PROJECT DESCRIPTION

SPECIFIC AIMS The broad agenda of this research proposal is to explore the nature of event representations in infants: How those event representations might undergird the acquisition of verb-argument structure in language learning; how infants parse events in the real world as revealed through the use of eye tracking; the relationship between seeing and knowing in event representation; and the role of intentionality in the development of structured event representations.

BACKGROUND AND SIGNIFICANCE

A. Theoretical Foundations When deaf children of hearing parents are not exposed to a language model, they invent their own communication systems using gestures (Goldin-Meadow, 1985). Such "home sign" systems have been shown to be rich in expressive power, and to exhibit many parallels to conventional languages including a primitive form of argument structure. When gesturing actions such as *giving*, home signers demonstrate that they are sensitive to the fact that giving entails three arguments: A giver, a recipient, and an object being given. The present research agenda is inspired by this phenomenon, which represents prima facie evidence that the human conceptual system constructs event representations that possess argument-like structures independent of overt linguistic input. Understanding the nature of this development addresses fundamental issues of the relation between language and thought and their origins.

The experiments proposed here examine the pre-linguistic state of infants by investigating how they might perceive actions like *giving* and *hugging* differently based on the arguments associated with their event representations. Experiments are proposed that explore the processes involved in event parsing through eye tracking. Using these procedures, one can begin to understand how representations are built up on-line, and what aspects of the event structure can influence the uptake of information required for understanding those events.

B. Broader Impacts Probing these basic questions about the origins of knowledge will provide significant advances in our general scientific understanding of how cognitive structures come into being. Such understanding can only enhance approaches to investigating cognition in general, and how knowledge can be most effectively transmitted to future generations through education at all levels. To the extent that we can identify the underpinnings of what makes language possible in humans, such knowledge can be used to understand and help individuals for whom learning language and understanding the intentions of others is diminished due to cognitive neuropsychological conditions. The context of this research takes place within Teachers College, which was founded with the aim of serving the poor and underprivileged members of the New York City community. The college has a very high rate of minority participation which is reflected in those students who have participated, and continue to participate in research training and data collection in the PI's lab. These students are from all levels of education from high school to undergraduate to graduate, many of whom are from minority populations that are traditionally underrepresented in science. Sitting as it does, at the edge of Harlem, the college attracts many students from this community and, likewise, the lab attracts many parents from this community to participate in the research. Minority participation in infant experiments is over 31% in the PI's lab, primarily from African American and Hispanic populations. All research in the lab is integrated into the teaching curriculum of the college, often with classes being held in the lab to demonstrate new techniques and technologies. Students who become directly involved in the running of the lab (about 25 since the inception of this project) learn an appreciation of how scientific methods work to answer questions about knowledge acquisition, and what practicalities are involved in acquiring that knowledge. As future leaders in the field of education, these students will bring with them a deeper understanding of how science works, its scope and limitations, and what it means to value good research in making informed decisions about educational and clinical practice.

Background Studies on Infant Event Representations

Event Structure and Language In a set of pioneering studies of the development of linguistic concepts in infancy, Golinkoff (1975) and Golinkoff & Kerr (1978) examined whether 14 to 24 month olds had general concepts of agent and patient, the fundamental elements of transitive structures in language. In studies employing looking time and heart-rate deceleration, they familiarized infants with filmed actions involving people pushing other people or pushing tables and chairs. On test trials, infants saw a new film in which there were reversals of roles and/or positions on the screen and there were some effects of role switching in this paradigm.

More recently, the intermodal preferential looking paradigm has been used successfully to reveal knowledge of linguistic structure in infants in their second and third years. Golinkoff et al. (1987) found that 16 to 19 month olds preferred looking at the correct video given simple active sentences such as “Cookie Monster is tickling Big Bird”. Similarly, Hirsh-Pasek & Golinkoff (1991) found that when 17 month olds were told: “She’s kissing the keys”, they look at a video of a woman kissing keys while holding a ball, and not one in which she is kissing a ball while dangling the keys. The authors suggest that this preference shows evidence of early knowledge of verb phrase structure. Infants understood that *kissing* and *keys* were linked in the meaning of the utterance. In another influential study using this paradigm, Naigles (1990) found that 24 month olds could use the argument structure of a verb as a means of identifying whether it was causative in meaning. Taken together, these results suggest that infants at the end of their second year can use some aspects of verb-argument structure in the comprehension of utterances. There is no evidence that infants under 12 months have such abilities. In fact, Casasola & Cohen (2000) found that 14 month olds could not form associations between actions of pushing and pulling and linguistic labels, whereas 18 month olds could do so easily. This suggests that linguistic input plays very little role in understanding events within the first year, but is easily assimilated by the middle of the second year.

The individuation of events through intentionality A common thread throughout the literature on event perception in infancy is the idea that events are individuated through intentional acts. Baldwin et al. (1999) developed a procedure to study event segmentation in infants similar to that developed earlier by Newtson (1973) with adults. Pauses were inserted either randomly within complex event or at the boundaries between intentional acts such as opening a fridge, picking up a towel etc. Infants showed increased looking time when pauses were randomly inserted rather than when pauses marked segment boundaries.

The question of when infants are able to perceive intentionality in the behavior of others remains controversial (Dennett, 1978; Johnson, 2000, for a review). While some researchers caution against overinterpreting the results of infant studies (e.g., Haith &Benson,1998; Corkum & Moore, 1998), others are less conservative, speculating on the existence of innate modules for the detection of causality and intentionality in others (e.g., Baron-Cohen, 1995). One indicator of intentionality of action is goal directedness. Meltzoff (1995) found that 18 month olds, when seeing a person attempt an action but fail, would imitate the action to its completion rather than directly mimicking the failure. However, they did not do so when imitating an inanimate mechanism on the same task. Woodward (1998) familiarized 5 to 9 month olds with either a human arm or a stick reaching for one of two adjacent objects. On test, the position of the objects was switched. Looking times increased when the human arm reached for the new object in the old position but not when the stick did so. This suggests that animate objects are expected to show intentionality but inanimates are not.

