Invited Speaker and Symposia Abstracts

The Cognitive Development Society Fifth Biennial Meeting Program includes two plenary invited talks, two plenary invited symposia, and four symposia sessions with three concurrent symposia.

Friday, October 26

8:45 - 9:45	Plenary Talk in Anasazi Ballroom Language and the Infant Brain: How Children Learn Patricia Kuhl, University of Washington		
10:15 - 12:30	Invited Symposium in Anasazi Ballroom In Memory of Esther Thelen		
	Anasazi North	Anasazi South	Zia Ballroom
2:00 - 3:45	New Directions in Social Cognitive Development: It's More than Theory of Mind	Computational Approaches to Language Acquisition: Connectionist, Dynamical Systems and Bayesian Perspectives	Attention to Language: The Interaction between Language and Cognition
4:00 - 5:45	Interactions between Social Cognition and Object Cognition	Rational Statistical Inference in Cognitive and Language Development	The Function of Action in Perceptual and Cognitive Development

Saturday, October 27

8:45 - 9:45	Plenary Talk in Anasazi Ballroom Learning to Perceive to Learn Rob Goldstone, Indiana University		
10:15 - 12:30	Presidential Symposium in Anasazi Ballroom Children's Learning		
	Anasazi North	Anasazi South	Zia Ballroom
2:00 - 3:45	Cognitive Developmental Perspectives on Social Categorization and the Implications for Intergroup Bias	The Role of Comparison in the Development of Relational Representations and Structured Thought	To Model or Not To Model – Is That a Central Question?
4:00 - 5:45	New Directions in Pretend Play Research	Knowing about Ignorance: Children's Judgments and Nonverbal Behavior in the Face of Uncertainty	Learning by Doing: The Role of Exploratory Play in Cognitive Development

Friday, October 26, 2007: 8:45 am – 9:45 am

Plenary Talk: Language and the Infant Brain: How Children Learn
Patricia Kuhl, University of Washington

Some of the most revolutionary ideas in brain science are coming from cribs and nurseries. In this talk I will focus on the new discoveries about early learning and the neural coding of learned information with special attention to language. Infants are born 'citizens of the world' and can acquire any language easily. But by the end of the first year of life, they've developed a specialty in one language, and their ability to discern sounds from other languages declines. Research on infants is showing that they use computation to crack the speech code, and that a social interest in language plays an important role in language learning. "Motherese," the exaggerated, high-pitched language we use to speak to infants and children is used in virtually every language studied, and infants' interest in it also contributes to their ability to learn. These precursors to language in typically developing infants are leading to the identification of children at risk for developmental disabilities involving language, such as children with autism. In the next decade, the techniques of modern neuroscience will play a significant role in our understanding of how infants learn.

Friday, October 26, 2007: 10:15 am – 12:30 pm

Invited Symposium: In Memory of Esther Thelen
Organizer: Linda Smith, Indiana University
Summary: Esther Thelen–through extraordinarily inventive experiments–changed the field's understanding of motor development. She showed developments such as reaching and walking not to be pre-specified but to be the self-organizing products of many heterogeneous processes interacting in a complex system of brain, body, and world. Thelen saw the broader value of these ideas beyond motor development. In celebration of her contributions, the presentations in this symposium consider the broader themes in Thelen's work as they apply to the problem of development generally, and to cognitive development in particular.

Thinking About Development: Reflections on Esther Thelen's Assumptions and Their Application to Developmental Inquiry
Robert Lickliter, Florida International University

This talk considers the development of intersensory perception. The talk will briefly review how Esther's basic assumptions about developmental inquiry are being applied to the study of early perceptual development and more broadly to our understanding of the development of "species-typical" behavior.

Dynamics in Statistical Learning
Rebecca Gomez, University of Arizona

This talk will present research suggesting that learning is a dynamically guided process, arising in the interaction of internal and external pressures. Moreover, learners, and the structure they can acquire, change as a function of experience, and are constrained by fundamental processes of memory. In contrast to "knowledge" constraints traditionally proposed in the literature on development and learning, the constraints proposed here arise naturally from the mechanics of learning and memory processes themselves.

Brain Development as the Ultimate Dynamic systems
Joan Stiles, University of California-San Diego

From the complexities of genetic variation and transcription, to the variable paths of neural development and its dependence on experience, brain development is far more complex and dynamic than is often assumed in debates about nature vs. nurture, nativism vs. cultural learning. Inherited and experienced factors interact constantly in an ever-changing organism. This is a complex, dynamic and self-organizing system.

Weird loops: From object recognition to symbolic play to learning nouns and back

Linda Smith, Indiana University

Cognitive development is also far more complex and dynamic than our usual debates allow. Developmental change is multi-causal in nature, with weird loops of causes which are also consequences and consequences that are causes, with considerable and nontrivial causal spread. The interdependencies among developmental changes in visual object recognition, object substitution in play, and object naming learning are presented as an example.

Friday, October 26, 2007: 2:00 - 3:45 pm

New Directions in Social Cognitive Development: It's More than Theory of Mind

Organizer: Kristina Olson, Harvard University

Summary: Social cognitive development has long been a topic of interest within cognitive development. Most textbooks and handbooks have chapters devoted to the study of social cognition in young children, though examining these chapters one often leaves with a feeling that social cognitive development is limited to the study of theory of mind and intentionality. It is rare to see core topics in social development or social psychology studied from a cognitive developmental perspective.

In this symposium we examine questions that are social, cognitive and developmental in nature and that are derived from other ongoing work in social cognition, social development, comparative psychology and cognitive development. We examine four unique topics—attachment, cognitive dissonance, social attitudes and preference development—using methods and theories derived from cognitive development. Finally, our discussant, Carol Dweck, will provide perspectives on the field of social cognitive development more broadly, emphasizing where the area of social cognitive development has been and where it is headed.

Evidence for Infants' Internal Working Models of Attachment

Susan C. Johnson, Carol S. Dweck, and Frances S. Chen, Stanford University

Nearly half a century ago, psychiatrist John Bowlby proposed that the instinctual behavioral system that underpins an infant's attachment to its mother is accompanied by "internal working models" of the social world—models based on the infant's own experience with her caregiver (Bowlby, 1958, 1969/1982). These mental models were thought to mediate, in part, the ability of an infant to use her caregiver as a buffer against the stresses of life, as well as the later development of important self-regulatory and social skills.

The current study reports the first direct evidence for human infants' "internal working models" of attachment. We used a standard visual habituation technique to assess infants' expectations of a caregiver's responsiveness to bids of attention from a infant during an abstractly depicted separation event. Securely attached infants, relative to insecurely attached infants looked significantly longer when the depicted parent ignored the child's cry and moved farther away from, rather than returning to the child, as though the securely attached infants, but not the insecurely attached infants were surprised to see a parent act unresponsively. These results are clear evidence that infants' interpretations of the social world are influenced by their own histories with their caregivers, as predicted by Bowlby.

The Origins of Cognitive Dissonance

Louisa Egan, Laurie Santos, & Paul Bloom, Yale University

The motivation to reduce cognitive dissonance (CD) between divergent beliefs, attitudes, and behaviors impacts adult cognitions in domains ranging from consumer consumption to morality. Previous work on the origins of CD has relied on induced behaviors, rather than behaviors generated by an individual, and has failed to employ simple and direct tests.

Our work explores CD in young children and capuchin monkeys through a non-verbal variant of Brehm's (1956) free choice paradigm. Children chose between two equally preferred stickers, A and B. Children then chose between the unchosen alternative and sticker C, which was originally rated as preferred as A and B. Children significantly chose sticker C over the unchosen A/B. In a control condition, children saw both A and B and received one of the two. Children then chose between the unreceived sticker and sticker C. In this condition, preference for C is absent.

Similarly to children, in the experimental condition, monkeys chose between M&Ms of equally preferred colors A and B, and then between the unchosen color and C. In the control condition, monkeys saw both A and B and received one of them. Then,

monkeys chose between the unreceived color and C. Monkeys preferred C to the unreceived alternative in the experimental condition, but preferred the unreceived alternative in the control condition.

These results are the first evidence of decision rationalization in young children and animals. They indicate a higher degree of motivational complexity in young children and capuchin monkeys than they are commonly believed to possess.

When do children begin to see lucky people as nicer than unlucky people?
Kristina Olson, Mahzarin Banaji, Elizabeth Spelke (Harvard University), & Carol Dweck (Stanford University)

Random or lucky and unlucky events happen everyday—people win lotteries and lose their houses in hurricanes. We know that young children have a limited understanding of random events (Weisz, 1980) and that even as adults people sometimes blame others for the random or unlucky events that happen to them (e.g., Lerner, 1971). Recent developmental research has indicated that school-aged children demonstrate a preference for lucky people compared to unlucky people (Olson, Banaji, Dweck, & Spelke, 2006).

The current work investigates how preschoolers (aged 2.5-5 years old) think about lucky and unlucky people. In two studies with differing methods we demonstrate that children as young as 3 view the lucky as nicer than the unlucky. The presence of this evaluation at such an early age sheds doubt on explanations provided by social and developmental psychology such as the Belief in a Just World (Lerner, 1980) or Immanent Justice (Piaget, 1932/1965). Other, more cognitive explanations such as affective-tagging or valence matching must be explored to explain this phenomenon.

Positive evaluations of lucky compared to unlucky individuals are important to examine both theoretically and practically. Understanding the mechanism underlying this "preference for the lucky" can help us understand how children develop preferences and attitudes more generally. Practically, we hypothesize that young children's preference for the lucky might lead to other social group attitudes given that some groups (e.g., the poor) tend to experience more unlucky events than others.

Social influences on children's preferences
Lori Markson & Christine Fawcett, University of California, Berkeley

Successfully navigating the social world demands that we moderate the influence of others on our own behavior, without ignoring the importance of others as sources of information in an uncertain world. Even infants are skilled at seeking information from others, especially in the face of unfamiliar events (Campos & Stenberg, 1981). Do young children look to others as resources when determining what to value and developing their own subjective preferences?

The current research investigates whether desirability and scarcity influence children's choices when choosing between novel or unknown items. In one study, we demonstrate that 18-month-old infants' preferences are influenced by the observation that others desire or prefer that entity to another. Further studies are investigating whether infants are differentially influenced by familiar, trusted individuals (e.g., parents), or more similar others (e.g., siblings or peers). A second study asks whether children's choices are influenced by the perception that a given good is scarce. We found that when faced with different quantities of unknown options to select from, three- and four-year-old children tend to choose one of the less abundant item, suggesting they assign higher value to the scarce good. This bias was observed in the absence of a social context. Further studies are examining whether children's choices may have been influenced by implicit social cues (e.g., "If there are fewer of these, other children must have chosen them."). Taken together, these findings highlight the impact of the social world on children's preferences.

