Final Workshop Report

Opportunities and Challenges for Language Learning and Education
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A. Executive Summary

This document reports on the workshop entitled, "Opportunities and Challenges for Language Learning and Education," held at the National Science Foundation Headquarters in Arlington Virginia on September 5-7, 2007. Scientific understanding of language learning is critical for three interrelated national priorities required for continuing American intellectual leadership and scientific innovation. The first of these is to understand the biology of language and its evolution in the learning infant. The second is the universal acquisition of literacy to create and maintain an educated citizen workforce. The third pertains to the design and fluent use of the human-machine interfaces required by the intelligent artifacts of the 21st century. The specific goal of the workshop was to explore fundamental research that can lead us toward these goals. An important and related goal was to integrate these research priorities with ongoing investigations at the NSF Science of Learning Centers (SLCs).

The workshop speakers were 18 leading national and international researchers in the areas of language and cognition; one third were investigators from the SLC's. A plenary session preceding the conference was led by David Lightfoot who summarized formal linguistic approaches to language learnability, and Lila Gleitman, who summarized the topic of lexical learning. The workshop was organized in 6 broad topical sessions: *Cognition and the Infant Brain*, *Bilingualism and Early Second Language Acquisition*, *Effects of Limitations on Input and Invention*, *Cross-linguistic Differences and Syntactic Inference, Language Design and Cognition*, and *Implications of Language for Education*. Three Participants were assigned to make short presentations in each of the 6 sessions. The individual presentations provided different perspectives on the initial issues identified for discussion, and they provoked excellent discussion. Below we briefly sketch the key issues and questions that were identified in the 6 workshop sessions as priorities for NSF funding. An expanded discussion appears as Section B, and the full narratives written by session leaders comprise Section C of this report

1) The biology of language: Modern progress in understanding the mind and brain had its inception in the computational approaches to language and its learning that accompanied—and, in some significant ways, caused—the computer revolution. To this day, neuroscientific and computational investigations of language acquisition continue to reveal fundamental properties of higher-order cognition. Discoveries during the last decade show that young infants exhibit foundational capacities and sophisticated responses to human speech at birth, suggesting innate universal components of language acquisition at the earliest stages in development. For example, optical tomographic studies have revealed that neonates are sensitive both to rhythmic and repetition-sequence information embedded in the complex continuously varying sound waves of speech. Many studies also show crucial interactions between computational and social mechanisms in explaining children's rapid learning of a specific language. However, key questions remain about early speech and language development that are within reach in the next decade given newly developed neuroscientific methodologies: (1) Are the neural, cognitive, and social mechanisms for acquiring language *unique* to language or subsumed by domain-general mechanisms of human learning? (2) What is the mechanism underlying the *critical period* for first and second language learning (the evidence shows that late exposure to a first or second language yields inferior final competence)? (3) What accounts for individual variation in language development even when age of exposure is held constant? (4) What is the developmental neurobiology of language as revealed by the tools of modern systems neuroscience, which now allows noninvasive neuroimaging, OT, and ERP studies of infants and young children?

2) The nature of linguistic representation: Understanding language acquisition requires detailed knowledge of what a human language can be, its universal properties and the limits of linguistic diversity. To further knowledge at this foundational level requires funding for fine-grained linguistic analysis of a broad sample of the 5000 or so under-studied languages of the world, and of formal and computational models of their structure and content. Concurrent computational, behavioral and neuropsychogical study of the learning functions for these typologically distinct languages is also of central importance: The following key questions were identified: (1) How do the component subsystems of each language (phonology, lexicon, syntax) grow and interact during development? (2) What mechanisms of information uptake and processing, in addition to core representational properties, account for the course and character of the linguistic system evolving in novice learners? (3) In what ways are these interim stages to be accounted for as changes in informational state of the learner, and how far as changes in cognitive-developmental state of the learner? Answers to these questions are likely to be intimately related and require a general theory of complexly interacting systems (this latter issue is taken up further in section B).

3) The role of input: At the heart of theories of language learning are questions about the role of language input. In normally hearing children the question focuses on the quality and quantity of language input and the importance of the role it plays, particularly in the acquisition of vocabulary. The abstractness of language processing and representation are emphasized by findings showing that the course and outcome of learning are much the same in hearing children's acquisition of auditory-vocal language and deaf children's acquisition of visual-manual (sign) languages, if exposure is to fluent adults from infancy. However, most deaf children are born into hearing families who do not sign. This allows investigation of language acquisition under extremely impoverished input conditions. Such linguistically isolated children develop idiosyncratic, but systematic, signs and sign-sequences that closely resemble, in lexical-semantic and syntactic content, early speech and understanding among normally situated hearing children. When these isolated deaf children are brought together in socially coherent populations, they develop sign-language systems with a complex grammar that evolves over generations, much as pidgin (limited-contact) languages evolve over generations as they acquire native speakers. Key questions that should be addressed in the next decade are: (1) To what extent, and in what ways, is the course of language development dependent on learner age? (2) Are language properties whose development continues throughout much of the lifecycle, such as vocabulary growth, more dependent on input opportunities than syntactic properties that appear to be formed and fixed in the earliest years of life? (2) How do the quantity, quality, and social context of language input affect language learning? (3) Can artificial languages, varying in their structure and provided to learners at different ages, reveal the critical properties of natural language learning in controlled experiments? (4) What does language invention under impoverished input conditions tell us about the evolution of language?

4) Language and thought: two sides of the same cognitive coin? Study of cognitive development in infants, toddlers and preschoolers over the last decade has pushed back to ever-younger ages demonstrations of at least the rudiments of many foundational representational capacities, ones previously thought to emerge only many years later. These studies of early cognitive abilities, as well as studies of numerical reasoning, raise the possibility that humans' non-verbal capacities are more sophisticated than initially thought, and more entwined with language itself. Such findings suggest that a true understanding of the links between language and thought will require more sophisticated studies relating non-verbal thought and linguistic representation. Key questions that can be addressed in the next decade are: (1) What are the non-verbal precursors of logical reasoning and do they constrain language processing? (2) Does domain-specific reasoning (and representational structure) affect domain-general capacities? (3) In what ways does the development of pragmatic and background knowledge influence reasoning and the interpretation of language? (4) To what extent might language play a causal role in development in nonlinguistic domains including numerical and logical

reasoning? (5) Do the many differences among the natural languages influence not only learning but also the adult reasoning styles and mental categories of their users?