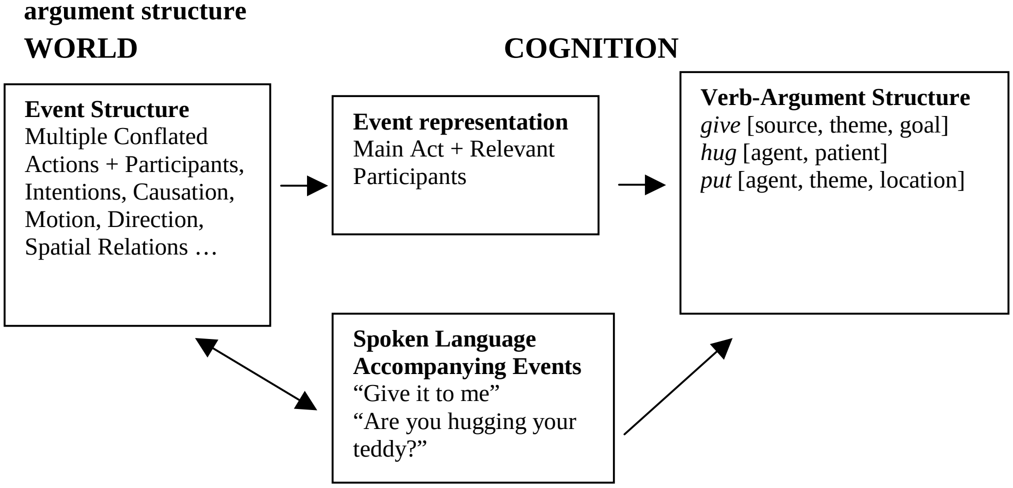
Gergely et al. (1995), on the other hand, suggest that animacy is not necessary for inferring intentionality. They habituated 12 month olds to animations of one ball chasing another (cf. Michotte, 1967). In its pursuit, the chaser ball made a detour around an obstacle. Infants who were then shown the ball making the same circuitous path, but with the obstacle removed, looked longer than those that were shown the ball making a direct path, even though the former condition was more perceptually similar to the training trials. This suggests that infants expected the chaser to make some rational, intentional choices in its goal structure (see also Csibra et al., 1999).

Intentionality and Event Structure

Everyday events consist of goal-directed, intentional-causal actions of people or animals or the intentional actions of vehicles as they are controlled by people. There are mental acts and states such as seeing, knowing, learning, and loving which may reveal themselves through subtle or not-so subtle forms of behavior. There are accidental occurrences like things falling over, and there are acts of nature, like snow falling, which may have causal but not intentional structure. We live in a world where things happen and sometimes people make things happen, and often things happen for a reason, an intention, a goal. The world is rich in structure, yet it can be confusing to the unprepared. A robot that did not have some kind of specific programming would not be able parse the events in the environment and be able to map those events onto the verb-argument structures of a natural language - let alone create its own language as home signers do. One has to see the world in a particular way, and infants must see the world in a particular way before they acquire language.

The relatively simple model I am working with proposes the mapping relationships outlined in Figure 1 for the induction of argument structure in language. First it assumes that there is structure in the world and its events, independent of any observers of those events. When viewing actions of other people, infants must extract an intentional-causal focus of the whole event ("what is the point of this activity?"). This is the "main act" of the event structure (cf. Slobin, 1986). The infant must determine which are the *relevant* participants in that event activity and encode those in the event representation (cf. Sperber & Wilson, 1995).Those elements of a situation that are determined to be relevant to the action in defining its essential properties are candidates for being the arguments of the verb in a linguistic representation of the event. Of course, this does not mean that the mapping is completely transparent. Since there is considerable cross-linguistic variation in the expression of argument structure for particular verbs, such mappings could not be universal or direct (cf. Chung & Gordon, 1998; Sandalo & Gordon, 1999). There must be some influence of language input upon the final determination of argument structure for any particular verb. However, event structures can provide a set of potential candidates that could act as arguments in the linguistic expression of a verb, and could form the basis for home signers in the invention of their own sign systems in the absence of such language input.

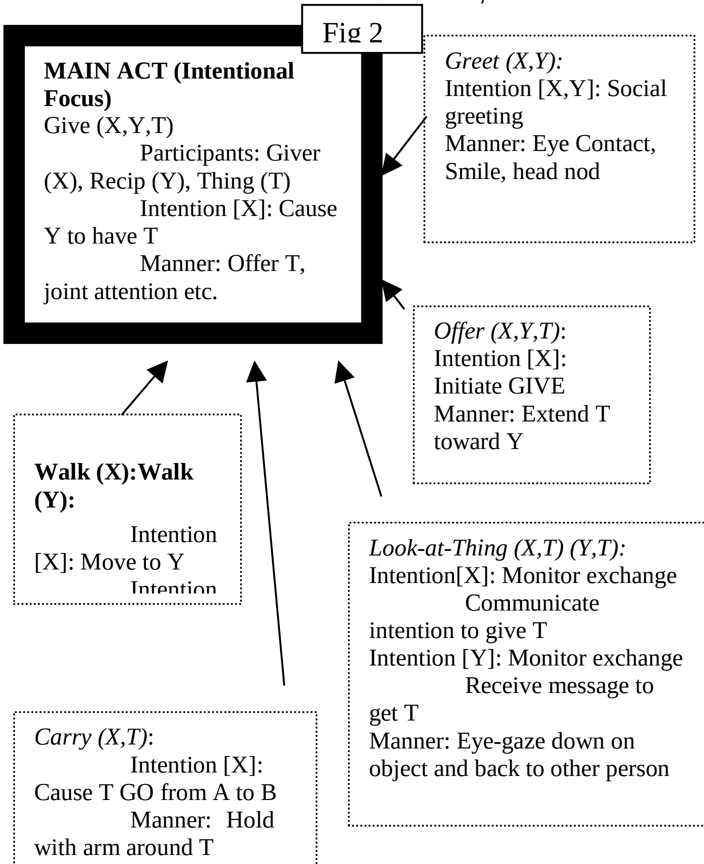
Figure 1 Mapping relations between events and language in the acquisition of verb-argument structure



How do we determine which is the main act and which are the subsidiary acts in an event structure? For most cases of animate action there is a core activity or set of activities focused around an intentional-causal nexus. Animate actions tend to be self initiated, goal directed and causal in nature (cf. Premack, 1990; Premack & Premack, 1995; Leslie & Keeble, 1987). Other actions might be a prelude to the main act (e.g., moving to get into position to act), or they may subserve the main act (e.g., eye-gaze signals intentions to act). One might think of the subsidiary actions as being equivalent to the sub-goals in a goal-structure framework (cf. Newell & Simon, 1972). Presumably, there are multiple cues that key observers into the intentional structure of the event. For example, in an event such as *GIVING*, this might involve *carrying an object, looking at the object*, *looking at the recipient,offering the object* etc. which are in aid of the *giving* rather than vice versa. In the proposed experiments I will investigate what role such cues might play in the process of defining a main act for infants.

In addition to the subordinate acts, there are also people, animals and objects that subserve the main act. In the model, these are candidates to become the arguments of the event structure and, ultimately, arguments in the language. The observer must determine which are the relevant participants in the main act. If the main act is *hugging*, the fact that one participant might be carrying a stuffed animal is not relevant to the causal-intentional structure of the event and adds no new information regarding the main act. It should not, therefore, be encoded in the event representation for that act. In the case of someone *giving* a stuffed animal to another person, then this object is informationally relevant. The intentional-causal structure of the event cannot exist without it and so it must be included in the event representation. Figure 2 presents a sketch of what an event representation might entail for a particular event of *giving* of the kind that is investigated in the current proposal. While details of the present model may be open to revision, such revision will surely be informed by the results of empirical investigation.