Discussant: *Carol Dweck, Stanford University*

Computational Approaches to Language Acquisition: Connectionist, Dynamical Systems and Bayesian Perspectives
Organizer: Sarah Sahni, University of Wisconsin, Madison
Summary: The goal of this symposium is to review the merits of computational approaches to research in language development. There is a rich history of using computational methods to create formal models of behavior which instantiate and test crucial aspects of psychological mechanisms. This approach is powerful because it forces researchers to try to understand the roots of behavior and not simply describe it. It is especially relevant to issues in development as many of these models address acquisition and learning.

As computational research has evolved, connectionist, dynamical systems, and Bayesian models have all emerged as popular approaches. Each is well-suited to investigate learning problems, although they lend themselves to different scientific theories. The symposium will consist of three presentations that: 1) Describe a line of work in language acquisition that has emerged from one of these approaches, and 2) Discuss unique aspects of a particular model and the approach. Each of the speakers is an expert in their field: Eliana Colunga (connectionism), Larissa Samuelson & John Spencer (dynamical systems), and Amy Perfors & Josh

Tenenbaum (Bayesian framework). The discussant, Linda Smith, will draw comparisons among the three approaches and highlight challenges faced by any computational model.

The topic of this symposium is important and timely as computational approaches are once again gaining attention in the field. This symposium will give members the opportunity to understand the unique merits of computational approaches as well as to clarify the different types of models, thereby providing insights concerning the relative strengths of each approach.

Learning to learn words: a connectionist account

Eliana Colunga, University of Colorado - Boulder

Young children's seemingly effortless ability to learn new words, which emerges sometime in the second year of life, provides an interesting puzzle in developmental psychology. The main idea of the Attentional Learning Account of early word learning is that children learn to learn words as they learn words, and that they do so by extracting second-order generalizations from the statistical regularities present in the structure of the vocabularies they are acquiring. The computational model I will present embodies two general principles we know to be part of human cognition and of connectionist models that are well-suited for testing this hypothesis: associative learning and generalization by similarity. Through a series of simulations and experiments with young children, I will show how this model lends insight into how children's rapid word learning develops across different contexts and across different languages. The strengths of this model include its relative simplicity, its modeling of real world regularities, its attempt to make the task of the model approach that of children in the lab, and its ability to make testable (and tested) predictions. I will discuss these strengths in the context of the different computational approaches showcased in this workshop. At the end, I will suggest that 1) computational modeling lends particularly well to the understanding of developmental phenomena, and 2) the choice of computational paradigm and its potential to provide insights may depend more on the hypothesis to be tested than on the relative strengths and limitations of the different approaches.

Language acquisition in a Bayesian framework

Amy Perfors & Josh Tenenbaum, Massachusetts Institute of Technology

On the basis of noisy and impoverished input, language learning infants must acquire both semantic generalizations (how to map world experience onto the words in the input) and syntactic ones (how to group those words into sentences). This mastery, especially in syntax, requires the ability to reason probabilistically about structured representations: grammatical rules depend upon the hierarchical organization of phrases, and knowledge of these rules is not all-or-none. Mastery also requires the ability to learn at multiple levels of abstraction. We see this clearly in the acquisition of the shape bias: on a specific level an infant must realize that toys called 'ball' may have little in common aside from their shape, and on a more abstract level, she must learn that count nouns in general tend to be well-organized by shape and not other features.

Bayesian methods are particularly suited to exploring the mastery of these two important abilities. The Bayesian approach naturally integrates statistical learning and structured representations and incorporates both into a normative framework for rational inference; this allows us to investigate the role of different types of representational structure in a principled and rigorous manner. Hierarchical Bayesian models also learn on multiple levels, making simultaneous inferences about both specific and more abstract hypotheses: as a result, they explain generalizations in a way that single-level learning cannot. We explore these advantages in the context of a model applied to learning about both the shape bias as well as aspects of verb argument constructions.

Keeping it real: A dynamic systems approach to word learning

Larissa Samuelson & John Spencer, University of Iowa

In this talk we will illustrate how we have used a particular computational approach based on Dynamic Systems Theory—Dynamic Neural Field Theory—to understand how young children's knowledge of names and categories is brought to bear in a task in a moment in time. We suggest that only by understanding how individual behaviors at this real timescale accumulate to create later behaviors, can we make progress in understanding the development of word learning biases and cognitive development more generally.

Our recent modeling work captures developmental changes in children's attention to shape from 1.5-to 4-years-of-age in forced choice and yes/no tasks. Our model instantiates differences in the tasks presented to young children—differences that drive comparison and decision-making processes, resulting in different patterns of noun generalization in the two tasks. Further, our model captures changes in the patterns of performance over development. Thus, the DNFT has implications at both real-time and developmental timescales.

This illustrates three unique aspects of the DNFT approach. First, the DNFT is a process-based account of behavior, learning and development. From this perspective, real-time, contextually grounded decisions constrain what is learned and what develops. Second, the DNFT represents a strong commitment to neuronal principles. This provides constraints for processes that underlie

decision-making as well as for hypotheses about developmental change. Third, the DNFT involves a commitment to an embodied view of cognition which is critical to grounding word learning in a real sensorimotor system.

DISCUSSANT: *Linda Smith, Indiana University*

Computational models both describe and predict, allowing the model to account for the underlying structures in a dataset and to show transfer (or not) to novel inputs. Each of the computational approaches summarized by the three presentations – connectionist, dynamical systems, and Bayesian – have advantages and disadvantages in meeting these descriptive and predictive goals as they are applied in different sub-domains of language and cognitive development. Among the challenges that will be highlighted are: (a) how the input is encoded, (b) the architecture used to instantiate the flow and compression of information between levels, (c) the ability of the model to adapt to changes in the distributional properties of the input, and (d) whether models that solve a particular learning problem can also be deployed to solve other problems, or must of necessity be domain- and task-specific.

Attention to Language: The Interaction between Language and Cognition

ORGANIZER: Banchiamlack Dessalegn, Johns Hopkins University

SUMMARY: Many in the cognitive sciences agree that there is an interaction between language and nonlinguistic cognition. The current symposium will address the consequence, mechanism and development of such interactions across development. Specifically, the papers will focus on two questions. First, how does language influence spatial cognition when language or spatial cognition is impaired? Are typical developmental patterns observed? The first two presenters will address this question by looking at spatial cognition in individuals with limited spatial language (deaf users of Nicaraguan Sign Language) and individuals with severely impaired spatial abilities but relatively spared language (people that have the developmental genetic disorder Williams syndrome). The presenters argue that knowledge of spatial terms is crucial in developing adult-like spatial representations.

Second, what is the nature of the mechanisms by which language and space interact across development? Does language simply selectively direct attention towards certain spatial representations or does language qualitatively change the nature of non-linguistic representations, and if so, how? The third presenter shows that directional spatial terms (e.g., left) help children and adults form a robust spatial representation, and proposes a specific hypothesis as the possible mechanism underlying the language effect. The final presenter shows that nonlinguistic mechanisms, e.g., attentional cues, can guide linguistic processes both in children and adults.

Overall, the symposium draws from a range of methodologies, populations and age groups to investigate the consequence, mechanism and development of interaction between language and nonlinguistic cognition -- thus yielding critical information about the structure of cognition over development.

DOES SPATIAL LANGUAGE GUIDE SPATIAL REPRESENTATION? EVIDENCE FROM NICARAGUAN SIGN LANGUAGE

Anna Shusterman, Wellesley College; Jennie E. Pyers, Wellesley College; Ann Senghas, Columbia University; Karen Emmorey, San Diego University; Elizabeth Spelke, Harvard University

How does limited language affect spatial representation? Past research suggests a role for language in the ability to use landmark cues in disorientations tasks, and that the acquisition of terms like left of and right of facilitates the use of landmark cues in these tasks. Does failure to acquire linguistic constructions like left of have a long-term impact on spatial representation? Furthermore, is language similarly related to other aspects of spatial cognition?

To address these questions, we examined spatial language and cognition in deaf users of Nicaraguan Sign Language. Senghas previously found that older signers, who learned early-emerging, less developed forms of the language, lacked left-right expressions, while younger signers, who learned a more developed form of NSL, linguistically marked left and right. Accordingly, older (Mage=30 years, n=7) and younger (Mage=21 years, n=8) signers were participated in tests of spatial language and non-linguistic spatial tasks including reorientation, mental rotation, map reading, and map drawing. Consistency in linguistic marking of left-right relations was correlated with superior performance on the reorientation task (r=.67, p=.02), suggesting a role for language in spatial representation even in adulthood. Older signers' performance on non-verbal tasks was above chance but worse than younger signers. This profile suggests that adults with limited spatial language achieve spatial abilities beyond those observed in young children, but that specific linguistic experience is necessary for fully developed spatial cognition. Variations in errors, reaction times, and cross-task performance shed further light on the nature of spatial representations in individuals with limited language.

A ROLE FOR LANGUAGE IN REORIENTATION? EVIDENCE FROM WILLIAMS SYNDROME

Laura Lakusta, Harvard University; Banchiamlack Dessalegn & Barbara Landau, Johns Hopkins University

One critical aspect of navigating the environment is being able to reorient oneself when disoriented. How is this task accomplished? Research has shown that species as diverse as rats, chicks, human toddlers and adults all reorient themselves by using the overall geometric structure of a layout. Surface featural cues (e.g., color) are also used, although use of these cues is more variable, depending on age, task conditions, and, most notably, language ability. The finding that language ability influences reorientation provides a case of interaction between language and non-linguistic thought. In this paper, we probe the nature of this interaction by testing reorientation in individuals with Williams syndrome - a rare developmental genetic deficit in which language is preserved but spatial representations are severely and selectively impaired.

We find that Williams syndrome individuals show a highly unusual pattern of performance in reorientation tasks, with failure to reorient using geometry alone, but success when geometry can be combined with surface featural cues. The results will be discussed in the context of current theories of modularity in reorientation, and the relevance of language in modulating spatial representations over development.

THE ASYMMETRIC RECODING HYPOTHESIS: HOW LANGUAGE MIGHT RECODE VISUAL REPRESENTATIONS

Banchiamlack Dessalegn & Barbara Landau, Johns Hopkins University

On several accounts language plays a powerful role in many cognitive processes. But what is the mechanism underlying such effects? We describe one language effect and lay out a hypothesis and some evidence to explain the underlying mechanism.

In previous work we found that providing specific directional terms to children enhanced their ability to match a visual target and avoid foils in which color and location were varied. Non-linguistic attentional manipulations did not show these effects, nor did linguistic instructions that did not include the directional terms.

We hypothesized that language provided the crucial figure-ground asymmetry as well as the specific directional information required for an accurate match. If this is true, then adults might be expected to show impairment if language is disabled by verbal shadowing.

We gave 60 adults the same task as the children in one of three conditions: No Shadow, Verbal Shadow, and Rhythm Shadow. Adults performed at ceiling in the No Shadow and Rhythm Shadow conditions, but fell to 4-yearold levels in the Verbal Shadow condition.

Thus, for both adults and children language appears to play a crucial role in carrying out this task. We lay out the Asymmetric Recoding Hypothesis which states that given an object without an inherent figure and ground, language forces the creation of an asymmetry between the parts, and thus enables the formation of a robust representation of spatial relationship. The details of the hypothesis, its predictions, and empirical test of the predictions will be discussed.