5. Multilingualism: Learning and using more than one language—as do many, if not most, human beings—has both practical and theoretical implications. According to the Census Bureau's 2006 American Community Survey, almost one in five Americans (over the age of 5) speaks a language other than English at home. In the United States, bilingualism and the acquisition of English as a second language have often been associated with poorer school performance, perhaps because the most commonly studied bilingual populations in the United States are immigrant groups with low socio-economic status, which has long been associated with poorer language and reading scores. In contrast, researchers outside of the United States have had the opportunity to explore situations in which bi- and multi-lingualism is socially supported, valued, and present across socioeconomic classes, and these studies indicate that such environments are not associated with poorer school performance, and, in fact, that bilingualism may confer specific cognitive processing benefits. In the next decade, key questions that can be addressed are: (1) How do the neural mechanisms underlying language represent two or more distinct symbolic systems? (2) What are the cognitive and educational consequences of multilingualism for US children? (3) What is the role of socio-economic status and socio-cultural context in bilingual (and monolingual) language development? (4) Does learning a second language impact mastery of the primary language? (5) In particular, it has recently been suggested (both in behavioral and neuro-cognitive studies) that bilingualism fosters 'cognitive flexibility' and 'meta-linguistic skill' including extension of the so-called critical period over a longer developmental period; such issues have obvious educational implications and are a funding priority.

6) Education and literacy: Language affects education in the acquisition of reading, but also more broadly in the acquisition of knowledge related to concepts in science. Behavioral and brain research on reading has increased our understanding of the neurobiological and environmental influences that underlie the large individual differences observed among children learning to read. Models proposing to explain reading deficits include one implicating neural processing speed. Interventions based on this model use game-based technology, and have yielded promising results. Research on science concept learning also has educational impact. Studies show that language input in science classrooms affects students' conceptual representations of the environment and therefore their processes for constructing meaning. Key questions that can be addressed in the next decade are: (1) How do variations across writing systems with different organizational principles (alphabetic, syllabic, and logographic) relate to differences in how they are learned and processed during reading? (2) Can neural principles lead to improvement in language and reading skills in children with deficits as suggested in preliminary results? (3) Can language input conditions in classrooms enhance students' conceptual representations of scientific concepts? (4) Can we build the capacity for translational research that connects basic science on language, cognition, and learning to improvement of educational outcomes in school settings?

7. Addendum: It is not possible in a 2-day workshop to cover the variety of topics that are worthy of NSF basic research funding for language acquisition in the coming decade. We therefore mention several topic-areas that are well developed scientifically (and important theoretically) and warrant funding but which were not emphasized by our panel: (1) the neuropsychological study of language learning in the presence of both congenital and acquired pathologies, e.g., learning with Autism Spectrum Disorder, Down Syndrome, Williams Syndrome, and acquired aphasia; (2) developmental delays including SLI and related syndromes whose major effects may be on the acquisition of literacy; (3) computational and behavioral simulations of subcomponents of language learning at various levels. Even with these further topics added, we do not mean this summary to be exhaustive, but rather a guide to some generally accepted and well developed areas that will repay immediate and mid-term investigation.

B. Some expanded general commentary

1. Complexly interacting systems

Language acquisition research is complicated by the fact that a large number of interacting variables contrast and conspire to shape the final outcome for any learner. Though languages are deeply alike in many of their design features, they vary marvelously in their particulars, and these may pose different learning and computational problems for the novice. Moreover, novices are exposed only to adventitious samples of the language they are to learn, rather than to what might count as a 'fair sample' of the language as a whole. These samples might well differ as a function of the social and educational class of the adult caregivers, and several other related socioeconomic variables. The child learners also differ among themselves in their sociality, their motivational states, their intelligence and various other cognitive-perceptual properties, including deafness or blindness, which are or might be related to their receptivity to linguistic input. Furthermore, some children are exposed to languages in different modalities, e.g., the visual-motor signed languages of the deaf, and the orthographically divers written languages. Many children are exposed to more than one language from birth or in the early learning years, in multilingual households or neighborhoods, so they face the problem of disentangling two linguistic systems in order to learn either of them. Finally, learners approach the language learning task in different neuropsychological states: some have a prior language; some are infants while others are much older; some learn in the presence of potentially influencing neurological conditions including Autism, Down Syndrome, Williams Syndrome, and so forth. All of these differences in language learned, learners, and learning circumstances also complicate the scientist's task in understanding the representational and processing causes and enabling conditions for language learning. Yet the same factors offer research testbeds that are informed by the comparison and contrast among these factors—sometimes by experimental artifice but sometimes because the contrasting conditions have been supplied by the natural situations in which novices find themselves during the period of language acquisition. As sketched in the Executive Summary, the six sessions of this workshop each highlighted research involving different subsets of these factors, and posing key questions for the immediate and mid-term future in language acquisition research. However, analysis of these component-learning variables does not suggest that their interactions are in any way simple or linear. On the contrary, recent research suggests complexity in these interactions that goes beyond what presently known statistical modeling can account for, and argues for a frontal scientific attack on complexity theory

2. Conceptual framework for NSF-fundable basic scientific investigation of language learning

The research agenda of modern linguistics is shaped by a pair of interrelated questions. What are the range and limits of language diversity? And what are the representational and processing resources that make all humans able to acquire the language of their environment after the relatively brief exposure period of infancy and early childhood. As we have emphasized, answers to these questions are likely to be intimately related. An explanation of why languages vary in just the ways that they do may derive from either representational or processing capacities of learners. Key questions for the coming decade concern the explanatory relation between language diversity and language learning.

(a) What are the limits of language diversity? Answering this question requires detailed linguistic investigation of the languages of the world. At present, rich linguistic descriptions are available primarily for the languages of Europe and East Asia, with most of the roughly five thousand extant languages inadequately studied, potentially distorting or limiting theories of language variation.

(b) To what extent do universal properties of human languages derive from (a) representational primitives specific to language, perhaps the result of targeted brain adaptations for language, (b) aspects of the human conceptual system, (c) procedures for taking in, storing and manipulating information? A theory of learning by necessity includes a model of the domain to be learned, an uptake function specifying how information is taken in and related to this model, and an update function indicating how new information is used to change the representation of the domain. Apportioning the explanatory burden to these components of the learning theory will require several kinds of research. Research relating typological generalizations to hypotheses about learners' initial syntactic and semantic representations can determine the degree to which children approach diverse languages with the same representational resources. Research addressing the conceptual and cognitive resources that learners bring to the acquisition task can help to apportion explanation to linguistic or extra-linguistic factors. Research with miniature artificial languages and computational modeling can help to identify the relative contributions of information uptake and mechanisms of representational updating.

(c) How do the components of language knowledge (e.g., phonology, lexicon, morphology, and syntax) interact in the course of development? To what extent do some solutions to learning problems only become apparent when prior problems have been solved? Do developmental changes in processing speed, working memory, or information streaming cause the input distribution to be different for learners and adults, potentially impacting the utility of recently acquired knowledge in subsequent learning? Recent advances in investigative procedures (e.g., eye-tracking and neuropsychological measures) are expected to underpin rapid progress on these questions in the immediate future. Cross-linguistic comparisons are useful here, too, as languages with different word-orders present grammatical information to the learner at different times in processing, allowing researchers to identify the role of information uptake in acquisition.