Fig 2



RESEARCH DESIGN AND METHODS

There are two principle research methods used in this project: Looking time habituation and Eye tracking. The basic methodologies are described here in advance of outlining the existing experimental data and proposed studies. The PI's present and previous labs at the University of Pittsburgh, NYU and Columbia have been engaged in these procedures for the last 6 years, refining our methods and receiving valuable advice from major figures in the field including Mark Strauss, Susan Rose, Rick Gilmore, Scott Johnson, David Lewkowicz.

Looking time habituation studies Stimuli in these studies involve presentation of repeated videos of simple actions such as *giving* and *hugging* (see Figure 3). Looking time to the training trials is measured to criterion; a test stimulus is presented with a deleted or changed element, and the new looking time is recorded to see if infants perceive a change in the event on test trials. For this method, I follow common parameters for looking times and habituation criteria. Infants are seated in a high chair in front of an 18 inch computer screen (head is approx 65 cm from the screen). A parent is sat to the side and somewhat behind them. Attention to the monitor is attracted with a shrinking ball and matching sound. Once attention is acquired, the habituation video begins. A low-light video camera beneath the display sends an image of the infant's looking to the control booth hidden behind a curtain in the testing room. To begin timing, the infant must look at the screen for at least 0.5s. To end the trial, the infant must look away for at least 1s. Looking time data are gathered on-line via a video camera. To avoid excessively long looking times, trials are timed out after 60s. At the termination of a trial, the screen goes blank, followed by the attractor stimulus and a new trial. Habituation criterion is met when the infant's looking time on three consecutive trials averages under 50% of the average of the three longest consecutive looking times (usually, but not always, the first three trials). There is a minimum of 6 habituation trials before test. Test trials consist of alternations of the novel video (NEW) and the familiar one (OLD) with two presentations of each with orders assigned to two conditions (N-O-N-O, and O-N-O-N). This method of alternating NEW and OLD trials on test is a standard procedure to avoid the possibility of regression-to-the-mean effects. Earlier methods of testing last habituation trial against first test trial are generally avoided for this reason. Order of test trials is counterbalanced across two groups within the experiment. Analyses employ repeated-measures MANOVA comparing NEW vs. OLD test trials, and between subjects tests of order and action type. In addition, *a priori* t-tests will be carried out to test specific differences between OLD and NEW trials on test. Gender effects will be examined separately in all experiments, but such effects are not predicted at this time. All experiments are counterbalanced for gender within age groups.

Participants The main age group for experiments in this study consists of 10 month olds. This is an age where infants have not yet begun to produce language but are, as it were, on the cusp of doing so. There is no evidence that 10 month olds have any receptive knowledge of argument structure, although I do not discount the possibility that language exposure has begun to have some influence in the present domain. Therefore, this age group represents a snapshot of what the cognitive system looks like as productive language begins its mapping to conceptual structure.

With the 10 month group established as a developmental anchor point, further studies will are conducted on a select set of conditions with younger infants that are 6 and 8 months of age. If results point in an interesting developmental direction, procedures will extend to 4 month olds. Pilot data in later sections of this proposal will provide a basic picture of how this developmental profile is shaping up in the present experimental context. Numbers of infants in each experiment will be at least 12 per condition. Requisite group size will be determined by power analysis if data are not significant with this sample size. Equal numbers of males and females are tested in each of the conditions. Parents are asked about their infant's TV viewing experience to see if this has an effect on habituation functions. In addition, parents are asked if their infants engage in games of giving ("Give that to Mommy!"), hugging, showing, and whether they appear to understand such games, and others that are relevant to the actions that they are viewing in the videos. In general, we have found that most parents do not report such activities in 10 month olds suggesting that self-engagement in activities is not a particularly strong influence on their understanding the act of giving, although it might be more important for more complex actions.

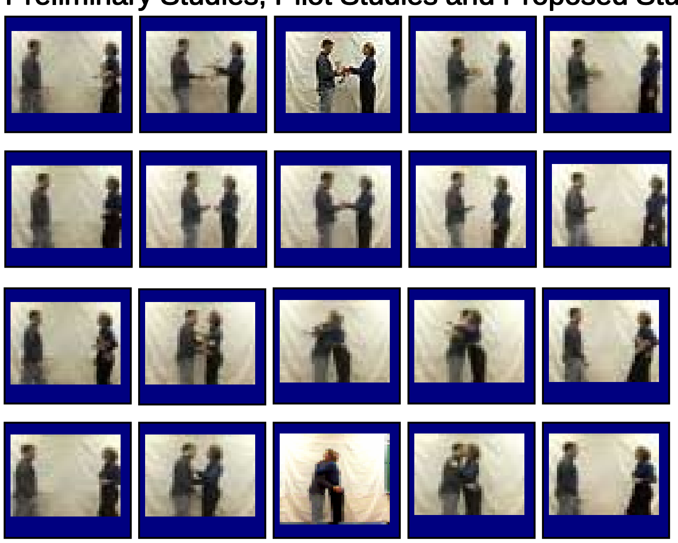
Coding For looking time measures all coders are pretrained for reliability, requiring 90% or better agreement with other on-line coders. All videotapes of infant looking are reviewed blind for accuracy, experimental error, interference by the parent, and excessive infant fussiness.

Eye Tracking Methods

Data Acquisition and Analysis Eye tracking uses an *ASL model 504* remote infra-red eye tracker with integrated *Flock of Birds* head motion tracker. The remote eye tracker registers eye-gaze direction by finding the angle between the pupil and corneal reflection. Gaze direction is calibrated to locations in space by showing the subject a series of calibration points on the video screen which attract them to fixate to those points. For adult studies, there are nine calibration points; with infants just two points at the top-left and bottom-right corners are used. Small, animated figures paired with corresponding sounds are used to attract attention to these locations. In procedures with infants, we first obtain a 2-point calibration, lock it in, then check all nine points for accuracy. If accuracy is not attained, then the calibration procedure is repeated until successful. Quite large head movements are tolerated within an area of about a one square foot without loss of signal. If the infant's head is turned away from the tracker, signal can be automatically reacquired as the subject's head moves back into position using the flock-of-birds magnetic head-position sensor. The sensor is about the size of a pencil eraser, weighs only a few ounces and can be worn comfortably on a headband by the infant. Although the eye tracker will produce numerical coordinates as output, we have found that coding is easier using video output which superimposes a crosshair of eye-gaze position over the video sequence being observed by the infant. Digital videos of these outputs are collected and loaded into *MacShapa* a Mac-based video coding system that allows flexible event coding that is calibrated with the video in a window on the coding screen and allows flexible querying of data patterns.