ATTENTIONAL ALIGNMENT GUIDES LANGUAGE LEARNING

Rebecca Nappa, University of North Carolina; John C. Trueswell & Lila R. Gleitman, University of Pennsylvania

Visual attention contributes to the process of event apprehension, such that the way a scene is explored influences the way it will ultimately be interpreted. Thus, the locus of speakers' attention as they interpret events guides their eventual descriptions of these events. This, in turn, causes speakers to produce cues, indicating their perspectives (such as the location of the speaker's gaze, and attention-directing gestures like pointing). Thus, the visual attention of a speaker influences both his own conceptualizations and descriptions of events and the listener/learner's conceptualizations of the same events, by way of attention-directing cues.

A set of experiments will be outlined demonstrating that this leads to significant conceptual alignment between speaker and listener, and guides the interpretation of complex events and ambiguous language (with particular emphasis on interpreting complex verbs). Specifically, when examining scenes depicting events that can be interpreted various ways, it will be demonstrated that the location of speakers' attention influences the way these scenes are ultimately described. This same effect can be seen when a speaker's attention is manipulated via gaze-direction cues (indicating that attention-directing cues from the speaker are utilized when interpreting complex events). Moreover, such attention-directing cues (gaze and pointing gestures) influence the way complex utterances (containing unfamiliar nonce verbs) will be interpreted by both adults and children in such a visual context. Through this attentional alignment, speakers and listener/learners arrive at aligned conceptual and linguistic representations of events.

DISCUSSANT: *Dedre Gentner, Northwestern University*

Interactions between Social Cognition and Object cognition

Co-Organizers: Kristin Shutts & Katherine Kinzler, Harvard University

Summary: The goal of this symposium is to ask how children integrate their perceptions of the social world with their evaluations of the physical world. For example, how do properties and past behaviors of other individuals influence children's own preferences for different kinds of objects? To whom do children look when seeking information about unfamiliar objects, and when reasoning about physical events?

The first two papers in the symposium (presented by K. Kinzler and K. Shutts) provide evidence that infants and children attend to social category information (e.g., about spoken language, gender, and age) when reasoning about their own preferences for foods and artifacts. The third paper (presented by C. Fawcett) presents data showing that when children are given the opportunity to choose among objects hidden from view, they trust opinions of individuals who have shown concordant object preferences in the past. The fourth paper (presented by V. Jaswal) shows that young children are able to use testimony from adults in order to overcome errors in reasoning about physical events involving objects. Together the findings suggest that infants and children are able to use knowledge in one domain (e.g., the social realm) in order to solve problems in other domains (e.g., object preferences and object mechanics).

Infants' selective preference for "native objects"

Katherine D. Kinzler (presenter), Emmanuel Dupoux, & Elizabeth S. Spelke, Harvard University

From birth, humans display a remarkable sensitivity to language and linguistic differences. Neonates prefer their native language to a foreign language, and even discriminate two foreign languages provided that they have sufficiently different rhythmic properties.

The present paper questions whether 1) infants demonstrate a social preference for a speaker of a native language over a speaker of a foreign language, and 2) whether this early social preference influences infants' early understanding of and preference for objects. In Experiment 1, 5-6 month-old infants demonstrated a visual preference for people who previously spoke in their native language with a native accent. In Experiments 2 and 3, 10-month-old infants preferred to accept one of two identical toys when offered, and one of two different toys when modeled, by a speaker of a native language rather than a speaker of a foreign language. These effects obtained even though language was never directly paired with the objects. Experiment 4 provides evidence that 12-month-old infants preferentially choose foods that are first eaten by a native speaker rather than a foreign speaker.

Together, these findings suggest that infants attend to social information to inform their early preferences among objects, including preferences for some objects over others, differential willingness to accept one of two identical objects when offered by individuals of different social categories, and even preferences among foods that they have previously tasted and enjoyed.

Social categories guide young children's preferences for novel objects

Kristin Shutts (presenter), Mahzarin R. Banaji, & Elizabeth S. Spelke, Harvard University

Humans as a species are extraordinarily gifted at learning information from other humans in their social group. From language to dance to dress, humans come to act like those around them. This "cultural learning" begins at an early age; even infants look where others, and do what others do (e.g., Meltzoff & Moore, 1977; Scaife & Bruner, 1975; Tomasello, Kruger, & Ratner, 1993).

In the present work, we ask whether children are selective in whom they learn from, by investigating the influence of social categories on young children's preferences for novel objects. In two experiments, three-year-old children were introduced to pairs of unfamiliar individuals, each of whom stated a preference for a different novel object. Members of pairs differed according to gender (male, female), race (White, Black), and age (child, adult). In Experiment 1, children demonstrated robust preferences for objects endorsed by same-gender individuals, but did not use race information as reliably as a basis for inferring their own preferences. In Experiment 2, children again selected objects favored by same-gender individuals, and also demonstrated a preference for items endorsed by same-age peers over adults.

These data provide a window into the social categories that children deem to be meaningful, and their influence on the development of the child's own object preferences and choices.

Young children understand the subjective nature of preferences
Christine Fawcett (presenter) & Lori Markson, University of California, Berkeley

How do we decide whose recommendation to trust? Trusting others with preferences similar to our own is often a good heuristic, but equally important is knowing how to extend that trust. To address this question, we have been exploring how children's sensitivity to shared preferences influences their determination of who is a reliable source of information about objects.

In a series of experiments, two-year-old children learned two actors' contrasting preferences for various items in a particular category (e.g., foods). One actor shared the child's preference and the other did not. Children were then tested on their use of preference information when making inferences about the two actors' preferences for new items in categories that varied in relevance to the original category. Children were more likely to select an unseen item described by one of the actors as "her favorite" if that person had previously demonstrated a shared preference with the child for other items in the same category. Interestingly, children were more likely to extend their trust in a person's preferences across related categories (e.g., toys and books) compared to unrelated categories (e.g., television programs and foods).

The findings demonstrate that two-year-old children view a person who shares their preference as a reliable source of subjective information, at least within a designated category. This work further informs our knowledge of how children's understanding of the social world influences their reasoning about the physical world.

Trust in testimony about the physical world
Vikram K. Jaswal, University of Virginia

The physical world seems largely knowable from personal experience. In two studies, we investigated toddlers' willingness to revise a belief about the physical world—in particular, about the trajectory of a falling object—on the basis of what an adult tells them.

In Study 1, 30-month-olds saw an apparatus consisting of three chimneys affixed atop three cups. Opaque, curved tubes connected each chimney to a non-adjacent cup below. The experimenter dropped a ball through one of the chimneys and invited children to search for it. Children had a robust "gravity bias," incorrectly searching the cup directly beneath the chimney where the ball had been dropped 76% of the time (see also Hood, 1995). However, if the experimenter mentioned the actual cup where the ball landed before inviting children to search, they made the gravity error just 25% of the time (and searched correctly 67% of the time).

In Study 2, we explored the limits of toddlers' deference by using clear rather than opaque tubes. Children made the gravity error just 11% of the time (and searched correctly 84% of the time). However, if the experimenter mentioned the gravity cup before allowing children to search, they made the gravity error 52% of the time (and searched correctly just 41% of the time).

In short, children expect that adults will provide them with veridical information: They frequently weighted an adult's testimony more heavily than expectations based on naïve physics, or even than what they had just seen with their own eyes.

Symposium Discussant: *Susan Carey, Harvard University*

Rational Statistical Inference in Cognitive and Language Development
Organizer: Fei Xu, University of British Columbia
Summary: Researchers in cognitive development tend to be either nativists or empiricists. Nativists emphasize innate concepts and knowledge whereas empiricists emphasize learning mechanisms. This symposium presents a new approach to the study of cognitive and language development, integrating domain-specific prior knowledge and rational statistical inference mechanisms within a Bayesian framework. The four participants will present a set of papers illustrating how this approach has generated both new empirical findings and new computational models. Two of the participants, Xu and Denison, will present empirical studies on word learning, property induction, and infant statistical inference. The other two participants, Kemp and Griffiths, will present models of causal learning, word segmentation, and how learners acquire abstract causal schemata and semantic knowledge. We aim to go beyond the nature-nurture dichotomy by presenting a concrete proposal on how to integrate statistical information in the input with prior knowledge.

Rational statistical inference in word learning and property induction
Fei Xu, University of British Columbia

Research in language and cognitive development has discovered both powerful learning mechanisms and early concepts and knowledge in infants and young children. However, it remains unclear how statistical learning mechanisms interact with conceptual biases. I present two case studies illustrating how a Bayesian framework provides us with the tools for integrating

statistical information with prior knowledge. In the first set of experiments, we show how children and adults integrate their prior knowledge about words (e.g., count nouns tend to refer to kinds of objects) with input statistics (e.g., the number of exemplars and the perceptual span of the exemplars) in learning words at multiple hierarchical levels (subordinate-level, basic-level, and superordinate-level). In the second set of experiments, we show how children and adults' generalization of novel properties are modulated by a prior bias (i.e., some properties are generalizable but some are not) using the same statistical information as in the word learning studies. Together we provide evidence that the same statistical inference mechanism is employed in multiple domains but its application is modulated by prior biases.

Statistical inference in human infants
Stephanie Denison and Fei Xu, University of British Columbia

Two sets of experiments investigated whether basic statistical inference mechanisms are available in infancy so they may potentially guide learning later on, using a violation-of-expectation looking-time procedure. In the first set of experiments, we asked 8-month-old infants to generalize from a small sample to a larger population using basic principles of probability. For example, infants were presented with either 4 red and 1 white Pingpong balls or 1 red and 4 white Pingpong balls being pulled out of a box, and they were then shown a box filled with many red Pingpong balls and a few white ones. If infants can use basic principles of probability in this task, they would find the 1 red and 4 white Pingpong ball sample unexpected. Results showed that infants looked longer at the unexpected outcome. In a second set of experiments, we asked if 11-month-old infants were sensitive to whether the sample was a random sample from the box or not. Results showed that given random sampling, infants showed the same pattern of looking as the 8-month-old infants in the first set of experiments. But in the non-random sampling condition where the experimenter expressed a preference for a certain color balls then looked into the box while pulling out the sample, the looking time pattern was predicted by the experimenter's expressed preference and not by the proportions of red vs. white balls in the box. These studies suggest that basic statistical inference mechanisms may be available early in infancy.

Bayesian models as a tool for revealing inductive biases
Tom Griffiths, University of California at Berkeley

Many of the central problems in cognitive development - from making inferences about causal relationships to learning language - are inductive problems, requiring children to generalize beyond the observed data. Research in mathematical statistics indicates that one of the most important factors involved in successfully solving inductive problems is having appropriate inductive biases, limiting the set of possible solutions to those problems. Understanding how children make generalizations thus requires understanding their inductive biases. I will argue that computational models based on the principles of Bayesian statistics provide a tool for revealing the inductive biases of human learners. I will demonstrate the value of this approach through two case studies: analyzing the knowledge about causal systems that guides learning about blicket detectors, and examining how different assumptions about the nature of words determine the output of statistical models for extracting a lexicon from unsegmented speech. These case studies show how Bayesian models can be used to reveal the inductive biases that allow children to learn so much about the world from small amounts of data.