3. The place of language acquisition studies in NSF/SBE funding.

National scientific goals for a technically sophisticated and adept citizenry, and for maintaining national leadership in designing and using the communicative artifacts of the 21st century require understanding of how humans and other 'intelligent' machines can acquire a natural language. Specifically, the study of language acquisition is central to two broad national priorities for American technological leadership and innovation. The first concerns the design and fluent use of the intelligent machines that characterize the novel material artifacts of the 21st century, from Blackberries to supercomputers. In light of the success of such machinery in mediating human-human interaction (e.g., texting) and the transfer of information (e.g., Googling), it is striking to realize that this success has not smoothly translated to what appear on the surface to be far simpler human-machine interactions. The crippling present-day inadequacy of human-machine communication are obvious to anyone who attempts to interact with the partly automated 'menus' that greet one when telephoning for information or contact with the merchant, the bank, or medical emergency services. Such machinery as exists is successful and reliable only for the simplest input-output tasks (e.g., ATM transactions) but is fallible or frustratingly inflexible when the task requires even a modicum of what is informally called 'common sense.' Indeed, sixty years after the onset of the computer age, there still exists no machine with the spoken-language communicative skills of the average 3-year old child. The most promising engineering solutions for this class of problems are widely understood to require fundamental investigation into the only known device—the human child—which evolution has created and which, barring extreme pathology, acquires the ambient language (or languages) of the surrounding community without formal instruction in the first few years of life. The critical barriers to massively interactive human-machine computation will likely be breached only when we understand the sophisticated skills of the infant and pre-school human language learner.

The second cluster of language-centered skills necessary for national leadership and important to national goals for a technologically sophisticated citizen workforce. These have to do with the acquisition of literacy. Reading and reading-comprehension are forms of linguistic communication that are required for any position that rises above the menial in the increasingly technical American and, indeed international, societies of the 21st century. Surprisingly, in contrast to the apparent simplicity and automaticity of spoken-language acquisition by pre-school children from every walk of life, literacy skills do not emerge 'automatically' in the general population. Rather, these (along with basic numeracy skills) are established and honed during childhood and early adolescence via explicit instruction from the adult community, usually by intensive schooling throughout the K-12 period. Learning to read, though clearly parasitic on prior spoken (or signed) language competence, requires a kind or level of knowledge that goes well beyond the early-acquired aspects of talking and understanding. In light of the significant failures in the present-day public school systems to achieve anything close to universal literacy, basic research in this topic-area is a clear and continuing national priority.

4. International Collaboration in Language Learning Research

Language research is cross-disciplinary and multi-national. An international consensus exists about the need and timeliness of studies on language, its underlying brain mechanisms, and applications for 21st Century education and policy in the USA. Many scientific funding agencies in Europe and Asia are actively promoting research on language learning and the brain mechanisms that enhance and limit humans' capacities to learn languages at various ages, technologies that support second language learning in children and adults, and the implications for education of the foregoing research. Nevertheless, systematic international collaborative research programs on language learning remain sparse. Synergies can be promoted through NSF support of international collaborative research on language learning, and vehicles for fostering these collaborative programs should be developed.

C. FULL SESSION NARRATIVES

SESSION 1

Cognition and the Infant Brain

The question of how human children acquire language is one of the most exciting yet challenging scientific questions in the 21st century. The acquisition of language is exciting because it is so remarkable; human language is among the most complex systems in the known world, yet young children routinely acquire it, with little apparent effort, in just a few years —and in so doing they do what no other creature can do. It is difficult to study for some of the same reasons: because humans and humans alone acquire language, one cannot use many of the standard techniques for understanding neural function; one cannot study language in rats or pigeons, nor ethically conduct "deprivation experiments" in which experimental animals are raised in unusual environments; lesion experiments are likewise out of the question.

But the question of how children acquire language remains of paramount interest, in part because it is a paradigm case of human learning; the way in which infants go "from zero to sixty" – from first words to full sentences, in just a few years — should be the envy of educators everywhere, all the more remarkable because children generally do it with little or no explicit instruction.

Panel One focused on three central questions in language acquisition: the nature of the mechanisms that allow children to acquire language, the extent to which the neural and cognitive machinery for acquiring language is *unique* to language (or general to all human learning)*,* the ways in which those mechanisms may atrophy or otherwise change with age (the 'critical period' phenomenon).

Studies demonstrate that at birth young infants exhibit a universal capacity to detect differences between phonetic contrasts used in the world's languages (see Kuhl, 2008 for review). This universal capacity is dramatically altered by language experience starting as early as 6 months for vowels and by 10 months for consonants; native language phonetic abilities significantly increase while the ability to discriminate phonetic contrasts that are not relevant to the language of the culture declines. The explanation of this transition from universal to specific-language perception includes both computational processes (statistical learning) and specific enhancement observed in language learning situations that include social interaction. Statistical learning supports learning at the phonetic level as well as at the early word learning level, and whether and how phonetic learning promotes word learning and the reverse is one of the emerging topics of great interest in this arena.

A key emphasis has been on studies in which experimenters observed the learning of unfamiliar or artificial languages, with an eye towards understanding the precise input-output relations that govern language learning, both in children and adults. Experimental studies of the mechanisms of linguistic development are opening new avenues in all three of the core questions. In the case of critical periods, for example, recently developed techniques allow researchers to compare not just the outcome of language acquisition in children versus adults, but also the nature of the inferences that are drawn by both children and adults in genuine learning situations.

Recent work emphasizes the mechanisms of acquisition, which is a significant change of emphasis in the field. Much recent work has focused on developing a notion of 'statistical language learning' (in which infants and adults are thought to acquire the patterns of natural languages through computing statistics such as the co-occurrences or correlations among sounds or categories of elements in the stream of speech). However, a range of learning mechanisms has recently been proposed, including new ideas about rule learning, Bayesian learning, new types of connectionist models, and hybrids of these. Critical or sensitive periods for language acquisition could involve changes over age in the fundamental mechanisms that underlie learning (particularly implicit learning or pattern learning of the type that is most relevant to learning the formal properties of language). There are several bodies of evidence suggesting that there are changes over age and maturation in the nature of language learning: not only the typical types of evidence showing that first and second language learning achieve differing outcomes, but also evidence from studies of pidgin and creole languages, studies of children learning sign languages from inconsistent input, and particularly from her own lab, studies of children and adults learning miniature languages in the laboratory. While it has often been proposed that the account of such age differences lies in the loss over age of a domain-specific language acquisition mechanism, she suggested that another viable hypothesis is that there are much broader, domain-general changes in pattern learning over age and that these might underlie sensitive period effects in language learning.

Recent studies show that when children and adults are exposed to identical input and learning experiences for acquiring miniature languages, which they learn to perceive and speak over the course of 5 to 7 days of learning, they differ in critical ways. A crucial feature of these studies is that one part of the miniature languages is inconsistent in its structure: most of the time a grammatical function is signaled by one type of function word, but in an unpredictable minority of contexts, the same function is signaled by a different function word. A series of studies investigate how children, as compared with adults, learn from such inconsistent input. The results indicate that children virtually always regularize the input, producing rules in their own speech where the input is inconsistent. (More specifically, children acquire the main function word and ignore the inconsistent usages.) Adults, in contrast, will most often reproduce the inconsistencies to which they are exposed, though in circumstances of very complex inconsistencies, they begin to look like children. These results cast a new light

on why children may be better language learners than adults: their more limited cognitive abilities may make them better able to acquire the major patterns of their input – in part because they ignore or fail to learn the complex inconsistencies. The nature of learning mechanisms is often best revealed by examining learning in the worst or most inconsistent circumstances. In these studies, even laboratory performance shows striking differences between adult and child learners and provides an opportunity for understanding the nature and breadth of such adult-child differences in learning.