Design There are several practical constraints related to eye tracking that do not occur with simple looking-time procedures. First, the acquisition of eye position data is precarious, and loss of data is quite common. Setup time can sometimes be quite long, depending on the cooperativeness of the infant. Our strategy has been to maximize data collection for those babies for which we are able to collect good data on eye tracking. Each infant is shown several different test videos with breaks in between where they can watch more interesting fare such as Winnie the Pooh, Sesame Street, Baby Einstein and so on. Each baby views 6 different videos. For each one, we keep playing the video until we have data on 5 sequences of the video from habituation and 5 from test. The order of videos is rotated across conditions so that infants do not see the same videos in the same order, and each video may come first in the sequence with one set of infants. Order effects are examined when the data are coded, although this does not seem to be a major problem. Some infants will be tested using the full habituation paradigm to examine whether looking behavior predicts habituation functions (cf. Johnson, et al. 2003).

Preliminary Studies, Pilot Studies and Proposed Studies



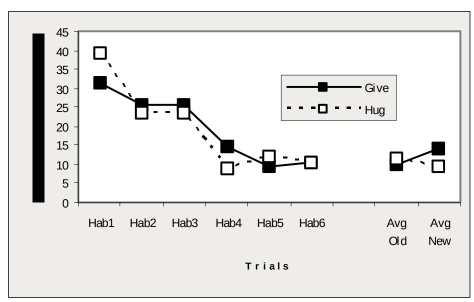


Fig 3

Experiment 1: The Give/Hug Study In this first study, we investigated event representations for two common actions of *giving* and *hugging* which differ in the number of participants required by the action (Scherf & Gordon, 1998; 2000; Gordon, 2002). An event of *giving* requires a giver, a receiver, and a transferred object. *Hugging* requires only two participants, a hugger and a hugee. Twenty-four 10 month olds were tested using the visual habituation procedure. In the GIVE condition, they saw a looped video event of a girl *giving* a stuffed animal to a boy (GIVE w/). The girl (carrying the stuffed animal) and the boy (empty handed) enter the screen from opposite sides, walk to the center, the girl gives the toy to the boy, and they each exit from their respective sides. On test, infants see the same action, but without the toy (GIVE w/o). As stated in the methods, the test procedure alternates the NEW (GIVE w/o) and the OLD (GIVE w/) stimuli to control for regression effects. Figure 3 shows selected frames from the GIVE w/, GIVE w/o, HUG w/ and HUG w/o videos. In the actual videos, the toy was roughly 5cm x 9cm in profile and was very clearly visible.

In the HUG condition, instead of giving the stuffed animal to the boy, the girl brings the arm holding the animal around the boy and *hugs* him. In like manner, the test condition involves deleting the toy from the event. Comparing the GIVE and HUG conditions, the stuffed animal is relevant to the action of giving, whereas it is irrelevant to the act of hugging. Infants in the GIVE condition showed longer looking time to the novel test trials (NEW) than to the familiar test trials (OLD) (**p=.02). However, infants in the HUG condition did not show longer looking times to the NEW test trials (see Figure 3). If anything, there was longer looking to the OLD test trials, albeit non-significant (p=.11). These data provide preliminary evidence that, when infants perceive events, they selectively attend to objects that are relevant to the action in question (potential arguments), but not to objects that are irrelevant to the action. These data replicate earlier studies reported in Scherf & Gordon (1998; 2000) employing modified presentation parameters and obtaining cleaner effects (see Methods section).

It could be postulated that the GIVE training trials were somehow more attractive to infants than the HUG videos, hence inducing them to pay more attention and being more likely to notice the toy's disappearance. If this were the case, one would expect longer looking to GIVE than to HUG during habituation trials. Figure 3 shows that infants looked equally long at GIVE and HUG trials during habituation thus failing to support this hypothesis.

Experiment 2 & 3 Developmental Changes from 6 to 10 months

To examine the developmental origins of the pattern of looking behavior in the Give-Hug experiment (above) we have also tested 6 and 8 month olds (24 per age group). These data, along with those for 10 month olds are presented in Fig 4 focusing on differences in looking time for OLD vs. NEW test stimuli. Eight month olds showed a similar, but attenuated pattern as the 10 month olds (*p=.05 for GIVE, ns for HUG). Six month olds, on the other hand, show no effects for either GIVE or HUG conditions. It might be hypothesized that the current procedure is inappropriate for 6 month olds because they simply do not process any differences that may occur between complex events. To examine this possibility, we habituated infants to the GIVE w/ video, and tested with the HUG w/ video as the NEW stimulus.

FIG 4

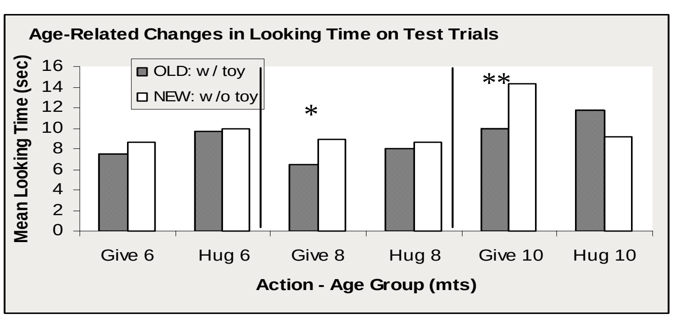
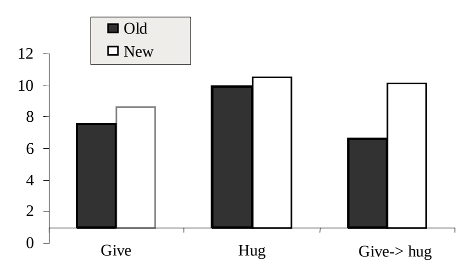


FIG 5



This change in the event structure was clearly detected by the 6 month olds (p=.03) (Fig 5), thus showing that they are capable of responding to gross changes in actions. On the other hand, the mere deletion of the toy from the GIVE action, does not seem to create a major change in the meaning of the action for the 6 month olds.

What do babies attend to?

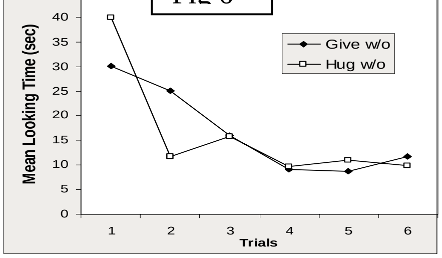
We argue that increases in looking time in this procedure are indexing the infant's sensitivity changes in the *meaning* of an event. But first, we must probe infants' behavior more carefully to determine what, exactly, they are perceiving or representing in the present procedures, and how the whole pattern of data fits together into a coherent story. This is particularly important in the light of the strong disagreements that currently exist in the field of infant cognition with respect to the interpretation of habituation studies that claim to tap into higher cognitive processes (see Bogartz et al., 1997). It should be noted that most disagreements have occurred with respect to the "Violation of Expectation" paradigm in which the infant sees a particular event occurring during familiarization, then sees a follow-up event that either conforms to or violates some expected outcome. In such studies, it is claimed that longer looking times indicate the infant's surprise at outcomes that violate expectations about the world. Critics of this procedure suggest that infants might only be showing increased attention to low-level changes in the visual array and that a reversal in the procedure --switching the familiarization and test stimuli-- would distinguish these claims (no increased looking should occur in the reversed procedure since there would be no violation of expectation in the original familiarization stimuli).