The acquisition of inductive constraints
Charles Kemp, Massachusetts Institute of Technology

Inductive learning relies critically on constraints, and psychologists have described many constraints that appear to guide children's learning. Most of these constraints are usually assumed to be innate, but hierarchical Bayesian models help to explain how some of these constraints can be learned. Hierarchical Bayesian models include representations at many levels of abstraction, and the representations at the upper levels can be viewed as constraints on the representations at the lower levels. The probabilistic nature of these models allows them to make inferences at many levels of abstraction. In particular, these models demonstrate how knowledge can be acquired at levels quite remote from the data of experience---levels where the learning problem amounts to the problem of learning inductive constraints.

The hierarchical Bayesian approach has been applied to problems from several different domains, including word learning, grammar learning, causal learning, and the acquisition of semantic knowledge. I will describe a model that learns causal schemata---systems of abstract causal knowledge that constrain inferences about sparsely observed causal relationships. I will also describe a model that discovers structural constraints on semantic representations. One such constraint is the M-constraint, which states that ontological knowledge is better described by a tree structure than a set of arbitrarily overlapping clusters.

The Function of Action in Perceptual and Cognitive Development

Co-Organizers: Jessica Cicchino and David Rakison, Carnegie Mellon University

Summary: Children are not passive observers of the world around them; rather, what they encounter and encode is dictated largely by the actions they produce. In recent years a substantial number of research programs have begun to recognize the role that experiences producing and observing action play in how infants and children interpret their surroundings. The goal of this symposium is to bring together the latest research regarding how these early action experiences shape the development of cognition in a variety of domains. To this end, the first two papers discuss the influence of infants' exploratory behaviors on their perception and integration of object features. The next paper explores how children equate their own actions with the actions performed by others and investigates how these experiences influence how children imitate. Finally, the last two papers consider links between infants' ability to produce actions and identify these same actions or motion types when performed by other people or entities.

Bringing together findings from a variety of areas within early cognition in which action experience bears on development will allow for consideration of multiple mechanisms by which early action and cognition are connected. Additionally, the research presented here will shed light upon the nature of action representations early in life and the origins of knowledge regarding objects, motion, and people. Thus, this symposium will result in a better understanding of how and why action experience influences cognitive and perceptual development.

The Relation Between Motor Development and Infants' Representation of the Surface Features of Objects

Lisa M. Oakes, University of California, Davis, and Sammy Perone, University of Iowa

Consider the following event: a hand reaches toward a round purple object, squeezes it, and then the object squeaks. What do infants learn about this event? There are several reasons why the surface features of the objects might be less salient than the action and sounds in these events; one possibility is that object appearance is intimately tied to the actions performed on the objects. Actions and object features are represented together in the human adult brain. We will present data revealing a developmental trajectory from 7-month-old infants representing only the sound and the action to 10-month-old infants representing the appearance as well as the sound and the action. At 10 months, infants link the actions to object appearances in this type of event—learning, for example, that purple objects are rolled and yellow objects are squeezed. Infants' sensitivity to object appearance may therefore be related to their developing motor skills. Indeed, we observed that between 6 and 7 months attention to the surface features of the objects was significantly related to infants' motor skills. When assessed in an object-exploration task, infants who were more effective at picking up objects, and who successfully picked up a wider variety of objects, represented object appearance in the multi-modal, dynamic events just described. Infants who were less motorically skilled failed to represent appearance. The possible bases of this relation, and potential mechanisms of development, will be discussed.

Object Exploration and Detection of Attribute Change in Infancy

Amy Needham and Klaus Libertus, Duke University

Object exploration is action in the service of learning about the attributes of an object: mouthing an object allows you to determine its texture; looking at an object allows you to determine its color (Gibson 1988). Infants' exploration of objects undergoes important changes over the first several months of life. For instance, Rochat (1989) showed striking changes in infants' exploratory behaviors over the first five months of life: two- and three-month-old infants tend to show relatively more oral exploration; four- and five-month-old infants show relatively more visual exploration. These changes should have consequences regarding which object attributes are detectable or salient to infants while they explore them, which should in turn have functional consequences for the attributes of objects that infants respond to. This possibility was investigated in the current research.

Using a method devised by Ruff (1984), 4-, 5-, and 7-month-old infants' detection of a change in either texture or color was assessed. A textured teether or colored spoon was presented to the infant on three consecutive trials, and on the fourth trial an object that was the same except for one attribute (the teether's texture; the spoon's color) was presented instead. Infants' visual and manual exploration time was measured and the percent change in the amount of exploration is shown above. Our results show that the younger infants, whose exploration is primarily oral in nature, showed a large increase to the change in texture. In contrast, the older infants, whose exploration is primarily visual in nature, showed a large increase to the change in color. Additional evidence of a control condition involving no change between trials three and four will also be presented.

These findings support the conclusion that infants' tendency to engage in oral or visual exploration of objects influences the information they obtain. In this sense, we can think of infants' visual and oral exploration as reflecting the aspects of the objects to which they have attended. Further, these results indicate that infants' decisions about whether to explore an object by mouth or by eye determines much about how they will perceive that object. Implications for perceptual-motor relations will be discussed.

Picky Imitators: 'Prior Experiences' of Self and Other Influence Children's Imitation

Rebecca Williamson and Andrew Meltzoff, University of Washington

Our recent research shows that preschoolers' imitation varies as a function of their own prior action experience. We showed that if children have had a difficult time with a task, they are more likely to adopt the distinctive action they observe another use. Here we investigate whether 3-year-olds also use another person's difficult prior experience as a guide to imitation. Can the prior difficulties of others substitute for the prior difficulties of the self in rendering children more open to learning and imitating novel acts they see?

The children (N=16) saw two experimenters each take a turn at completing a straightforward task (e.g. opening a drawer to get a toy). E1 either had an easy or a difficult experience with the task. E2 then modeled using a distinctive means (such as flipping a switch) to complete the task easily. When E1 had a difficult time with the task using ordinary means, children were more likely to imitate E2's novel action (M = 75%) than when E1 succeeded using ordinary means (44%). These preliminary results suggest that action imitation is not a blind process but is influenced by the prior experiences of both self and other. If children have a self-experience or observe from others that ordinary means are not efficacious, they are significantly more likely to adopt the novel means they observe. Human children are not blind imitators of action; prior experience influences what and when they imitate.

Producing and Processing Self-Propelled Motion in Infancy

Jessica Cicchino and David Rakison, Carnegie Mellon University

Self-propelled motion, or movement that begins without apparent external force, is a nearly irrefutable cue to animacy; by and large only people and animals, but not inanimate objects, are self-propelled. Because of the essential role that self-propelled motion plays in the development of early concepts of animates, there has been interest among researchers regarding the origins of the ability to recognize self-propulsion. In this talk we will explore the possibility that experience producing self-propelled motion by crawling influences infants' ability to process the self-propelled motion of other objects.

To investigate this issue, 5-, 6-, 7-, and 8-month-old infants were tested in a paradigm similar to that used by Markson and Spelke (2006) in which their preferential looking to self-propelled and caused-to-move objects was measured. Our results revealed that 5- and 6-month-olds attended to objects that engaged in a different type of motion than did 8-month-olds; crucially, the looking patterns of 7-month-olds with crawling experience paralleled that of older infants, and the looking patterns of non-crawling 7-month-olds mirrored that of younger infants. These findings indicate that infants' processing of self-propelled motion changes between 6 and 8 months of age and that the onset of self-locomotion is a factor that underlies this developmental progression. Furthermore, this discovery suggests that the close coupling between infants' action production and action perception may be more abstract than previously realized, as action experience in the current study facilitated perception of the movement of animated geometric shapes rather than the action of another person.

Acting and Understanding Action: Potential Developmental Relations

Amanda Woodward, Sarah Gerson, and Neha Mahajan, University of Maryland, College Park

Fundamental to human experience is the fact that we live in a world of perceived intentional agents. To adult eyes, the actions of others are not simply motions through space, but instead structured by goals, intentions, and perceptions. In the past decade, research has revealed that this aspect of social perception can be traced to early in the first year of life. Infants selectively attend to the goals of actions, responding more strongly to changes in actions goals than to changes in motion.

The existence of this ability early life raises the question of how it originates. Here, I consider the possibility that infants' own emerging ability to coordinate their actions in service of goals provides representational structure for the perception of others' goal-directed actions. Three kinds of evidence support this possibility. (1) There are correlations between infants' own abilities to produce goal-directed actions and their perception of others' actions as goal-directed; (2) Interventions that enable new modes of goal-directed action in infants also affect perception of those same actions in others; (3) Infants' analysis of others' actions as goal-directed is evident not only in their looking times, but also in their own overt actions. Taken findings indicate that infants' action analysis is rooted, at least in part, in their own experience as agents. The dramatic changes that occur in infants' motor competence during the first year are linked to developments in action perception.

<u>SATURDAY, October 27, 2007: 8:45 am– 9:45 Am</u>

Plenary Talk: Learning to Perceive to Learn
Rob Goldstone, Indiana University

Our concepts are at least partially based on the outputs of perceptual processing, but concept learning also has a reciprocal influence on the development of perceptual features. Rather than viewing the "vocabulary" of perceptual primitives as being fixed, this view maintains that the vocabulary is dependent on categorization demands. Two apparently opposed mechanisms of conceptually induced perceptual learning are unitization and differentiation. Unitization creates a single perceptual chunk for a complex assembly of stimulus components, whereas differentiation isolates originally fused perceptual dimensions. These mechanisms are reconciled in a neural network model that incrementally creates perceptual detectors based on categorical (supervised) and statistical (unsupervised) information. Empirical results from perceptual learning experiments in infants and adults are interpreted in light of this model. The implication of the model and surveyed experiments is that we create perceptual detectors from our experience with the world, and then use combinations of these detectors to shape our experience of this same world.

<u>SATURDAY, October 27, 2007: 10:15 am– 12:30 pm</u>

Presidential Symposium: Children's Learning
Organizer: Henry Wellman, University of Michigan
Summary: Children's learning is a classic topic for scholars of cognitive development (see e.g., Stevenson's 1973 book *Children's Learning*). In the last 15 years it has re-emerged as an exciting contemporary topic as well. Infants, children, as well as young and old adults all learn on their own, from others, and in the classroom. Cognitive structures impact learning, learning impacts cognitive structures, and for some topics, perhaps, the story of cognitive development becomes the story of accumulated learnings. The presenters in this symposium include leading voices in the field who will present theory and data about crucial issues and topics for understanding children's learning.