New experimental techniques are also opening up avenues for studying the role of social interaction in language, and may soon yield progress in our understanding of why children are, despite their remarkable capacity for language acquisition, apparently unable to learn foreign languages from television exposure alone. Presentations highlighted intervention studies of infant language learning illustrating the role of social interaction in early learning. The results are reminiscent of experiments on song learning in birds that also show a need for social interaction in communicative learning. In these experiments, infants at 9 months are exposed to a new language (Mandarin Chinese or Spanish) for 12 sessions over a 4-6 week period. Brain and behavioral tests show that infants the phonetic contrasts and words of a new language rapidly when exposed to live speakers, but not when the same material is presented over a standard television or via audiotape. Additional experiments reveal that infants' social skills assessed using independent video analysis—their attentiveness and ability to track the tutor's eye gaze—predict the degree to which they learn both phonemes and words. The results indicate interactions between the implicit computational mechanisms underlying language acquisition and those underlying social cognition. These studies relate to neurobiological models of communicative learning in other animals, such as passerine birds, in which social interaction is essential for learning. The studies may also provide scientific explanations for the linkage between language and social cognition as seen in autism spectrum disorders. More generally, scientific study of language acquisition in typically developing children may lead to deeper understanding of disorders of language and potential interventions.

New neuroscience tools (MEG, EEG, NIRS in particular) may allow future experiments to measure brain activation in areas critical to language during language experience with various languages, and under different exposure conditions (when exposure is 'live' vs. delivered from a non-human source). The tools of modern neuroscience—both structural/anatomical MRI studies showing the physical growth of language areas over time, and functional imaging (with whole-brain MEG or EEG measures) during language processing—will produce new perspectives on language acquisition.

The Panel also stressed the importance of developing new measures for studying language acquisition, especially techniques for studying individual differences; it was noted that reliable studies of individual difference require large number of subjects, more than might feasibly be obtained by one investigator, and that infrastructure for cross-university collaborations on large-scale projects is essential.

A variety of experiments now show individual differences in early measures of language learning that predict future language abilities. Thus, there is continuity in learning from early speech processing to the later growth of language. New studies show that infants' initial abilities to learn phonetically predict the rate of language acquisition to the age of three years. The experimental design rules out the possibility that the skills that vault language forward in the early learners are either simply auditory in nature or are attributable to a more general cognitive skill.

Experiments also indicate that native-language learning is linked to the decline in non-native abilities in individual children, potentially signaling a mechanism related to the 'critical period.' If native learning itself causes a decline in non-native abilities, then the 'critical period' phenomenon (the decline in the ability to learn a second language with increasing age) may be affected by experience, not simply time. An explanation of the

mechanism underlying the 'critical period' for language has been resurrected as a topic for experimental investigation, and multiple theories that are both exciting and new are being actively tested.

Another key question that received attention in Panel One and again later in the conference was the extent to which the mechanisms that allow us to acquire and represent language are optimal, or whether they might in principle be improved on; how elegant, in other words, is the machinery of language acquisition?

A question that was raised was how to resolve a rapidly growing literature that suggests that infants are born with remarkably sophisticated tools for learning with the reality that skills such as reading are often problematic.

How children acquire language is fundamentally interdisciplinary—drawing on fields such as psychology, linguistics, computer science, and neuroscience—and the Panel felt that one of the best ways in which the NSF might support progress in language acquisition was by encouraging research collaborations between different labs that address related theoretical questions with differing techniques and with differing hypotheses about how language acquisition occurs. One suggestion was that it might be useful to support a continuing series of workshops on language acquisition, perhaps once or twice each year, with a relatively consistent set of researchers, on a model such as the McDonnell Foundation has done with a number of inter-laboratory research groups. The central notions are: first, that the group assembled for this workshop was a particularly well-chosen group of researchers who could have many profitable collaborations with one another; and second, that a very profitable outcome for the field would be obtained from supporting cross-university research collaborations, rather than just the more typical brief interactions at workshops. If this group were funded to meet on a regular basis and develop cross-laboratory collaborations to conduct research that is not presently ongoing at any single lab, we might expect new breakthroughs and important clarifications of ideas about mechanisms of language acquisition that otherwise might never take place in brief and more casual workshop interactions. While NSF officers noted that the already existing Science of Learning Centers does this, it does not presently support anything like the range of collaborations and cross-investigator interactions on a single topic that were represented at this workshop. A further suggestion was that funding specifically aimed at collaborations between researchers at two or more distinct universities might generate profitable research that would be otherwise difficult to undertake.

SESSION 2

Bilingualism and Early Second Language Acquisition

There are two motivations for conducting research on bilingualism and early second language acquisition. **This work can help us to understand how children master and use two or more languages.** In the United States, both bilingualism and early second language acquisition are common and appear to be increasing. According to the Census Bureau's 2006 American Community Survey, almost one in five Americans (over the age of 5) speak a language other than English at home. About half of these people report that they speak English very well. In the US, bilingualism and acquisition of English as a second language have often been associated with poorer school performance, perhaps because the most commonly studied bilingual populations in the United States are immigrant groups with low SES. In other social contexts (e.g., English-French bilinguals in Canada, Spanish-Catalan bilinguals in Barcelona) bilingualism is not associated with poorer school performance and appears to confer some cognitive advantages. In recent years, there has been an increase in immigration from Asia. The mean education level of Asian immigrants is considerably higher than that of immigrants from Latin America (e.g., in the 2006 ACS 48% of Asian immigrants had a Bachelor's degree while only 11% of those from Latin America did so). This creates the

opportunity for exploring the role of social contexts in determining whether two languages can be successfully acquired and the effects that bilingualism has on cognition and educational performance.

Studies of bilingualism and early second language acquisition can also serve as natural experiments providing insight into the mechanism of language development more broadly.
- o For example:
    - By studying the acquisition of English by internationally adopted children, Snedeker, Geren and Shafto demonstrated that many of the qualitative changes that occur in children's speech during early language acquisition persist in child learners. For example, adopted preschoolers learn many nouns and few verbs or closed class items. Their early utterances are short (most go through a single word stage) and increases in utterance length and syntactic complexity are strongly correlated with lexial development. The persistence of these patterns in older children, suggests that these shifts are attributable to the acquisition process, rather than cognitive development per se, and would be expected to occur whenever children learn through immersion in spoken language in the context of family life and daily routines.