Even though the present experiments do suggest facts about infant cognitive representations, they do not invoke assumptions of the violation of expectation paradigm. Rather, the present experiments claim only to be indexing <u>event discrimination</u> not expectation or surprise, and therefore assume only the pitfalls of standard discrimination experiments. At the same time, it is important not to make unwarranted assumptions about the nature of infant looking behaviors in these studies. In the next section, experiments will provide further insight into the interpretation of infant mental processing in this task.

Experiment 4 Testing the "Oddness" Account: GIVE-HUG Alternation

It is possible that infants in the GIVE/HUG study might have looked longer at the GIVE-w/o video simply because it was "odd" to see someone performing the actions of giving with no object being given. On the other hand, there is nothing "odd" about hugging someone without a toy. If looking times are explained by the oddness of the event, then infants should find the GIVE w/o videos more interesting than the HUG w/o videos regardless of training. To test this proposal, 10 month olds were shown alternating trials of the GIVE-W/O and the HUG-W/O videos, with looking times compared over 12 trials. Results of this experiment are shown in figure 6. Contrary to the predictions of the "oddness" account, infants in this experiment do not show longer looking times for the GIVE W/O than the HUG-W/O video (p=.8).

Fig 6



Low Level Perceptual Changes

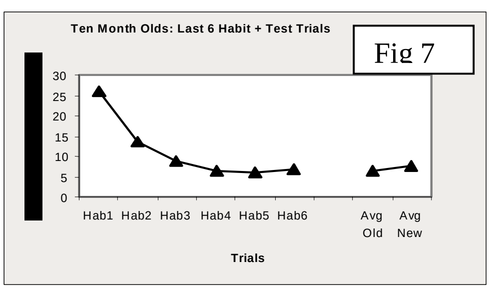
Another possibility is that there were subtle, low level differences in the GIVE and HUG videos that infants were paying attention to, and which led to differences in looking time. "Low-level" is taken to mean specifically *perceptual* differences relating to either the location of the toy in the scene, its motion properties, or the relation of the toy to other objects or persons in the scene. Differences having to do with the actors' attention to the toy etc. would require higher-level inferences about the intentions and are assumed to be associated with conceptual rather than perceptual discriminations. In general, it is hard to argue that the amount of movement of the toy was greater in GIVE than HUG videos. For example, in the HUG condition, the girl swept the camel in an arc around the boy's body with much greater motion than GIVE. In eye-tracking data, below, it will be seen that infants do, in fact, track the camel in these habituation trials. What has to be explained is not so much that infants dishabituated in the GIVE condition, but why infants did NOT dishabituate in HUG if changes in looking time index only changes in low-level information. The camel was large (5x9 cm) and prominent and moved a lot; but it only caused increased looking when its removal meant a change in the meaning of the event.

Experiment 5: Give Upside-Down (Pilot Data)

One method for distinguishing between low-level perceptual properties of a stimulus and its meaningful properties is to present the stimulus upside down. The idea is that the visual configuration is maintained, but it is often difficult to apply a meaningful interpretation to the stimulus. Such a strategy has been particularly important in examining the processing of complex static stimuli such as faces (Yin, 1969), which tend to lack individualistic and emotional aspects when encoded upside down, as in the famous Margaret Thatcher illusion (Thompson, 1980), even though still clearly recognized as a face. In this experiment, we employ the inversion strategy with our dynamic stimuli. Infants are presented with the stimuli from the GIVE experiment, inverted. Inversions are created through digital editing using Adobe Premier, which can flip the videos 180 degrees. Pilot data with 10 month olds on this procedure currently show no change in looking time when the toy is removed on test. To the extent that inversion distinguishes between attention to low-level perceptual changes, and meaningful changes, these data suggest that 10 month olds require minimally that the stimuli make sense in order for them to show recovery of looking time to the removal of the toy. Failure to do so, does suggest that the GIVE action is not interpreted meaningfully when inverted, and hence, there is no differentiation on removal of the toy. This procedure will be revisited in a later section in which it is presented for eye tracking.

Experiment 6 GIVE-TOY on HUG (Pilot Data)

This experiment directly addresses the claim that the perceptual properties of the toy are attracting infant attention in the GIVE video, but not the HUG video. The GIVE w/ video was edited so as to extract just the toy as it moved across the screen. This was then superimposed onto the HUG w/o video and synchronized so that the toy moved at the same rate as the people across the screen. Pilot data for this experiment are shown in Figure7 with the last 6 habituation trials and the OLD vs. NEW test trials (with vs. without toy). These data, quite remarkably, show no evidence of increased looking when the toy is removed. This is despite the fact that the video shows a toy camel floating across the screen as two people hug each other in the background. Indeed the toy appears to be much more prominent than in the original GIVE study and is quite comical to the adult observer. Failure to dishabituate is consistent with the interpretation that dishabituation occurs only when toy removal results in a change in event meaning. The perceptual prominence of the deleted object is apparently not particularly relevant.



Eye Tracking Studies

On of the best ways to investigate how infants process information is to track their eye gaze. Eye tracking provides highly detailed information on what is being acquired during the on-line processing of information as infants view action sequences. It provides detailed information on how looking patterns change as a function of a) dynamic changes in the depicted action; b) changes over repeated "learning" trials; c) changes due to context effects of prior stimulation. Data could also potentially reveal individual differences in looking patterns due to either developmental level or other differences in information processing style.

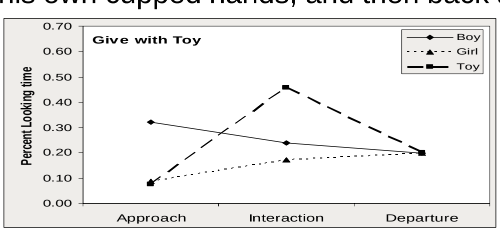
It is sometimes difficult to convey the richness of eye tracking data when they are flattened out into two-dimensional graphs. Looking at the crosshair of an infant's gaze as it scans across the video screen locking onto different elements feels, in many ways, like one is reading the infant's mind as they scan from eyes to hands to toy … and so on.[1] What is also fascinating is the extent to which different infants show such grossly similar patterns of eye gaze for a particular video. Most of the time, when you've seen one baby, you can grossly predict how the next one will direct their gaze for that particular video.