There's Nothing As Practical As a Good Theory
Robert S. Siegler, Carnegie Mellon University

Theoretical analyses of the development of numerical representations suggest that playing linear number board games, akin to Chutes and Ladders, should enhance young children's numerical knowledge. Consistent with this prediction, playing such a game for roughly one hour increases low-income, urban preschoolers' proficiency on a diverse set of numerical tasks: numerical magnitude comparison, number line estimation, counting, and numeral identification. The gains remain present nine weeks later and are equally strong for African-American and Caucasian children. Playing an identical game, except for the squares varying in color rather than number (akin to Candy Land), does not improve performance on any measure. Moreover, preschoolers' amount of home experience playing number board games is positively correlated with their numerical knowledge, whereas their experience playing card games and video games is not. Thus, playing numerical board games with children from low-income backgrounds appears to increase their numerical knowledge and helps them start school on a more equal footing with classmate from more affluent backgrounds. The more general theoretical and practical gains that can be realized through integrating information processing and socio-cultural approaches to cognitive development and learning will also be discussed.

Learning by expecting: The role of statistical learning in infant language processing
Jenny Saffran, University of Wisconsin

One way that learners discover structure in complex environments is to track statistical regularities in the input. How is this information actually used, in particular how is it used for language learning given the demands of language processing? This talk will explore the hypothesis that like adults, children, and some classes of computational models, infants exploit such regularities by making predictions about what will occur downstream while listening to language input. These predictions facilitate rapid processing, may spur subsequent learning, and suggest continuity between the mechanisms used for language learning and the mechanisms used for language processing.

Twisting the Lion's Tail: Exploratory play and children's causal learning
Laura Schulz, MIT

Despite almost universal agreement that children learn causal relationships through exploratory play, little is known about how children's play might support accurate causal learning. Children are poor at designing informative experiments and there has been little evidence for any systematic patterns in exploratory behavior. Here I suggest that, although the particular actions children take in exploratory play are quite noisy, children's spontaneous exploration is nonetheless consistent with rational principles of inductive inference. I will discuss several studies suggesting that there is a systematic relationship between children's prior knowledge, the evidence they observe, and their spontaneous exploratory behavior. In particular, I will suggest that children tend to engage in more exploratory play when the interpretation of evidence is ambiguous. Thus even though children's particular exploratory actions are unsystematic, they often spontaneously generate evidence that could support accurate causal learning.

Learning, Development, Primary Processes, and Secondary Processes: Discussion
David Klahr, Carnegie Mellon University

A symposium entitled "Children's Learning" must confront the venerable and vexing issues surrounding the difference between learning and development, and between what David Geary has provocatively defined as "primary" vs. "secondary" processes. Are the early forms of statistical learning described by Saffran, or the impressive achievements in causal reasoning described by Schulz, examples of primary or secondary processes? Are they instances of development or of learning? Are the processes that enable children in Siegler's studies to make substantial advances in their numerical knowledge after a brief period of play with a carefully crafted board game based on primary or secondary processes? A second, but perhaps related puzzle in all of this is why the early acquisitions are poor predictors of later learning in more conventional instructional contexts. For example, my own research raises the question of why the early acquisition of causal understanding reported by Schulz and colleagues doesn't seem to manifest itself when children first begin to attempt to create simple, unconfounded experiments in science classes.

SATURDAY, October 27, 2007: 2:00 – 3:45 pm

Cognitive Developmental Perspectives on Social Categorization and the Implications for Intergroup Bias

ORGANIZER: Andrew Baron, Harvard University

SUMMARY: Cognitive developmental approaches to social categorization have traditionally emphasized Piagetian assumptions of stage-like development, domain-general categorization, and egocentrism. In this symposium, we go beyond these early formulations by specifying crucial roles for linguistic labeling and domain-specific aspects of categorization, with an aim towards revising theoretical models of social categorization and demonstrating the implications of these models for intergroup bias.
Bigler and Dunham will offer complementary perspectives on the psychological consequences of categorizing others as belonging to outgroups. Each will focus on the ways in which categorization divides social space into ingroups and outgroups revealing developmental changes in the ability to integrate information about self and other (Bigler) and developmental stability in rapidly-emerging mechanisms of ingroup-favoritism (Dunham). Heyman will expand the focus by exploring the broader implications of labeling on stereotyping in the social domain. Finally, Baron will help to flesh out the unique features of this domain by focusing on the necessary and sufficient conditions for the acquisition of inductively rich social categories. As a pioneer in bringing cognitive developmental methods and theories to bear on issues of social categorization and inductive reasoning, Gelman is uniquely situated to integrate the conceptual issues raised by these new findings and will serve as a discussant on this symposium.
The established and emerging researchers in this symposium are accumulating new evidence which challenges existing theory and pushes us towards a new understanding of social categorization and its implications for intergroup bias.

Cognitive-Developmental Perspectives on the Coordination of Knowledge about the Self and Social Groups
Rebecca S. Bigler, University of Texas at Austin, and Meagan M. Patterson, University of Kansas

Categorization appears to play a central role in the process of social stereotyping and prejudice. As many theorists have noted, the development of social stereotypes may reduce the cognitive load inherent in processing category members as individuals. Individual humans are, however, themselves members of particular social categories. Social categories are unique, therefore, in that the cognitive representation of some (but not other) groups is inclusive of the self. How do children integrate their knowledge and beliefs about the self with those concerning social categories? What cognitive limitations might constrain the process? In a series of studies, we have used field experiments in which children are assigned to novel social groups to address questions

concerning the etiology of ingroup identification and intergroup attitudes. In these studies, children from a variety of ages are randomly assigned to novel social groups (e.g., "red" or "blue" groups) in their classrooms. The characteristics of these groups and, in some recent work, characteristics associated with the self are manipulated. After several weeks, children's views of themselves and others (i.e., trait evaluations, peer preferences, helping behavior, etc.) are assessed. In the proposed talk, we will summarize the findings from these studies and argue that children's ability to integrate information about the self and others changes across ages, and has important implications for social stereotyping and self views.

The Power of Membership: Minimal Group Biases in Childhood
Yarrow Dunham, University of California, Merced

Like categories of every stripe, social categories provide a means of placing an entity among relevantly similar others in support of inductive inference. However, social categories are a special case, as the entities involved often include the self, making social categorization particularly relevant for ongoing processes of self-definition and identity development. At the most basic level, this is as simple as establishing an ingroup/outgroup dichotomy based on a given property. Generally, the social categories we care about are based on properties we care about, such as biological distinctions (gender), ideological commitments (protestant, democrat), and facts about our history (nationality). The significance of social categories is commonly thought to be derived from the importance of these defining properties; however, this view is challenged by Tajfel's minimal group work demonstrating that even social groups based on trivial properties rapidly cause intergroup polarization. I present research from two lines of inquiry providing strong evidence for early-emerging minimal group effects in children. With respect to both familiar and novel social groups, children manifest ingroup preference as soon as or soon after they acquire the ability to categorize along a given dimension. What's more, ingroup preference appears across a wide range of measures, including traditional self-report preferences, implicit attitudes, resource allocations, behavioral expectancies, and systematic memory biases. Taken together these effects constitute an elaborate set of ingroup-favoring learning biases which could powerfully constrain further learning about groups, potentially supporting the rapid emergence and entrenchment of real-world bias.

Noun Labels and Social Reasoning
Gail Heyman and Cristine Legare, University of California, San Diego

Nouns typically identify context-independent kinds (Gelman, 2003) that point to deeper commonalities (Waxman, 1999). Previous research suggests that when noun labels are applied to people (e.g., 'carrot-eater') they imply stability (Gelman & Heyman, 1999). We will present recent research that builds upon this finding.

In a study of 80 8- to 12-year-olds examining the practical implications of labeling, we described characters' performance either with or without the use of nominalized descriptors such as 'math whiz.' Children in the labeling condition were more likely to attribute the characters' skill to innate ability and to predict that it would persist even in the absence of further practice, which corresponds to a conception of ability that has negative implications for achievement motivation (see Dweck, 1999).

In other research we are examining beliefs about when it is appropriate to describe people in terms of compound nouns (e.g. refer to a girl who spends time using telescopes as a 'telescope girl'). Results indicate that adults are more likely to view compound labels as appropriate when the associated activity is unique within the peer group, frequent, or enjoyable on the part of the individual being described. We are also finding that children as young as age 4 are more likely to view the use of compound labels as appropriate when the individual enjoys the activity, even after controlling for frequency. Taken together, these results suggest that the use of noun labels promotes a broad range of psychological inferences and helps to define human kinds.

Foundations of Social Categorization
Andrew Scott Baron, Harvard University

Recent research in cognitive development has revealed domain-specific constraints on the properties that are privileged during the categorization of living things (e.g., biological origins) and artifacts (e.g., intended function; Keil, 1989). Given the important developmental challenge of identifying social categories and the properties they project (e.g., behaviors, traits, preferences), it is surprising that few studies have explored constraints on social categorization (but see Deisendruck & laHavie, 2006). The present research seeks to understand how children acquire representations of social groups by asking whether there are limits on the properties that can define inductively rich social groups.

Across five experiments, participants (3-5-year-olds, 6-8-year-olds, adults) were introduced to two novel social groups in a picture book. Participants observed two individuals from one group behave in an anti-social manner, and were then asked to make inferences about new behaviors performed by new members of each group. We examined whether participants' inductive inferences were constrained by the property defining the group (e.g., biological properties such as skin color, non-biological properties such as hat color, the use of noun labels vs. proper names, and whether participants were asked to identify with one group over the other). We also explored whether these potential constraints undergo changes across development. Results

provide evidence for distinct necessary and sufficient conditions for social categorization while also revealing the rapid acquisition of social category concepts at all ages tested. These data also provide important insights into the relationship between categorization processes specific to social groups and the development of stereotypes.

Discussant: *Susan Gelman, University Of Michigan, Ann Arbor*

The Role of Comparison in the Development of Relational Representations and Structured Thought

Organizer: Leonidas Doumas, Indiana University

Summary: The ability to comprehend and reason about relations (i.e., relational thinking) is central in human cognition. Relational thinking includes reasoning about higher order relations (e.g. causal, similarity, contrasting) or specific relations (e.g. bigger, above, chasing). Relational thinking is powerful because it is structured, which allows the generation of inferences and generalizations that are constrained by the roles that elements play, rather than strictly the properties of the elements themselves. The role of relational comparisons in learning is emerging as an important area of developmental research. Relational comparisons allow learners to derive symbolic, abstract, and conceptual knowledge representations that are generative, in that children can then use them broadly in new contexts to reason about new elements. Thus relational comparisons can operate as agents of development. Acquired knowledge representations then also act as a second mechanism of development, since with greater knowledge, children can perform more sophisticated relational reasoning.

This symposium brings together researchers examining the productive interplay between learning and relational reasoning. Gentner, Christie, and Namy explore the benefits of various different organizations of relational comparisons, including the role of linguistic labels. Opfer, Furlong, and Bulloch describe the effects of relational comparisons on future generalizations. Doumas describes a computational theory of how comparison fascilitates the learning of novel relational concepts. Ankowski and Sandhofer examine the efficacy of comparison in various learning situations. Rittle-Johnson and Star examine relational comparisons in learning for mathematical concepts. Finally, Richland considers the interplay between acquisition of knowledge representations and children's developing processing capacities.