    - The comparison of phonetic development in infants from monolingual and bilingual environments can help us understand how distribution of phones in the input affects the formation of phonological categories. For example, Bosch & Sebastián-Gallés (2003) found that Catalan-Spanish bilingual infants showed a temporary loss of a Catalan vowel contrast at 8 months, the age at which we might expect the sensitivity to the contrast to disappear in infants who were not exposed to Catalan. They suggested that this loss could result from infants lumping these Catalan vowels with the single Spanish vowel that inhabits this perceptual region. Such a distribution would initially appear to be monomodal, suggesting a single underlying category. But with increasing amounts of data, an optimal learner would be able to discover the three categories that underlie the observed distribution. In contrast the input to monolingual Catalan speakers has a clearer bimodal distribution that might be apparent with smaller amounts of data and thus could be more easily learned. Thus this U shaped acquisition in the Catalan speakers provides evidence for distributional account of perceptual learning, which applies to all learners (monolingual or bilingual). Simultaneously it offers an insight into bilingual acquisition: this finding suggests that, initially at least, the acquisition of phonetic categories occurs over a input corpus which includes speech in both languages.

- o We see many other such opportunities. For example:
    - Research on monolingual infants has demonstrated that as children lose their ability to distinguish non-native phonological contrasts, they show an increasing sensitivity to native language phonological contrasts (Kuhl). There is some evidence that adults who were internationally adopted as children, lose the ability to perceive contrasts that existed in their birth language but not their adoptive language (Ventureyra, Pallier & Yoo, 2004). But we know little about how this happens or its relation to acquisition of the adoptive languages. Examining the relationship between loss of L1 categories and the development of L2 categories in these early second language learners could shed light on these processes in typically developing infants. Is the loss of some categories necessary to gain increased sensitivity to others?
    - Children's word learning is rapid and efficient largely because children have strong biases which shape their hypotheses about the meanings of words which are nicely adapted to the task. There is considerable controversy about where these biases come

from. Are they specific to word learning or by-products of other cognitive systems? Do they result from learning words and making generalizations about the kinds of meanings that words might have? Or do they match the input because of evolution or because both language and these biases are shaped by nonlinguistic cognitive constraints? Bilingual children provide some insight into these questions for two reasons. First, early in development their vocabulary in any one language is typically smaller than that of a monolingual. Thus they may allow us to tease apart the effects of word learning on lexical biases from the effects of maturation and cognitive development. Second, because their input is coming from two languages, it is qualitatively different in ways that might potentially effect the acquisition of word learning constraints. For example, the input to a bilingual child is often in violation of mutual exclusivity or the principle of contrast, since a given object (or even a given concept) can have two labels. Thus if mutual exclusivity were learned in a bottom up fashion (parallel to Smith's account of the shape bias), we'd expect that bilingual children would develop it slowly (or perhaps not at all). An initial study testing this assumption has found no evidence of a delay (Byers-Heinlein & Werker, under review). But the question merits further investigation.

Central topics for research:

- **The social context of bilingualism and early second language acquisition.** Bilingualism/early L2 learning occurs in a range of social situations. If we wish to understand the cognitive, linguistic and educational consequences of bilingualism, we need to be mindful of differences in SES across populations. Much of the research in United States has focused on bilingual children who come from families with low education level and incomes. In many cases the children's first language is given lower status by the broader community. In contrast, researchers outside of the United States have had the opportunity to explore situations in which bilingualism is socially supported, valued, and present across socioeconomic classes. This may explain some of the discrepancies across studies. To understand the true effects of bilingualism we must look at variety of populations, both so that we can control or neutralize differences in SES between bilingual participants and monolingual controls and so that we can examine how bilingualism interacts with social contexts. It is clearly possible for children to become fluent speakers (and writers) of more than one language. What social, economic, and educational circumstances support bilingual development? Under what conditions does bilingual language development break down?

- **Second language acquisition as a sensitive system for studying environmental effects.** First language acquisition is extremely robust. While children differ considerably in the number of words that they know or their length of their sentences, most typically developing children master the syntactic and phonological structure of their native language and achieve communicative competence, despite fairly profound differences in the amount and kind of speech that they hear. Second language acquisition is far more variable, even in children. Thus it may be a more sensitive place to study effects of wide range of contextual variables on acquisition (lead levels, input factors, cortisol, etc.) as well as changes in plasticity over development.

- **The cognitive advantages and challenges of bilingualism**. The current research suggests that there is no simple characterization of how bilingualism affects acquisition. In some cases bilinguals show advantages (e.g. auditory language discrimination Bosch & Sebastián-Gallés, 1997 and visual language discrimination Weikum, Vouloumanos, Navarra, Soto-Faraco, Sebastian-Galles, & Werker, Science, 2007), in other cases they perform just like monolinguals (e.g., Petito) , and in some cases they show delays in learning (Fennell, Byers-Heinlein, & Werker, Ch Dev, 2007). There is robust evidence that

bilingualism and early second language acquisition improve the development of metalinguistic skills and inhibitory abilities (Bialystock). Most theorists link attribute these advantages to the initial difficulties that the child most overcome to be a proficient bilingual. Future research should seek to understand where and how bilingualism taxes the learner, where and how it benefits the learner and the inter-relation between the two. To do this we need studies that use multiple methods to explore multiple phenomena (attention allocation, vocabulary development, speech perception, etc.). This could be done through longitudinal studies, or with cross-sectional designs that examine several phenomena within the same children (or population) at a single point in time.

- **How is bilingual language development affected by the relationship between the two languages being acquired?** This must be explored at multiple levels (syntactic, phonological, prosodic). Examining second language acquisition and how it proceeds may provide a method of collecting convergent evidence about the nature of the hypothesis space that learners consider and the regularities that underlie crosslinguistic differences (see e.g., Baker, 2005).

- **When does early second language acquisition result in bilingualism and why?** When a second language is introduced in childhood there are a wide range of possible outcomes: the second language may or may not be acquired, the child may become a bilingual, or the first language may cease to develop or even be lost. While broad observational studies have been useful, there is a need for research the examining the development of the specific abilities and mechanisms. Such studies should explore a range of populations: immigrant children learning the majority language in school and on the playground, children learning a noncommunity language in the classroom, adopted children learning a second language from a family member or caregiver.

- **The inter-relations between second language acquisition and first language maintenance or loss.** We know very little about language loss or how it is linked to second language acquisition. Research is needed to understand the roles of input and social factors in first language maintenance. There is even less work on the cognitive mechanisms that account for language loss. Such studies should explore a range of populations: from adopted children who have little use for the first language and appear to lose it quite rapidly, to immigrant children who are introduced to the community language in school while often maintaining their first language at home, to adults who experience temporary losses of fluency when they cease to use their native language for prolonged periods. What is the relationship, if any, between growth and fluency in the second language and stagnation or disfluency in the first language and what aspects of a bilinguals experience allow them to maintain fluency in both languages? Many have observed that language appears to be lost more quickly during childhood but such comparisons are typically based on individual case studies and impressionistic reports. Do children loose language more quickly than adults when placed in similar situations? Is this linked to the same factors that account for age of acquisition effects in first and second language acquisition? What is left behind when a language is lost? The creation of laboratory models of these phenomena (paradigms for studying artificial language learning and loss) could be useful for developing and testing hypotheses.