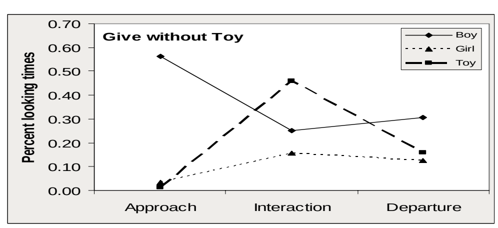
In the context of the current studies, we can ask whether the pattern of eye tracking obtained from infants in these studies can enrich our understanding of how they process information. For example, is there a difference in the gaze direction for GIVE vs. HUG videos? Do infants look at the toy more during habituation in the GIVE video than the HUG video? Do infants look at elements of the video that would indicate the intentional structure of the action? At present, we have coded only a small number of infants on these videos, with between 4 and 6 infants per condition. However, the results are extremely promising. Initial data collection has been with 12 month olds, although it appears that younger infants will actually be easier to test since they might be less fussy and more easily stimulated by simple videos.

The preliminary data reported here represent these early analyses using quite crude, but easily perceived, distinctions. Event sequences are segmented into three clearly defined phases: **Approach, Interaction**, and **Departure**. Each total event sequence lasts about 5s (roughly 200 frames total, with approx 50/150/100 frames for each phase respectively). Data are recorded on a frame-by-frame basis, noting where the infant was looking on each frame, and using this to determine what proportion of the frames of each phase they were looking at different elements. For present purposes, the areas of interest are BOY, GIRL, TOY, OTHER. "OTHER" usually refers to background areas and is not of interest to the present analysis. When fixations are on the human participants, they are almost always on the face and eyes. Distinctions of precise body locations are not presented in this preliminary analysis. In test condition videos where the toy is absent (w/o), the location where the toy would have been on the w/ TOY video is coded as TOY. In other words, the AOIs are defined identically regardless of whether the toy is present or absent. Looks to the location of the absent toy might indicate something like a "search" for the missing object. Data from GIVE and HUG are shown in the figures below.

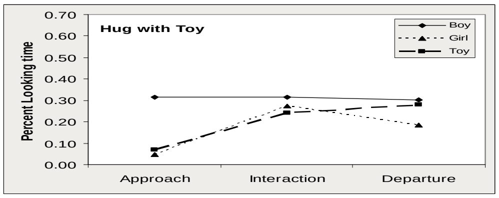
Experiment 7 Eye Tracking with GIVE & HUG videos

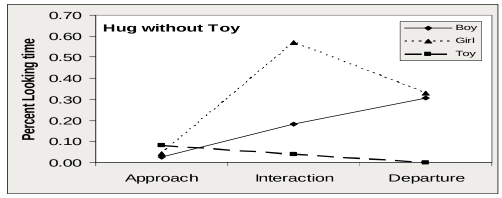
These pilot data are very revealing. First, they show that, for the GIVE video, there is sharp increase in looking at the TOY during the interaction stage, which would suggest intense processing of the transfer of possession activity. Deletion of the toy in the GIVE w/o video has almost no effect on looking behavior: Infants persist in looking to the location where the toy had been during the interaction phase. Since persistence did not occur for all conditions, it seems unlikely that this is just a perseveration effect. Rather, it is likely that infants were engaged in some kind of search process for the lost toy. This account is illustrated nicely by an infant in the original habituation study. Upon seeing the GIVE w/o video with the toy missing, looked down at his own cupped hands, and then back and forth to the video.





[1] If interested, the reader can view eye-tracking videos from the PIs lab at http://www.tc.columbia.edu/faculty/pg328/files.htm However, these should not be construed as a supplement to the present proposal and they are NOT required viewing.

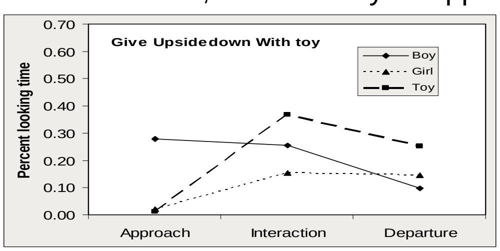


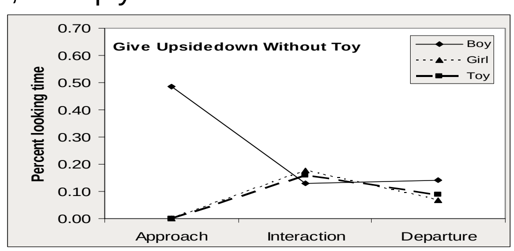


Eye tracking data for the HUG condition differ considerably from GIVE. In this condition, there is no spike in attention to the TOY during the interaction phase. There is an increase from the approach phase that parallels gaze directed at the GIRL.[2] Essentially, infants spend equal time looking at the three elements in the interaction phase. In the HUG w/o video, infants did not look to where the toy had been, but increased attention to the GIRL in equal measure to that previously paid to the TOY. The contrast with GIVE is dramatic, and suggests that infants spend much more time processing information about the toy in the GIVE condition, explaining some of the reasons why they increase looking time when the toy disappears. However, the data also indicate that attention to the toy in the HUG condition is not zero, and is being attended to as much as the actors when it is there. There is just no search when it is gone.

Experiment 8 Eye Tracking for GIVE UPSIDE DOWN Video

Perhaps the most startling result from the eye tracking pilot data come from the GIVE UPSIDE DOWN condition. Eye tracking in these conditions looks almost identical to the upright condition when the toy is present. One could turn the eye tracking monitor upside down and not be able to tell whether the stimulus was presented upright or inverted. The same cannot be said for the w/o condition. Unlike the upright GIVE condition, there is no spike in the interaction phase to look at where the toy had been. Again, this is reflected in the fact that infants do not show increased looking time in the test condition in the habituation test for these stimuli. These data are quite telling. They suggest that in the inverted GIVE condition, infants are doing precisely what is claimed in the low-level account. They are drawn to particular elements of the scene through perceptual salience, but there is little or no interpretation of the event by the infant, as one of GIVING. Hence, when the toy disappears, it simply fails to attract attention.





On-line changes in Eye Tracking

One of the questions that will be addressed in analyzing the eye tracking data is how long infants take to fixate on the appropriate stimuli and how this changes developmentally. Do they get it right away on the first trial? Or does it build up over repetition. Since events in the world do not usually happen repetitively, absent the infant's own urging, it would behoove the perceptual system to lock onto the right event parsing pretty quickly, although this is something that might show an interesting developmental change. In fact, it might be part of the reason why infants do love to see things over and over again in the classic Piagetian "circular reactions." Fig 8 shows changes over the 5 trials in looking to the TOY for the three phases of the event. In these data, one can see that looking to the toy shows an increase to the third trial, then slopes down again. A similar, but smaller effect occurs in the approach phase, suggesting that there is a parallel change in anticipation of the toy exchange. This pattern suggests an interesting new perspective on changes in information processing during this procedure. As we apply the eye tracking

[2] The data clearly show a bias toward looking at the BOY in these videos. We are currently investigating the basis for this bias. If it is a side bias, then additional babies will be run with side of entry reversed.