Comparison in relational learning

Dedre Gentner, Northwestern University; Stella Christie, Northwestern University; Laura Namy, Emory University

Comparison processing has been implicated in the development of relational thought. Our research investigates the generality of comparison as a learning mechanism and the specific processes by which comparison fosters learning. These include learning by abstracting common relational structure from a comparison and learning via progressive alignment - from close literally similar pairs to more distant abstract analogs. We have also found that common linguistic labels can foster relational comparison, thereby promoting relational insight. In Study 1, 3-year-olds watched as we labeled a novel spatial relation, either exemplified with a single standard or with two standards side-by-side. Children who compared two standards were more likely to extend the label to another item with the same spatial configuration than were those who saw only one standard, suggesting that comparison promoted attention to the common relation.

Study 2 showed that 4- and 6-year-olds who received relational labels were better at learning a relational concept than those who simply saw the same two analogous exemplars without labels. However, 3-year-olds were unsuccessful in both conditions. In Study 3, we gave 3-year-olds the same relational concepts using a progressive alignment from close pairs to the same far analogs that were used in Study 2. The 3-year-olds who received a combination of progressive alignment and relational labels during training were able to successfully learn the relation. In sum, we find that comparison can reveal common relations; that common labels promote this process of comparing and abstracting; and that for early learners, progressive alignment can accelerate relational learning.

What makes relational reasoning so smart?

John E. Opfer, Ellen E. Furlong, and Megan J. Bulloch, Ohio State University

Representations of relations are often celebrated for their positive effects on generalization (e.g., ignoring superficial similarities), but relational representations may also have negative effects. To examine this, we investigated development of relational reasoning on two relational-match-to-sample tasks in domains of biology (Study 1) and number (Study 2).

In Study 1, participants (3-, 4-, 5-year-olds, and adults) generalized novel information on two types of problems—offspring problems, where relational matches yielded accurate generalizations, and prey problems, where perceptual matches yielded accurate generalizations. On offspring problems, we replicated prior findings of increasing relational matches with age. However, we observed decreasing relational matches on prey problems. These findings suggest that the relational shift commonly observed

in analogical reasoning may reflect a general increase in children's sensitivity to reliably accurate information rather than an overall preference for generalizing over perceptual similarity.

To examine this issue further, Study 2 tested how well children ignored perceptual similarity when asked to generalize the hidden location of an object, where relational matches yielded accurate generalizations. We again found relational information allowed preschoolers to ignore perceptual similarities. Representations of spatial-numeric relations, however, had a cost for the youngest children in particular: spatial-numeric associations appeared to be so automatic that learning was impeded when numerical relations failed to fit children's prior representations.

Taken together, results from Studies 1 and 2 suggest that what develops in relational reasoning is not a freedom from the bonds of perceptual similarity but an increase in the sensitivity to which relational similarities are—and are not—reliable.

A computational model of the development of structured relational representations
Leonidas A. A. Doumas, Indiana University

Traditional connectionist models based on distributed representations provide a good account of younger children's reasoning based on whole-object similarity, but do not account well for later relational thought. Alternately, systems based on structured relational representations provide a good account of older children and adult's relational thought, but provide no account of where the relational representations come from in the first place. However, while we can account for the behavior of both younger and older children, we cannot account for how the ability to reason relationally develops.

DORA (Discovery Of Relations by Analogy) is a symbolic connectionist network that uses time as a signal to dynamically bind distributed (i.e., connectionist) representations of relational roles and objects into explicitly relational (i.e., symbolic) structures. DORA relies on the processes of comparison, analogical mapping and intersection discovery to highlight shared abstract properties between separate systems and subsequently predicates these similarities as explicit (i.e., symbolic) properties of the systems. These processes permit the discovery and predication of shared properties and relations across otherwise different systems and thus bootstrap the discovery of relational structure from unstructured examples. We propose that DORA's learning mechanism provides an account of both analogical development as well as the transition from similarity to category-based induction.

The Effect of Stimuli Features on Children's Ability to use Comparison and Contrast for Category Acquisition
Amber N. Ankowski and Catherine M. Sandhofer, University of California, Los Angeles

A large body of research has demonstrated that viewing multiple examples leads to better performance on a variety of tasks acrosss a variety of measures. However the specific situations in which comparing or contrasting multiple exemplars is effective for category acquisition has not been investigated. Comparison entails simultaneously viewing two or more examples that are similar in some relevant dimension (e.g. comparing two red things), while contrasting involves viewing two or more examples that differ in a relevant dimension (e.g. contrasting a red thing with a blue thing). The current studies examined whether children's ability to learn through comparison or contrast is affected by the concept children are learning and the specific examples they are viewing. The studies presented in this talk systematically examine the efficacy of comparison and contrast 1) in learning categories versus relations and 2) when the stimuli do and do not vary in ways that are irrelevant to the concept to be learned. As a whole the studies reveal that the specific features of stimuli presented affect children's ability to use comparison and contrast for category acquisition. Importantly, the results of these studies show that contrast in at least one dimension is essential for children to learn a new category. The current studies also suggest an explanation for discrepancies in previous research regarding the relative effectiveness of comparison and contrast for category acquisition. The results suggest that comparison and contrast are not always powerful tools for learning, but instead their effectiveness is situational.

When it pays to compare: Benefits of comparison in mathematics classrooms
Bethany Rittle-Johnson, Vanderbilt University; Jon R. Star, Michigan State University

Comparison is emerging as a fundamental learning mechanism and an important teaching approach. We have identified and combined key findings on comparison from research in cognitive science and mathematics education that might facilitate three key learning outcomes in mathematics - procedural transfer, procedural flexibility and conceptual knowledge. One series of experiments focuses on seventh- and eighth-grade students learning to solve equations (e.g. $2(x - 3) = 8$). A second experiment focused on fifth-grade students learning about computational estimation (e.g. About how much is $27 * 48$?). Having students compare multiple solutions to the same problem, rather than studying the same solutions one at a time, led to greater procedural transfer and flexibility (and comparable conceptual knowledge) across the experiments. A recent experiment is exploring how different types of comparison impact learning, such as comparing isomorphic problems with the same solution method vs.

different solution methods to the same problem (as in our original studies). Preliminary findings suggest that condition interacts with prior knowledge. Although there is general agreement that comparison facilitates learning, attention to what is being compared and by whom is critical to understanding comparison and to facilitating mathematics learning.

Learning and Processing in Children's Development of Analogical Reasoning
Lindsey E. Richland, University of California, Irvine

Children's comparative reasoning skills improve with age. I will describe a series of studies that use picture analogy tasks with children ages 3 to 11 to explore the mechanisms behind this development. Existing findings show that children's comparative reasoning improves in two ways: ability to identify and compare increasingly multi-part, complex relations, and the ability to reason relationally in spite of salient, irrelevant distraction. The series of studies I'll describe investigated the relationships among children's knowledge acquisition, developing working memory, and developing attentional control on these known patterns of comparative reasoning development.

Overall, two studies of U.S. children and two cross-cultural studies suggest that in spite of theoretical arguments that propose one or the other, all three factors are crucial. Further, the relationship between these factors follows predictable patterns. We find that the ability to handle complex relations relies upon developing working memory capacity but is moderated by knowledge acquisition, while maturational processes for controlling attention seem to constrain comparative reasoning over and above the effects of learning.

To Model or Not To Model—Is That a Central Question?
Organizer: Vanessa Simmering, University of Iowa
Summary: Computational models have played a substantive role in the study of cognitive science for decades. Within the domain of cognitive development, however, formal models are still relatively uncommon. In part, this reflects the unique challenges of modeling developmental process: models must change over multiple time scales, and they must be exquisitely sensitive to variability, to context, and to past history. In the last decade, several theoretical frameworks (e.g., connectionism, dynamic systems theory) have demonstrated that they can effectively tackle the unique challenges of development. This raises the central question of this symposium: should the field of cognitive development embrace formal models of development? If so, how do we balance the potential costs and benefits of computational models with the long, productive history of rigorous empirical work motivated largely by conceptual theories?
To evaluate these questions, this symposium brings together both modelers and non-modelers from two research domains—visual cognition and social cognition. In recent years there have been rapid developments in these domains on both theoretical and empirical fronts. Thus, these fields provide rich material for exploring the benefits and drawbacks of using computational models to understand cognitive development. The inclusion of speakers from separate domains emphasizes the generality of the issues at hand. To conclude, the discussant will synthesize the arguments presented by the four speakers, and discuss how these perspectives may impact future research in cognitive development.

Development of Visual Cognition: No Pressing Need to model Results of Shape-specific Scale Error Studies
Peter Vishton, Natalie H. Brito, and Kaitlin L. Brunick, College of William & Mary

Science progresses by collecting observations, developing theories to explain the observations, and refining theories on the basis of additional observation. In developmental science, theories have typically been presented in the form of prose descriptions. Computational models (CMs) provide an alternative, more precise language for stating theories. In any CM, the sources of relevant information and the methods of processing that information are formally stated and operationalized. The predictions made by a CM are also more specific, making theories easier to evaluate and, when appropriate, falsify. This property can lead to a shorter cycle of theory refinement. However, CMs require more start-up costs and can obfuscate simple results within the complexity of the model itself.

We will consider this in the context of results in the domain 2.5-year-olds' "scale errors": actions that are appropriate to the shape of objects but inappropriate to their size. For instance, children at this age may attempt to put a doll-sized shoe on their foot or step into a miniature toy car. In our studies, after children reached for a small cylinder with one hand, they were significantly more likely to reach for a large version of the cylinder in the same way. If the size change was accompanied by a shape change, however, children more frequently engaged in an appropriate two-handed reach. A CM could be developed to account for this phenomenon, but it seems unlikely to enhance our understanding of it, at least at this stage of experimentation.

A Theoretical Framework for Modeling the Development of Visual Cognition

Vanessa R. Simmering, John P. Spencer, and Evelina Dineva, University of Iowa

Human behavior demonstrates remarkable associative abilities – we can associate multiple features to form objects (the shape and color of a banana), associate objects with labels (learning new words) and actions (using chopsticks), even associate objects with locations (finding a spoon in someone else's kitchen). How are such associations built up from experience, and what type of real-time, embodied system would allow such associations to form quickly and efficiently? In our talk, we will present a theoretical framework—the dynamic field theory—that confronts the dual challenges of driving the behavior of a real-time, embodied system and forming novel associations quickly over time. Critically, this framework has shed new light on seemingly disconnected findings—from the use of space to associate objects and labels separated in time, to the formation of imitative tendencies by associating actions with object features. These examples highlight one of the key features of formal theories—the integration of disparate observations.

We will also discuss a second key feature of formal developmental theories—to shed light on what is developing. On this front, our emphasis on the real-time details that bring together perception, action, and cognition place strong constraints on proposals about developmental change, revealing that a relatively simple developmental change—an increase in the precision and stability of neural processes—can do a great deal of developmental work. We conclude by taking the stance that development may simply be too complex to understand without formal theories. That said, such understanding can only come by balancing the strengths of clever, novel experimentation with systematic theory development and model testing.