- **Bilingualism and the Language/Cognition Interface**: There is ample evidence for a bilingual advantage in some cognitive tasks. We need a fuller understanding of the mechanisms and how they unfold. Early second language learners can also provide insight into the role that language in general plays in cognitive development. For example, children who are internationally adopted, typically lose their first language and begin acquiring a second one during childhood. This results in a developmental disassociation of linguistic and cognitive skills. By studying these children we can explore whether language plays a causal role in a particular phenomenon (e.g., understanding number or theory of mind).

We can also examine the role that cognitive development plays in language acquisition by comparing second language learners of different ages.

- **How do two languages live in the same brain?** How do bilingual children keep the two languages separate during acquisition? Are they represented separately at every level of linguistic analysis or are there some levels in which a single system must process both languages without distinct representations for each one? Note that separate representations can result either from having distinct neural areas devoted to each language (spatially distinct) or from having a single system in which the representations for each languages are marked or tagged. How do bilinguals comprehend both languages? There is some data suggesting that during word recognition bilinguals do not actively segregate speech input and funnel it to the correct set of linguistic representations. Instead words from both languages are activated (even in the monolingual mode) and then compete. Are there any levels of processing at which comprehension involves the active inhibition of the unused language? In this respect bilingual production is likely to be quite different from comprehension, since in some way the speaker must ensure that the message is encoded in the correct language. But there is little relevant work on production processes in bilingualism.

- **Plasticity and language acquisition.** There is ample evidence that older learners generally achieve a lower level of proficiency in a second language than younger learners. However it is still unclear what the biological and cognitive changes of these effects are. Future research should examine specific language acquisition mechanisms in learners of different ages (older adults, young adults, adolescents, children) and learners in different circumstances. For example there is little work examining informal adult L2 acquisition from a cognitive perspective and comparing it with child language acquisition. Such research should focus on all levels of linguistic structure (e.g., phonetics as well as syntax) and should employ sensitive tasks that tap theoretical critical phenomena.

- **Cross-modal bilingualism:** Further studies of children who are bilingual in a spoken and signed language could be extremely informative. Signer/spoken bilingualism may be qualitatively different. The two languages do not have similar sensory-motor interfaces. This could result in less interference and competition between the languages at the level of perception and production. In this situation it should also be particularly easy for the child to separate the input for each language. Several populations are of particular interest. Children who learn a signed and spoken language from birth are important for theoretical reasons. Children who have limited or impaired access to a spoken language or its written form are of interest because impoverished situations like this may be particularly informative for understanding what the child contributes to the language learning (e.g., children learning Signed Exact English, children with hearing aides, children with cochlear implants

Desiderata for research in bilingualism and early second language acquisition

- To study bilingual language development we must know about monolingual development in both languages. This often necessitates collecting original data from both monolingual comparison groups. As a consequence, one benefit of bilingual research is that it results in more cross-linguistic acquisition research. To understand language acquisition it is critical that we examine children learning a diverse set of language in a diverse set of cultural contexts. Right now we are in danger of over-fitting our model of acquisition to small number of data points. We have vast amounts of data available on parent-child interactions in a handful of languages. The vast majority of input studies examine families in industrial (or postindustrial) communities that share some child rearing practices, which while common are quite recent inventions (e.g., reading to infants). We have little knowledge of language acquisition in agricultural societies or hunter-gatherer groups.

- No two bilingual situations are the same. Children differ in the languages that they are learning, the relative proportion of their input that is in each language, their maturational rate, their cognitive abilities and the individual motivations. For this reason, the best research designs include within subject manipulations or multiple tasks so that each child can serve as their own control. When we find a difference between two populations, this difference is typically open to multiple interpretations. But when we can isolate these differences to particular tasks or conditions which can be linked to the learning process or input of the bilingual child, then such differences become interpretable.

- Because each bilingual situation is unique it is important for researchers to explore the generalizability of their findings. This can be done by simultaneously conducting closely matched studies in multiple bilingual populations or by attempting to replicate prior findings in new populations. Such studies should examine situations that vary in: the relation between linguistic phenomena in the two languages (e.g., in speech perception cases where two phonetic distinctions are reduced to one in the child's second language vs. cases where one distinction splits vs. cases where the two languages have overlapping categories with different boundaries); the social prestige of the two languages (e.g., minority/majority languages vs. multilingual communities); the socio-economic status of the bilingual families; the age at which each language is acquired; and the context in which the languages are acquired.

- For these reasons it is critical to support multi-site studies both within the United States and across the world. This is the only way to examine the full range of bilingual situations. This will also expedite language by allowing researchers to examine learning situations that are unusual and geographically dispersed (e.g., older children who are adopted internationally, adults experiencing first language loss). Funding for small working groups to develop research collaborations of this kind could have a powerful effect.

SESSION 3

Effects of Limitations on Input and Invention

All theoretical accounts agree that human children are prepared to learn language. But what are they prepared with? One way to explore the nature of the biases children bring to the learning situation is to observe language-learning in varying circumstances—circumstances that vary in how much linguistic structure the child encounters. The assumption is that children bring the same processing biases to whatever circumstances they encounter. To the extent that child outcome remains the same across these various input situations, we have strong evidence that the child's processing biases are themselves important in determining the language the child develops—that the child's developmental trajectory is buffered from vagaries in the input. However, to the extent that each varying input situation results in a different child outcome, we not only have evidence that input matters, but we can begin to explore the patterns between input and child outcome to make inferences about the child's biases and processing strategies.

In other scientific domains, when we are interested in understanding the mechanisms that underlie developmental change, we attempt to experimentally manipulate the situation, altering circumstances of the environment and observing the effects of those alterations on the organism's outcome. But for obvious ethical reasons, we cannot tamper with the circumstances under which children learn language. The alternative is to take advantage of the varied circumstances that children find themselves in when they attempt to learn language.

Any particular manipulation of the environmental conditions under which language-learning takes place has the potential to alter the language-learning outcome.

Experiments of Nature

Examining variations in learning conditions constitutes a research program for studying language-learning, and a way to think about the findings of such a program. A property of language that is *unaffected* by a given manipulation can be said to be developmentally *resilient*—its developmental course is impervious to the change in input conditions. Importantly, the more radical the manipulation is—that is, the more different the conditions are from the conditions that surround the typical language-learning situation—the more impressive it is that a given property of language continues to crop up, and the more we learn about contributions that children themselves make to the learning process. In other words, the more we see children go beyond their input, the better view we have of how children are prepared to learn language.

It is likely, however, that some properties of language will *not* survive a particular manipulation and may, in fact, not survive a variety of manipulations. Such properties of language are *fragile* for it is these properties whose development is sensitive to changes in input conditions. These are the properties that may be the first to go when language learning goes awry, and the properties whose developmental course we can do most to alter.