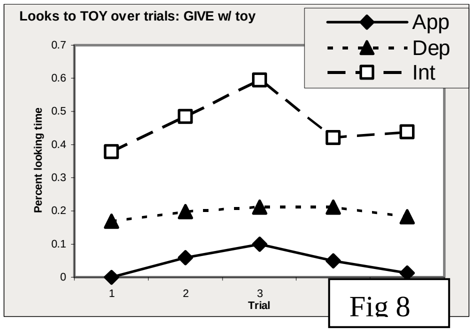


Fig 8

analysis to full-scale habitation experiment, such changes over trials will be incorporated into the analysis of looking times as a predictor of habituation and dishabituation. For all of these analyses, we will examine infants throughout the current age range (6 - 12 months), and continue up into 18 and 24 month olds, to examine any developmental changes in this function. All eye tracking studies will also be carried out with adults for comparison.

The centrality of GIVE in 3 argument events

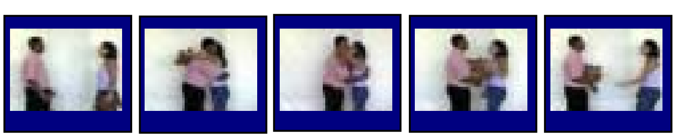
The present results indicate that infants pay special attention to transfer of possession and GIVE as an action. If this is the case, then it nicely parallels the role that transfer of possession plays in organizing verb-argument structures in language. A large proportion of 3-argument verbs in language involve an underlying transfer of possession, albeit where the manner in which the transfer occurs might be encoded in the individual verbs. That is, an object can be *given, thrown, passed, flipped, slid,* or *hurled* from one person to another, thereby generating a 3-argument structure. In each case, the underlying conceptual representation involves the transfer of possession by whatever manner is indicated by the individual verb (cf. Pinker 1990). I take it that for a noun phrase to be a third argument to a verb requires that it's referent be a necessary part of the conceptual representation underlying that verb (giving just isn't giving without something to give). If necessity is the mother of argument status, then it turns out that there are relatively few roles that objects can play in action schemes that rise to this criterion. If an object is not involved in change of possession, then it can be involved in change of location (*put, place, send, drop*) or perhaps some kind of transfer of information from one person to another (*tell, say, show, e-mail, fax, shout*). Beyond these basic action schemes, there is little that you can do with an object that allows it to achieve argument status. Hence, the narrow focus on GIVE within this research project reflects its centrality in basic event structures that involve three arguments.

There are two issues that arise from such a consideration. First, to what extent do the findings with GIVE, generalize to other 3 argument event representations that do not involve transfer of possession? Second, to what extent are basic conceptual action schemes, like transfer of possession, conceptually salient to young infants? Third, how is giving defined in the infant? Is it a physical or an intentional concept? In other words, is a change of possession enough or do infants require more intentional cues?

NOTE: *All experiments to be described from here on in will occur in parallel with eye tracking*

Intentionality and Theory of Mind

Experiment 9 Unintentional transfer of possession: Hug w/give



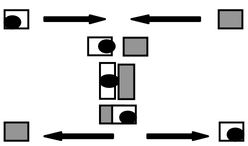
In the event model proposed earlier, it was suggested that intentionality is important in determining event structure. For example, infants must understand what peoples' intentions are in order to determine what is the point of a set of actions and upon which action do they converge as the main act? In this experiment, we examine whether infants will treat an event as one of giving if the main act is actually hugging, but there is still a change in possession. The video for this experiment looks just like the HUG video, except, as the girl and boy disentangle from their hug, the toy slips from the girl's possession to the boy. Early pilot data with 10 month olds in this condition do not show evidence of dishabituation when the toy is removed on test. However, this is based on only 4 subjects at the time of writing. If this is indicative of the general trend, then it would suggest that simple transfer of possession is not sufficient to specify an act of giving for infants. Rather, giving must be the main act.

Experiment 10 GIVE without intentionality cues

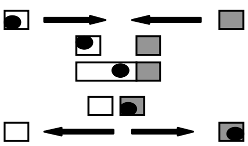
In this experiment, the infant sees a GIVE video, but intentional cues such as the girl and boy looking at each other, down at the object, motioning toward offering and accepting etc. are absent. Instead, there is a minimal change of possession where neither party acknowledges either the other or the toy. As usual, the test stimulus involves removal of the toy.

Experiment 11: Abstract GIVE vs. SQUEEZE

In this experiment, we examine whether infants show evidence of an abstract notion of transfer of possession. We will provide the elements of the GIVE/HUG procedure using abstract animated shapes instead of real people transferring real objects (see Figs 10 & 11).



Abstract GIVE: Infants will see an animated sequence of a white square containing a circle approaching from the left side of the screen. The circle will exhibit minor motion within the square as it moves so that it is clearly perceived as a separate object. Another gray square, without the contained circle, will approach from the right side of the screen. As they meet in the middle, the white square will extend itself to the gray square and the circle will be transferred from the white square to the gray square as the white square reforms into a square. The squares will then exit from the side that they entered. On test, the same sequence will be presented, except that there will be no circle inside either square, and hence no transfer.



Abstract SQUEEZE: The video sequence will be the same as above, except that when the squares meet in the middle, there will be no transfer of the circle. Instead the squares will elongate on contact as if they are squeezing each other. They will then pass each other and exit to the opposite side from whence they came. In this way, the ball will exit on the opposite side as in the GIVE condition. Test videos will again involve deletion of the ball from the sequence.

Intentionality Manipulation If infants are to interpret these animations as acts of “giving” and “squeezing”, then this requires they attribute some degree of intentionality to the abstract shapes. Studies by Gergely (1995) and Csibra et al., (1999) suggest that infants will interpret moving shapes as acting intentionally if they engage in behaviors such as chasing and avoiding obstacles. Similarly, Johnson (1998) found that 12 month olds will follow the gaze of a furry blob only if it initially interacts contingently with them using a high-pitched squealing noise. To manipulate intentionality in this experiment, one group of infants will first witness an animation of one square chasing the other, avoiding obstacles and making detours, as in Gergely’s (1995) presentations. A second group will see the squares moving around in a random manner, but with the same amount of total movement. This manipulation will allow us to see if intentional behavior attributed to the shapes confers upon them a stronger intentional interpretation when engaging in transfer of possession actions.