Development of Gaze Following and Joint Visual Attention

Chris Moore, Dalhousie University

Gaze following or joint visual attention is a fundamental aspect of the triadic or object centered interactions that characterize infant social behavior during the latter half of the first year. Gaze following in infants has been studied in three main ways. First there have been manipulations of the gaze cues that infants are exposed to. Second, there have been manipulations of the spatial layout of targets in relation to the environment. Third, there have been manipulations of target type and salience. Results reveal a protracted developmental pattern from about 6 to 18 months. Young infants follow gaze primarily on the basis of head turns only when salient targets are fully in view. Infants gradually learn the significance of eye direction and become able to follow gaze even when targets are hidden or absent altogether. A review of existing research on gaze following suggests that a developmental account based on the entrainment of visual spatial attention and the learning of the predictive value of gaze cues in relation to possible target locations is most consistent with the overall pattern of results in this literature. As this empirical review shows, we've made substantial advances in our understanding of the development of gaze following through rigorous experimentation with parents and infants. I will conclude my talk by looking to the future to evaluate how far this empirical approach can get us and what computational modeling might (or might not) add to the mix.

Modeling the Development of Gaze Following

Jochen Triesch, Hector Jasso, and Gedeon O. Deak, University of California-San Diego

Despite a long history of empirical research, central questions about the development of gaze following have remained unanswered. Why do infants learn to follow gaze? What causes the improvement of gaze following ability with age? What do various competence levels in gaze following reveal about the infant's understanding of the intentional and referential nature of other people's looking behavior? While computational models will not be able to settle these questions, we think that they can provide an important contribution to the discussion. We will illustrate this by discussing recent efforts to model the development of gaze following with a biologically plausible reinforcement learning model. This model can qualitatively account for many of the behavioral findings. At the same time, it makes a number of novel and interesting predictions, such as the existence of a new class of mirror neurons for looking behaviors. It bridges time scales from seconds (individual gaze shifts) to years (development of gaze following) and explains the observed behavioral change in terms of underlying changes to the neural substrate, offering a parsimonious account of a specific aspect of infant social development.

Questions in Development: The View from Cognitive Science

Discussant: *Rob Goldstone, Indiana University*

NEW DIRECTIONS IN PRETEND PLAY RESEARCH

ORGANIZER: Deena Skolnick Weisberg, Yale University

SUMMARY: Young children spend much of their time engaged in pretend play with objects and situations they know are not real. Far from being a frivolous activity, pretense is a fundamental part of children's cognitive development; indeed, its absence is a diagnostic signal for autism. There are many links between pretending and other cognitive skills, including theory of mind understanding, counterfactual reasoning, and general representational abilities, but these links are as yet poorly understood. The three talks in this symposium explore these issues by describing the various forms that pretense can take and by investigating the crucial functions that pretense can serve in development.

The symposium participants have many years of experience in researching pretend play from a variety of theoretical backgrounds. Marjorie Taylor's and Alison Shawber's groundbreaking research has illuminated children's relationships with their imaginary companions and the cognitive and social underpinnings of these relationships. Karen Neary, Ori Friedman, and Alan Leslie study the mechanisms behind pretense. Their current research investigates how children interpret the characteristic speech patterns in pretense, expanding our knowledge of how children comprehend and produce pretend acts. Judy DeLoache is best known for her work on children's understanding of maps and scale models, but her recent work on children's scale errors raises questions about the nature of children's representational abilities in realistic and pretend contexts. These three talks will be followed by commentary from Deena Skolnick Weisberg, whose research focuses on the unexpected and nuanced cognitive structures that underlie pretend play behavior.

THE DISTINCTION BETWEEN ROLE PLAY AND NON ROLE PLAY PRETENDING IN PRESCHOOL CHILDREN

Marjorie Taylor & Alison B. Shawber, University of Oregon

Pretend play includes diverse behaviors ranging from simple acts of object substitution in which a block stands for a car to elaborate superhero scenarios. Individual differences in pretend play have important connections with social and cognitive development, but it is challenging to interpret the diverse findings in this area. One problem is that there is no widely used assessment that captures the distinctions considered to be important in current theories of imagination. The research to be presented here was guided by Harris's (2000) theory distinguishing role play in which children imagine and act out the part of another person or creature from non role play pretending.

In this study we streamlined a procedure for coordinating parent and child interviews about (1) personified objects in which the child creates a role that is projected onto a toy, (2) pretend identities in which the child acts out an imagined character using the self as a vehicle, and (3) invisible friends in which the child interacts with a character but does not rely on environmental support. We also included a new behavioral role play task and an assessment of non role play pretending. The results with 200 preschool children suggest that non role play and role play pretending have distinct roles in development. Non role play pretending correlates with age and verbal comprehension, suggesting its connection to symbolic development, whereas role play correlated with children's ability to generate an imagined conversation and other variables related to their interest and engagement in social interaction.

TESTING BETWEEN MENTALIST AND BEHAVIORAL ACCOUNTS OF PRETENSE: EVIDENCE FROM PRESCHOOLERS' INTERPRETATION OF PRETEND-SPEECH

Karen R. Neary, University of Waterloo, Ori Friedman, and Alan M. Leslie, Rutgers University

Are young children mentalists or behaviorists about pretense? The mentalist account holds that children represent pretense via the mental state concept PRETEND. Behavioral accounts claim children lack this concept and instead view pretense as a kind of behavior, 'behaving-as-if'. The accounts differ in their predictions about how children interpret pretend sounds. Suppose, mother makes chewing sounds while 'feeding' a doll. How will the children interpret the sounds? If they are mentalists they will represent: mother PRETENDS the doll makes the sounds. But children will be challenged if they are behaviorists about pretense: When making the chewing sounds, mother does not behave-as-if the bear is eating, instead she behaves-as-if she were eating.

As the above example shows, behavioral accounts have difficulty explaining children's ability to represent pretend sounds as coming from counterfactual sources (from the bear rather than from the actor). But do children really have this ability? We investigated this question, thereby testing between mentalist and behavioral accounts. Children listened to requests, some spoken normally (no pretense) and others in a high-pitched voice with the pretense that a teddy bear was uttering them. To correctly fulfill the requests, children had to represent the normal utterance as the actor's, and the high-pitched utterances as originating

from the bear. Children succeeded at ages two and three. These findings suggest that young children are mentalists, not behaviorists, about pretense.

Dual Representation in Pretense and Scale Errors
Judy S. DeLoache, University of Virginia

Dual representation is an important aspect of young children's interaction with symbolic objects and in particular their interaction with replica toys. It involves mentally representing a given object in two different ways at the same time.

In pretend play with replica objects, the young child manipulates an object as if it were something other than what it actually is. A toy bottle is carefully inserted into a doll's mouth as if it contained milk and the doll could drink. Such play depends on dual representation: While pretending, the child has in mind a real baby and bottle, and knowingly/intentionally uses the toy "as if" it were something other than itself.

In the commission of a scale error, young children also interact with miniature replica objects as if they were larger objects. However, scale errors involve serious attempts to use miniature objects as if they were their real counterparts. Crucially, the child actually tries to get into a miniature car or to sit on a tiny chair. Thus, scale errors involve a failure of dual representation, with the child's actions based on his or her mental representation of the real one.

The research to be presented includes a study directly comparing the nature of 18- to 30-month-olds' behavior in the spontaneous commission of scale errors with children's behavior when instructed to pretend with the same replica objects. The nature of the behaviors—in which dual representation serves very different roles—are markedly different.

Commentary: Future Directions for Pretend Play Research
Deena Skolnick Weisberg, Yale University

The three talks in this symposium explore the many ways in which children engage in representational pretend play as well as links between this behavior and other aspects of cognitive development. In this commentary, I aim to draw out several common threads from these research projects. All three talks rely on pretense being a representation of events that are not real. What is the nature of this representation? How do children view their own pretend activities, and how should their beliefs be taken into account in a theoretical analysis of pretend play? Also, how should pretense be understood theoretically? To what extent is it the expression of a basic mental state concept as opposed to just a behavioral sequence?

I will also connect the issues raised in these talks to other topics in cognitive development. For instance, pretend play is not the only form of play; children also explore objects playfully and engage in a variety of reality-based play activities. How do these different types of play relate to each other? Additionally, it would be interesting to explore whether the cognitive and social skills gained via pretense generalize into the child's life beyond the play context. Finally, what are the relationships between the kinds of representations deployed in pretend play and the representations that children may use to make causal inferences and to understand other minds?

Knowing About Ignorance: Children's Judgments and Nonverbal Behavior in the Face of Uncertainty
Organizer: Elizabeth Robinson, Warwick University, UK
Summary: The goals are to (i) move beyond established finding that children are more inclined than adults to over-estimate the knowledge gained from limited information, and (ii) raise interesting questions for discussion, concerning the processes underlying developmental differences in awareness of uncertainty. The topic is intrinsically important, since accurate monitoring of one's own uncertainty seems crucial for effective deliberate acquisition of knowledge. Additionally, the research has wider implications for accounts of implicit vs explicit understanding, the concept of realist errors, and our understanding of children's perspective-taking skills.

The set of participants, representing three countries, is appropriate because their presentations have an overall coherence while each makes unique points: Papers 1 and 2 examine how children's explicit judgments of certainty become adult-like. Paper 1 shows increasing concordance between objective uncertainty and subjective judgments, about guesses, deductive and inductive inferences. Paper 2 shows age-related change in apparently illogical behavior: Certainty ratings by both children and adults discriminate between events that are objectively equally uncertain, but discriminate in opposite ways. Papers 3 and 4 question whether children's inappropriate denials of uncertainty are in line with sensitivity to alternative possibilities. Paper 3 contrasts judgments and acknowledgment of possibilities about ambiguous figures and ambiguous utterances. Paper 4 contrasts children's explicit judgments with measures of implicit awareness.

Together the papers demonstrate that a complete picture of children's understanding of uncertainty, needs to include evidence

from events with different objective and subjective levels of certainty, and to contrast children's metacognitive evaluations with explicit and implicit acknowledgment of possibilities.

Children's Evaluation of the Certainty of Inferences
Bradford Pillow, Northern Illinois University

The first set of experiments included participants from kindergarten through fourth-grade and adults. It investigated recognition of differences among deductive inferences, inductive inferences based on strong or weak evidence, and guesses based on some or no evidence. Participants made inferences and guesses about the color of a hidden toy, then rated their certainty about their conclusion and explained how they reached it. Results indicated a gradual differentiation among deduction, induction, and guessing, although only adults distinguished between strong inductions and weak inductions. By fourth grade children gave appropriate explanations for conclusions reached by deduction or induction.