We focused in our discussions on a number of "manipulations" found in the real world that affect either the nature and quality of the child's linguistic input or the timing of the input.

Grounding sounds in the world. Although the auditory input blind children receive is no different from the sighted child's auditory input, the sounds are not correlated with the visual cues that many theories take to be essential to language learning. Nonetheless, blind children learn language at the same pace as sighted children. Whatever language-learning mechanisms we attribute to the child will have to be able to account for these facts.

The timing of input. Internationally adopted children learn one language in their native country and are exposed to a second language in their adopted country. The timing of exposure to this second language can vary dramatically, thus allowing us to explore the effect that age of exposure to (presumably good quality) input has on language outcomes (and therefore the effect that nonlinguistic cognitive development has on language learning).

The quality of input. Deaf children provide particularly rich possibilities in terms of varying the quality of a child's linguistic input. Deaf children born to deaf native signers learn sign language as effortlessly and naturally as hearing children learn spoken language. But many deaf children are exposed to less-than-perfect sign input, either from deaf parents who learned their sign language late in life or from hearing parents who are learning sign language along with their children. The children go beyond the sign model provided by their parents. The question is whether they do so for all properties of language and for input that has little to no linguistic structure

What kinds of properties must a behavior have in order to serve as input to a linguistic system? The most extreme case is of a deaf child raised by hearing parents who do not learn sign language but choose instead to raise their child by an oral method (i.e., they attempt to teach the child to speak). Under these circumstances, most profoundly deaf children fail to acquire speech and, of course, do not have a model of a sign language. The interesting phenomenon is that each of these children, referred to as 'homesigners,' invents a gesture system that has many of the fundamental properties of language. These children receive non-linguistic gesture as input, but produce language-like gestures as their output. Are they transforming non-linguistic gesture into language, or are they treating their hearing parents' gestures as irrelevant to the language-creation process? Examining homesigners in different cultures where speakers display different patterns of non-linguistic gesture can help address this question (homesign systems in different cultures should differ if non-linguistic gesture is serving as input to the system). The larger issue is pinpointing how far children can go toward inventing a language—the properties of language that homesigners are unable to invent are likely to be just those properties that children need linguistic input to acquire and special circumstances to create.

The size of the community. Homesigners are in a unique situation—they receive non-linguistic gestures as input but produce language-like gestures as output. They are, in effect, in a language community of one, as the child does not share a communication system with anyone. To explore the effect of community on language creation, the gesture systems homesigners create can be compared to sign languages that are currently evolving in deaf communities. Take, for example, Nicaragua where deaf children were brought together into a community for the first time 35 years ago. The deaf children had been born to hearing parents and were likely to have invented gesture systems in their individual homes. When they were brought together, they needed to develop a common sign language and Nicaraguan Sign Language (NSL) was the result. A comparison of homesign and the sign system invented by the first generation of signers offers us a way to explore the importance of having a community of language users and (at least) two factors: (1) ***Being a producer and receiver of the system.*** The homesigner produces language-like signs but receives as input non-linguistic gesture and is thus a producer of his system but not a receiver; the first generation of Nicaraguan signers both produced and received their signs. (2) ***Variability in the input.*** The homesigner marches to the beat of his own drum—whatever variability there is in the system is his own doing; each of the Nicaraguan signers brings a potentially distinct system to the mix, providing variability that might enrich, or restrict, the system (the community language might end up being no more complex than the simplest homesign system).

Multiple generations. NSL has not stopped at the first generation. Every year, new students enter the school and learn to sign among their peers. A second generation of signers has as its input the sign system developed by the first and, interestingly, changes that input so that the product becomes more language-like. The second generation, in a sense, stands on the shoulders of the first, with (at least) two factors distinguishing their circumstances: (1) ***The input changes.*** The second generation is not starting from scratch; they apply their language-learning skills to input that has some language-like qualities and therefore should be able to take the language that much further. (2) ***The system is seen by a fresh eye.*** A second generation signer approaches the system constructed by the first generation with a fresh mind, and thus has the potential to reorganize the system in ways that the inventors of the system might not; we can therefore explore whether it is just length of time that matters (e.g., a homesigner who continues to use, and presumably develop, his system for 30 years) or whether it is important for the system to be passed through generations of fresh minds.

Who is the learner/creator*?* There is another interesting wrinkle in the language-creation story—it matters how old the creator is. Second generation signers who began learning NSL relatively late in life (after age 10) do not exhibit linguistic advances and, in fact, use sign systems that are no different from those used by first generation signers. It may only be children who can take full advantage of the input provided by the first generation to continue the process of language development. Thus, we see in NSL that language development depends not only on what the creator has to work with, but also on who the creator is.

The Nicaraguan situation is unusual only because it has been so well studied and publicized. All sign languages of the deaf evolved in situations where deaf individuals came together and developed a system to communicate with one another. There are currently evolving sign systems whose circumstances differ in interesting ways from those in Nicaragua. For example, one community, now in its seventh generation and containing 3,500 members, was founded two hundred years ago by the Al-Sayyid Bedouins. Within the last three generations, 150 deaf individuals were born into this community, all descended from two of the founders' five sons, and created Al-Sayyid Bedouin Sign Language (ABSL). ABSL differs from NSL in that it is developing in a socially stable community, with children learning the system from their parents. In Nicaragua, deaf children are born only to hearing parents and are not exposed to sign until they arrive at school. We can select communities that will allow us to explore particular factors that might be relevant to language learning and creation, in this case, the timing of exposure to input and the size of the community.

Social structure and language change*.* Evolving sign languages such as ABSL can also offer a unique perspective on classic questions in historical linguistics. The signers from each of the generations are likely to differ, and to differ systematically, in the system of signs they employ. By observing signers from each generation, we can therefore make good guesses as to when a particular linguistic property first entered the language. Moreover, because individual families in the community are tightly knit, with strong bonds within

families but not across them, we can chart changes in the language in relation to the social network of the community. For example, some linguistic properties remain within a single family, others spread throughout the community. Is there a systematic difference between properties that do and do not spread? In addition, because we know who talks to whom, we may be able to determine who was responsible for spreading a particular property (the men in the community? the women? the adolescents? a socially dominant family?).

Looking at changes over time in evolving sign systems requires a comparative base. We can achieve such a base by examining how mature languages (signed or spoken) change over time, that is, by doing historical linguistics, choosing the circumstances to either match or contrast with the circumstances that surround evolving sign languages.

Many of the situations we have described entail the acquisition of languages in a non-speech modality. The acquisition of visual-manual languages can provide new opportunities to explore the foundational properties by which human languages are instantiated. The prominence of perception/action pairings in visual-manual communication provides a unique perspective for understanding the biological basis of human communication.

Experiments in the laboratory

Complementing the approach that takes advantages of "experiments of nature" are studies that can be done in the lab where the same properties of input can be manipulated in a controlled fashion. We recommend that the two types of studies be used in concert, using natural manipulations (which have the advantage of being real-world phenomena with all of the richness and messiness they entail) to generate hypotheses, and laboratory experiments to test those hypotheses in a controlled fashion. Strategically using both types of studies to explore mechanisms of language-learning will require across-lab co-ordination, as it is rare for a single group to be able to use these very different forms of experimentation.

