M., Campos, J.J., Sorce, J.F., Emde, R.N., & Svejda, M. (1983). Emotions as behavior regulators: Social referencing in infancy. In R. Plutchik & H. Kellerman (Eds.), Emotions in early development (vol. 2): The emotions. New York: Academic Press.

Klinnert, M., Emde, R.N., Butterfield, P., & Campos, J.J. (1986). Social referencing: The infant's use of emotional signals from a friendly adult with mother present. Developmental Psychology, 22, 427-432.

Landry, S.H. (1986). Preterm infant's responses in early joint attention interactions. Infant Behavior and Development, 9, 1-14.

Landry, S.H. (1995). The development of joint attention in premature low birthweight infants: Effects of early medical complications and maternal attention-directing behaviors. In C. Moore & P.J. Dunham (Eds.), Joint attention: Its origins and role in development. Hillsdale, NJ: Erlbaum.

Landry, S.H., & Chapieski, L. (1988). Visual attention during toy exploration in preterm infants: Effects of medical risk and maternal interactions. Infant Behavior and Development, 11, 187-204.

Landry, S.H., Garner, P., Denson, S., Swank, P., & Baldwin, C. (1993). Maternal attention-directing strategies and infant exploratory behaviors: Effects of intraventricular hemorrhage in low birth weight infants at 12 and 24 months. Research in Developmental Disabilities, 14, 237-249.

Lasky, R.E., & Klein, R.E. (1979). The reactions of five-month-olds to eye contact of the mother and of a stranger. Merrill-Palmer Quarterly, 25, 163-170.

Leekam, S., Baron-Cohen, S., Perrett, D., Milders, M., & Brown, S. (in press). Eye-direction detection: A dissociation between geometric and joint attention skills in autism. British Journal of Developmental Psychology.

Lempers, J. D. (1979). Young children's production and comprehension of nonverbal deictic behaviors. The Journal of Genetic Psychology, 135, 93-102.

Lempers, J.D., Flavell, E.R., & Flavell, J.H. (1977). The development in very young children of tacit knowledge concerning visual perception. Genetic Psychology Monographs, 95, 3-53.

Leung, E. H. L., & Rheingold, H. L. (1981). Development of pointing as a social gesture. Developmental Psychology, 17(2), 215-220.

Lock, A. (1978). Action, gesture, and Symbol: The emergence of language. London: Academic Press.

Loveland, K.A., & Landry, S.H. (1986). Joint attention and language in autism and developmental language delay. Journal of Autism and Developmental Disorders, 16, 335-349.

Maurer, D. (1985). Infants' perception of facedness. In T. Field & N. Fox (Eds.), Social perception in infants. Norwood, NJ: Ablex.

Mayer, D.L., & Dobson, V. (1982). Visual acuity development in infants and young children, as assessed by operant preferential looking. Vision Research, 22, 1141-1151.

McArthur, D., & Adamson, L.B. (1995). Joint attention in preverbal children: Autism and developmental language disorder. Poster presented at the Society for Research in Child Development meeting, Indianapolis, IN.

Moore, C. (1996). Theories of mind in infancy. British Journal of Developmental Psychology, 14, 19-40.

Moore, C., & Angelopoulos, M. (1995). The role of movement in the development of joint visual attention. Manuscript submitted for publication.

Moore, C., & Barresi, J. (1993). Knowledge of the psychological states of self and others is not only theory-laden but also data driven. Behavioral and Brain Sciences, 16(1), 61-62.

Moore, C., & Corkum, V.L. (1994a). Social understanding at the end of the first year of life. Developmental Review, 14, 349-372.

Moore, C., & Corkum, V.L. (1994b). The origins of joint attention. Paper presented at the International Conference on Infant Studies, Paris, France.

Moore, C., Corkum, V., & MacLellan, S. (1995). Infants do not use eye direction in early joint attention. Manuscript submitted for publication.

Moore, C., & Dunham, P.J. (1995). Joint attention: Its origins and role in development. Hillsdale, NJ: Erlbaum.

Moore, C., & Frye, D. (1991). The acquisition and utility of theories of mind. In D. Frye & C. Moore (Eds.), Children's theories of mind. Mental states and social understanding. Hillsdale, NJ: Erlbaum.

Morissette, P., Ricard, M., & Gouin-Decarie, T. (1995). Joint visual attention and pointing in infancy: A longitudinal study of comprehension. British Journal of Developmental Psychology,.

Mumme, D.L., Won, D., & Fernald, A. (1994). Do one year-old infants show referent specific responses to emotional signals? Poster presented at the International Conference on Infant Studies, Paris, France.

Mundy, P., & Sigman, M. (1989). The theoretical implications of joint-attention deficits in autism. Development and Psychopathology, 1, 173-183.

Mundy, P., Sigman, M., Ungerer, J.A., & Sherman, T. (1986). Defining the social deficits in autism: The contribution of nonverbal communication measures. Journal of Child Psychology and Psychiatry, 27, 657-669.

Murphy, C. M. (1978). Pointing in the context of shared activity. Child Development, 49, 371-380.

Murphy, C. M., & Messer, D. J. (1977). Mothers, infants, and pointing: A Experiment of gesture. In H. R. Schaffer (Ed.), Studies in mother-infant interaction. London: Academic Press.

Raver, C.C., & Leadbeater, B. (1995). Factors influencing joint attention between socioeconomically disadvantaged adolescent mothers and their infants. Landry, S.H. (1986). Preterm infant's responses in early joint attention interactions. Infant Behavior and Development, 9, 1-14.

Scaife, M. & Bruner, J. S. (1975). The capacity for joint visual attention in the infant. Nature, 253, 265-266.

Schaffer, R. (1984). The child's entry into a social world. New York: Academic Press.

Sorce, J. F., Emde, R. N., Campos, J. J., & Klinnert, M. D. (1985). Maternal emotional signaling: Its effects on the visual cliff behavior of 1-year-olds. Developmental Psychology, 21, 195-200.

Sigman, M., & Kasari, C. (1995). Joint attention across contexts in normal and autistic children. In C. Moore & P.J. Dunham (Eds.), Joint attention: Its origins and role in development. Hillsdale, NJ: Erlbaum.

Symons, L.A., Hains, S.M.J., Dawson, S., & Muir, D.W. (1996). 5-month-olds sensitivity to adult eye direction in dyadic interactions. Poster presented at the International Conference on Infant Studies, Providence, RI.

Tabachnick, B.G., & Fidell, L.S. (1989). Using multivariate statistics. New York: Harper & Row.

Tomasello, M. (1995). Joint attention as social cognition. In C. Moore & P.J. Dunham (Eds.), Joint attention: Its origins and role in development. Hillsdale, NJ: Erlbaum.

Tomasello, M., & Farrar, M. J. (1986). Joint attention and early language. Child Development, 57, 1454-1463,

Trevarthen, C. (1979). Communication and cooperation in early infancy: A description of primary intersubjectivity. In M. Bullowa (Ed.), Before speech: The beginning of interpersonal communication. Cambridge: Cambridge University Press.

Trevarthen, C., & Hubley, P. (1978). Secondary intersubjectivity: Confidence, confiding, and acts of meaning in the first year. In A. Lock (Ed.), Action, gesture, and symbol. London: Academic Press.

Werker, J.F., & McLeod, P.J. (1989). Infant preference for both male and female infant-directed talk: A developmental study of attentional and affective responsiveness. Canadian Journal of Psychology, 43, 230-246.

Werker, J.F. & Tees, R.C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. Infant Behavior and Development, 7, 49-63.