The second set of experiments, with participants from kindergarten, 1st-, 3rd-, and 4th-grades, assessed recognition that another person's level of certainty about an induction conclusion may (i) vary according to the strength of the supporting evidence, and (ii) contrast with what the child knows to be true. Children observed a puppet make strong inductions, weak inductions, or guesses about a hidden object, and rated the puppet's certainty in its conclusion. Children knew what pattern of evidence was available to the puppet and whether the puppet's conclusion was correct or incorrect. Younger children tended to base certainty ratings on the correctness of the puppet's conclusion rather than on the strength of the evidence available to the puppet. Children have difficulty applying their understanding of inferential reasoning when evaluating the thoughts of another person who does not share their perspective.

Children prefer to guess about determined rather than undetermined outcomes
Elizabeth Robinson, Warwick University, UK

Children's over-estimation of knowledge in the face of uncertainty is well-documented. Typically in this research, the state of affairs about which children are ignorant, but judge they know, already exists. We confirm over-estimation of knowledge in such circumstances, but show that it is ameliorated for an outcome yet to be determined. In Experiment 1, 5- to 6-year olds (N = 88) judged how sure they were about (i) which of one two toys the Experimenter had hidden behind his back, or (ii) which one of the two he was about to pick from a bag. Children rated themselves as more sure in condition (i), mean score 3.25 out of 5, than in condition (ii), mean score 2.66 (p = .03). In Experiment 2, children indicated whether they preferred to guess the outcome of the fall of a die before it had been thrown, or after it had been thrown but remained hidden. Five- to 6-year-olds (N = 64) strongly preferred to guess after the die had been thrown (p = .004), suggesting that they felt more sure what the outcome was in that condition.

The results suggest that children's knowledge that there is something to be known, makes it particularly hard from them to realise that it is unknown to them.

Interestingly, in a paper-and-pencil version of the die-fall prediction task, adults showed the opposite pattern, preferring to guess before the die was thrown. This is in line with the literature on adults' gambling preferences. We discuss possible developmental accounts

What can ambiguous figures tell us about children's understanding of uncertainty?
Sarah Beck, Birmingham University, UK

Five- year- olds experience the phenomenon of ambiguous figure reversals, where a picture appears to flip between two interpretations, e.g. a duck and rabbit (Gopnik & Rosati, 2001) and they find it easy to give an alternative interpretation of ambiguous figures (Doherty & Wimmer's production task, 2005). These figures may offer 5- and 6- year olds an easy way in to acknowledging uncertainty about how ambiguous input should be interpreted. In Experiment 1 we used the production task: Children had to give an alternative interpretation to that given by the Experimenter. This was as easy with ambiguous messages as with ambiguous figures. It was much more difficult for children to acknowledge that they could not know for certain the intended interpretation of an ambiguous message. In Experiment 2 we compared performance on the production task with that on a thought bubble task in which children had to identify what a person who saw an ambiguous figure would think. As before, children found it easy to give an alternative interpretation of the ambiguous figure, but they consistently rejected the uncertain thought bubble, which depicted someone thinking about a duck or a rabbit. Five- and 6- year olds find it easy to switch between alternative interpretations of an ambiguous input, but are unable to acknowledge the uncertainty that arises because of the existence of these alternative possibilities. We discuss this in the light of recent work on children's handling of determined and undetermined possibilities, and children's implicit understanding of ambiguity.

Preschoolers' Sensitivity to Referential Ambiguity
Elizabeth Nilsen, University of Waterloo, Canada

Children younger than 5 tend to judge ambiguous messages as unambiguous, particularly when they are aware of the intended meaning (e.g., Sodian, 1988). The goals of the present study were: first, to investigate preschoolers' implicit (indicated by eye fixation patterns and latencies) and explicit (indicated by actions) sensitivity to referential ambiguity and second, to assess whether a child's privileged knowledge interferes with his/her ability to detect message ambiguity from a naïve other's perspective. Four-year-olds participated in a message evaluation task wherein they had to assess an adult listener's knowledge of the location of a hidden sticker after the listener was provided with an ambiguous or unambiguous description of the sticker location. On half of the trials, children were aware of the location of the sticker whereas on the remaining trials, they were unaware of the sticker's location.

When preschoolers possessed privileged knowledge about the sticker location, their explicit judgments indicated they viewed a description to be unambiguous, even when that description was ambiguous from the listener's perspective. However, measures of implicit awareness demonstrated that even when preschoolers had privileged knowledge about the sticker location, ambiguous messages led to more consideration of an alternative location and longer response latencies than unambiguous messages. These findings demonstrate that children can detect referential ambiguity in language directed to others even when their own knowledge clarifies the intended meaning of a message.

Learning by Doing: the Role of Exploratory Play in Cognitive Development
Organizer: Elizabeth Bonawitz, Massachusetts Institute of Technology
Summary: Although it is widely accepted that children 'learn by doing' and that children's exploratory play is critical for development, there are diverse definitions of play and little is known about how children's exploratory play might provide evidence that could support learning. Indeed, there have been few findings of systematic patterns in children's exploratory play and considerable research suggests that children do not spontaneously design informative experiments. Nonetheless, research across a range of fields suggests that play is critical to cognitive development. This symposium bridges work in educational psychology, machine learning, and cognitive science to examine the role of exploration in children's learning.
Specifically, this symposium looks at how parents and educators evaluate children's play, how exploration may be computationally optimal, how play shapes categorization and reasoning, and how spontaneous exploration is shaped by evidence and prior knowledge. Our first speaker discusses disagreement between mothers and experts in the nature and value of play. Our second speaker will present approaches from machine learning aimed at discovering efficient, effective exploration. Our third speaker presents research suggesting that children's categorization and inferences are influenced by their exploratory play. Finally, our fourth speaker suggests that children's exploratory play is formally rational, in that children integrate prior knowledge and evidence in making decisions about exploratory play, much as they do in making causal judgments. By addressing the problem of children's exploration from these different perspectives, we hope to provide a broad and unique contribution to our understanding of children's play behavior.

Mother Versus Expert Beliefs: Disagreement in the Nature and Value of Play
Kelly Fisher, Temple University; Kathy Hirsh-Pasek, Temple University; Roberta Golinkoff, University of Delaware

The current research examined parental and early childcare expert beliefs about the nature of play and how such play activities relate to academic learning. Mothers (1130) and experts (99) rated 27 common childhood activities individually on (1) their classification as play or nonplay behavior and (2) their influence on future academic learning. Two categories of play activities emerged from parent ratings: unstructured play (e.g., free play such as blocks, dress up) and structured play (e.g., reading books, using computers). The majority of mothers (54%) classified all activities as play while 46% viewed unstructured activities as most playful and structured activities as less playful. Mothers believed all play activities had inherent academic learning value; however, unstructured play had less learning potential compared to structured activities. A seeming antithesis to parental perceptions, professionals viewed structured activities as non-play behavior. Further, professionals acknowledged more learning value in unstructured play compared to its counterpart.

Our findings highlight the existence of a conceptual disparity in society. Experts see strong, inherent differences in unstructured and structured play. In contrast, the majority of mothers do not clearly delineate these forms of play; rather, they view all activities as playful. This conceptual disparity may provide one answer for the seeming move toward structured play in the U.S. A broadening view of play may result in a society that identifies more behavior as playful with less delineation in types of play—allowing for an increase in structure in children's lives in educational and home settings.

Reward bonuses for efficient, effective exploration
Michael L. Littman, Rutgers University

Children must strike a balance between taking the time to perfectly understand their environment and taking advantage of what they already know. Viewed mathematically, solving this exploration-exploitation dilemma is computationally difficult, even in the case in which the environment simply consists of two unknown values (so-called 'bandit' problems). Natural environments present an even more challenging problem because the number of possible events to consider learning about vastly outnumbers the opportunities to explore. In practice, children can never completely experience their world, but nonetheless need to understand it well enough to navigate, make predictions, and explain the events around them.

The exploration-exploitation dilemma has long been recognized in the engineering disciplines as a problem that learning systems must face. Recent work in computer science has highlighted the importance of retreating from perfect optimality and settling for 'good enough' solutions. This talk will survey some new developments in machine learning that introduce reward bonuses for insufficiently explored states and show that the resulting learning algorithms balance exploration and exploitation while remaining computationally tractable. They can also search hypotheses spaces, even given noisy experience, to find rules that allow them to make predictions in the absence of exhaustive experience. These computationally tractable solutions from the artificial intelligence community could provide insight on the potential limitations, constraints, and mechanisms that may shape children's exploration and understanding of the world.

The Influence of Personal Exploration on Young Children's Artifact Categorization
Brenda Phillips, Deborah Kelemen, Krista Casler & Rebecca Seston, Boston University

Our presentation explores how young children reason about artifacts by examining the specific conditions needed for toddlers to construe tools in terms of particular functions. In particular, we examine how first-hand exploration influences children's functional categorization of artifacts.

Our general method involves presenting children with two physically dissimilar but functionally equivalent novel tools. Children briefly see an adult use one tool to perform a task (e.g., "bell box" activation) but receive no function information about the other tool although act upon it and manipulate it equivalently. Children are asked to choose between the tools to perform the demonstrated task and an alternative food-crushing task on eight trials, across two days of testing.

Our past research has revealed that 2.5-year-olds–after seeing just one intentional demonstration by the model and having one try themselves–become functionally fixed. They consistently return to the demonstrated tool for box-activation and avoid using it for alternative purposes. Additional research has now indicated, however, that certain learning conditions must hold for 2.5-year-olds to display this fixedness pattern. In short, if 2.5-year-olds are not given hands-on experience they display a pattern of flexibility, transiently viewing an artifact's function relative to the current, situational need. Thus, like monkeys, they use any tool for any task as long as it is physically viable.

These findings suggest that the absence of exploratory play reduces toddlers' abilities to make enduring stable function-based artifact categorizations. The implications of these results for understanding children's artifact knowledge will be discussed.

The Role of Theories and Evidence in Children's Spontaneous Exploratory Play
Elizabeth Baraff Bonawitz & Laura Schulz, Massachusetts Institute of Technology

In this talk we show that, given identical evidence, children with different naïve theories exhibit different patterns of exploratory play. Karmiloff-Smith & Inhelder (1974) demonstrated that before children develop an adult 'Mass Theory' of balance, they entertain a 'Center Theory', believing that all objects should be balanced at their geometric center. Even younger, 'No Theory' children balance blocks by trial and error. In Experiment 1 we let Mass Theorists and Center Theorists play with a block that was weighted off to one side. We then "balanced" the block on a post either at the block's geometric center or at its center of mass. (Thus evidence that was theory-consistent for a Center Theorist was theory-violating for a Mass Theorist and vice versa.) We also introduced a novel toy (a peg and rings). Children were allowed to play freely for 60 seconds. When the evidence about the balancing block was consistent with the children's theories, they showed a standard novelty preference and played mostly with the novel toy. When the evidence violated children's theories, they preferentially played with the balancing blocks. In Experiment 2, we replicated the design with younger, No-Theory children; they showed a novelty preference regardless of whether the block was balanced in its geometric center or center of mass. These results suggest that children's spontaneous exploratory play is systematically affected by the interaction of their naïve theories and the evidence they observe. We discuss these results in terms of the optimality of children's play.