Experiment 12 PUT vs. WIPE

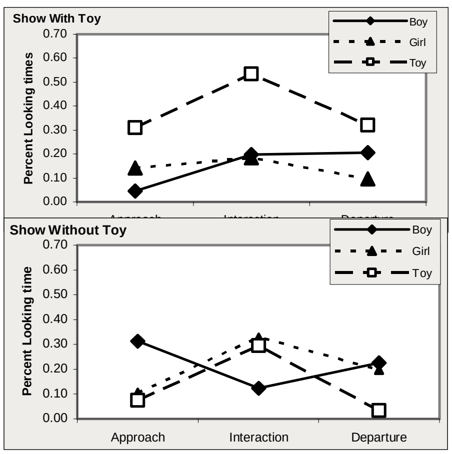
One major alternative to transfer of possession as a candidate for 3 argument event status is change of location. This is interesting because there are superficial similarities to change of possession, except with inanimate receptors. Being inanimate, this reduces considerably the possibilities for intentional action and interaction. Infants will see a girl carry an object, move it to another location and place it down on top of a table. Test will involve the same actions with the object missing. The contrast condition will be where the girl picks up the object, carries it the table, but then wipes the table with her other hand and walks off with the toy. The videos will end soon after the action so that there is no lingering, for example, of the toy on the table. If change of location shows argument status for the object, then infants should again show dishabituation in the PUT w/o video, but no dishabituation in the WIPE w/o video using the same logic as in the

GIVE/HUG experiment. If such a result obtains, it would suggest that the paradigm generalizes further than just transfer of possession.

Experiment 13 SHOW: The Role of Theory of Mind in Transfer of Information

This experiment investigates another kind of 3-argument event that involves transfer of information rather than transfer of objects to people or locations. The relevant action is SHOW,

where the girl in the video shows the toy to the boy who wildly overacts in delight at seeing the toy. This is followed by a return to their respective sides. Test, again, involves the same action with the toy disappeared. Preliminary data with both habituation and eye tracking have been collected in this condition and are of considerable interest. So far, infants are showing no signs of dishabituation when the toy disappears. That is, even though they see an odd behavior “showing nothing” infants do not show increased looking as they did in the GIVE experiment. However, when we look at the eye-



tracking data, they show clear evidence that infants are looking at the toy during the interaction phase, and somewhat less when it has disappeared. It seems as if they see the toy, but they just don’t get it! This makes sense, if one considers that understanding SHOW requires some rudimentary understanding of the mental states of those involved, which may not be available at this young age. Thus, the results can be potentially informative as to the infant’s current status vis a vis their theory of mind. What these data also suggest is that eye tracking is not a proxy for dishabituation. What you see is not always what you get.

The Centrality of Change of Possession: Converging evidence from other paradigms

In this final section, I propose experiments that differ in their procedures and address issues relating to the infant’s understanding of transfer of possession as a central conceptual organizer. The first experiment employs a variation on the A-not-B procedure of Piaget. The second experiment asks if infants can infer a change of possession that occurs behind an occluder employing a violation of expectation paradigm. These experiments are more speculative with respect to their outcomes.

Experiment 14 A-not-B: GIVING and WAVING with hidden objects

Piaget’s A-not-B task involves repeated hiding of an object to a location A, which the infant then retrieves, assuming they can do the standard object permanence task. The object is then hidden at A, then moved to a new location B. Infants who fail on this task, continue to look for the object at A. In recent studies, it has been shown that infants show advanced behavior on this task (searching at B) if the new location is made more salient, or there is some disruption in the properties of the initial perseverative component (Thelen et al. 2001). This experiment exploits this property of the A-not-B procedure as a way of indexing the salience of an action. In particular, is change of possession a particularly powerful means of breaking the perseverative behaviors built up in the A-not-B procedure? In this procedure, 9 to 11 month olds are given the standard hiding procedures of the A-not-B task, where a favored object is hidden under a cloth repeatedly over 3 trials. If the infant retrieves the object at this location on the three trials, it is then moved to under a second adjacent cloth as in the standard A not B procedure. If the infant shows the A-not-B perseverative error, the procedure is then repeated, but now, when the object is transferred it is either 1) taken from A, given to a second person, who then hides it under B, or 2) it is taken from under A, the retriever then waves at a second experimenter while holding the object, then puts the object under B. The idea of this experiment is that the high salience of transfer of possession in these infants will cause them to pay greater attention to the change of location in the GIVE condition, and result in fewer perseverative responses in continuing to look to the A location. In pilot studies with this procedure, we have found some infants break their perseverative behavior with GIVE, but none with WAVE.

Experiment 15: GIVE/HUG with occlusion and future projects

Again focusing on the question of salience of transfer of possession, this experiment asks if infants can infer transfer of possession if the act itself is hidden from view. In this experiment, infants will see the GIVE and HUG videos except the interaction phase will be hidden by a screen. If infants are tracking the location of the object, then they should infer that a transfer of possession has occurred behind the screen. There will be two familiarization videos in which the girl and boy enter behind the screen with the girl carrying the toy. In one, the girl exits with the toy, in the other, the boy exits with the toy (see the first and last frames in Fig. 3). On test, infants in different conditions will see (1) the full GIVE w/ video with no occlusion, (2) the full HUG w/ video or (3) the HUG w/GIVE video, in which there is transfer of possession, but hugging rather than giving is the main act (see fig. 9). Thus, there will be 3 x 2 conditions. If infants are tracking change of possession after the boy and girl emerge from the screen, do they then infer that there was some kind of act of GIVING occurring behind the screen? If so, they should show longer looking if dropping the screen now involved hugging rather than giving. Note that this is a violation of expectation paradigm rather than simple event discrimination as in the previous experiments. The procedure will include eye tracking to see if longer looking is contingent on infants tracking the location of the toy in the familiarization trials (cf. Johnson et al. 2003). If this procedure bears fruit, it will allow for the next step in this project that will examine the role of argument structure in language in determining infant interpretations of events. In these future studies infants would hear a description employing either a 2 argument or 3 argument linguistic structure ("Hey, she's blicking him!" or "Hey, she's blicking it to him") to see if infants pick up on the linguistic cues to infer what kind of action occurs behind the screen.

Time Line

Experiment	*Description*	*Status*	*Subject Ages*	*Eye tracking*	*Schedule*
1,2,3,4	give/hug	Complete	6-10 m		Done
5	give UD	Pilot 10m	6-10 m		Y1
6	give on hug	Pilot 10m	6-10 m		Y1
7	give/hug ET	Pilot 12m	6-10 m	x	Y1
8	give UD ET	Pilot 12m	6-10 m	x	Y1
9	Hug w/give	Pilot 10m	6-10 m	x	Y1
10	give - Intent		10 m	x	Y2
11	Abstract		10 m	x	Y3
12	Put/wipe		6 -10 m	x	Y2
13	Show	Pilot 10-12m	6-10 m	x	Y1
14	A not B	Pilot 10m	9-11 m		Y1
15	Occlusion		10 - 12m	x	Y3

Year 3 will involve preparation of manuscripts for dissemination and piloting of new experiments for continued funding.