Experiments of nature have the virtue of being rich phenomena grounded in the real world. However, it is rare to find situations that contrast on only one dimension. Laboratory experiments can do just that. We discussed two types of studies that would complement the natural manipulations we identified.

Artificial languages can be constructed and given to learners at different ages, thus varying the timing of input. Artificial languages have been used to explore whether learners can learn languages that vary in how they are structured and to explore the kinds of cues learners use to abstract whatever structure is present in the language. Artificial languages can be constructed to vary the type, quality, quantity, and variability of input, factors that experiments of nature suggest might (or, in some cases, might not) be important in language learning.

Another approach is to use a natural language but limit the data to which a learner (in this case, an adult) has access. To the extent that what the adult gleans from the data in this learning situation is comparable to what a child-learner gleans from natural data, we have evidence that the cognitive state of the learner is not determining the language-learning trajectory. Moreover, we can then use this paradigm, systematically varying the kinds of data that are given to the adult, to explore factors implicated as relevant to language learning in experiments of nature.

One goal of the research program we have outlined is to explore whether there is convergence across manipulations in the properties identified as resilient. It is an empirical question as to whether the same property of language will survive a variety of input manipulations—that is, whether it will be resilient across a range of naturally occurring learning conditions and across laboratory situations. If so, we can be that much more certain that this particular property of language is fundamental to human communication, a property whose development is robustly over-determined in humans. But it will be equally informative if a particular property turns out to be resilient only under certain conditions. Whatever mechanisms we propose to account for language-learning will have to account for the fact that a property can be developed under a particular set of circumstances but cannot be developed under other circumstances. In this way, exploring language learning under varying circumstances can help us build models of the mechanisms that underlie how children learn language.

SESSION 4

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Cross-linguistic Differences and Syntactic Inference

There is need and opportunity to productively connect experimental psycholinguistics with detailed inquiry into language variation/typology. This could involve partnership with Endangered Languages initiatives to mutual benefit of both programs.

Experimental psycholinguistic research to date has been done on a very small sampling of the linguistic diversity of the world (mostly Indo-European languages, a few East Asian languages). As our understanding of the structure of other languages is expanding rapidly, we would hope to find a corresponding increase in research on the acquisition and processing of these languages. Cross-linguistic psycholinguistic research will allow researchers to control for many more variables than does work on Indo-European languages alone, and it should give a more realistic picture of how variation shapes processing and how different grammars pose different challenges to learners. One potentially fruitful avenue for new research might involve collaboration with research on Endangered Languages. Researchers in endangered languages programs know a lot about languages that learning theorists should be aware of. Conversely, learning theorists might be able to make discoveries about how languages are best learned and taught that could be vital to the success of language preservation and revitalization programs that concern people working on endangered languages.

How in detail does one infer abstract structure (phrase structures, parameter values, subcategorization frames, etc.) from noisy and variable surface input? How does statistical learning feed into deductive/algorithmic grammatical structure?

Models based on universal grammar and parameter settings do not by themselves answer questions about language learning, because they typically say nothing about how the parameters can be set and/or how the structures can be acquired on the basis of exposure to raw data. On the other hand, pure statistical-based learning models, in their currrent form, do not obviously account for all the abstract and discrete inferences that language learners seem to draw. The field is ripe for getting beyond either/or models, to see how statistical tracking could be used to feed into rule construction/structure determination /parameter setting. Critical to such an effort are studies examining the full range of inferences that are licensed from artificial language data and the degree to which such inferences implicate representations like those found in natural languages.

1. What is the interactive relationship between the demands of processing, the demands of learning, and the structure of possible human languages?

Specific features of the grammar of a particular language provide hints that help the language processor uncover the structure of a sentence and the grammar. . Conversely, all human languages must be parseable in real time, or humans will not be able to use them in the ways that they do and must. Similarly, all human languages must be learnable in a finite amount of time, or they will not be learned and will not (continue to) exist. What role do these constraints play in shaping the grammatical systems that exist? Are there linguistic universals that can be explained in these ways in a much fuller and tighter way than before? (For example, overt case marking on noun phrases is much more common in verb-final languages than in verb initial languages. Is this because there must be some information that the parser can get started on early in the sentence in most/all languages?)

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How can what is known about language typology connect with studies of artificial language learning?

There is a long standing puzzle of why some perfectly reasonable looking linguistic systems are extremely rare or not attested in natural languages, both at the level of syntax and at the level of phonology. It is not known for sure whether such languages are literally unlearnable by humans, because of biases in their innate endowment for language, or if they are learnable with difficulty because of inefficiencies in the information packaging, or if they are easily learnable but humans happen never to be exposed to the right kind of data. There might be an opportunity to resolve these matters now with the rise of artificial language learning methodologies. "Impossible languages" of various kinds can be constructed to see if people have a harder time learning such languages in a smaller-scale laboratory setting.

How does the structure of conceptual knowledge of (say) events relate to the structure of linguistic representations?

Certain features of clause structure are widespread or universal, for unknown reasons. For example, many languages have grammatical subjects at the beginning of the clause, and very few have them at the end. All languages seem to group the theme argument with the verb, but not the agent argument. Are facts like these iconic reflections of the ways that humans conceptualize events, or are they idiosyncrasies of the language system? Can we find experimental ways to determine people's nonlinguistic representations of events in the world, and then compare the results with what is known about linguistic structure?

How much does a language learner generalize from one (construction, word, rule) to others? Along which dimensions does this happen? What determines this? Can one improve (second) language acquisition methodologies by making these avenues of generalization explicit for learners?

Comparative linguistics and linguistic typology has pointed to various implications that learners could in principle take advantage of to simplify the learning process. Which of these are valid across a full range of human languages? Do learners in fact make use of these opportunities that seem implicit in linguistic structure? In what domains do learners generalize conservatively (e.g., lexical knowledge?) and in what domains do they generalize more boldly (e.g. grammatical knowledge?)? At what level of abstraction are these generalizations best expressed? Are there differences in how learners of different ages generalize, and along which dimensions?

Second language teaching almost never makes explicit valid generalizations about morphology and syntax in the language being taught (e.g. patterns in the word order or agreement morphology). Could better results be achieved if students were explicitly guided to the valid generalizations that young learners seem to reach automatically?

How does a learner detect errors (such as over-generalizations) in language processing and acquisition? How do you know if you made a mistake, and what do you do with that knowledge?

There is an inherent paradox in language learning. If the parser can assign a structure to a new sentence, then there is likely nothing to learn about the grammar from that sentence. But, if the parser cannot assign a structure to a sentence, then how can the learner know what aspect of the grammar to change in order to parse a similar sentence appropriately at a later time. This paradox raises important questions about how parsers detect errors in processing and how these errors are used by learners to update their representations. Similarly, what is the import of the rare but attested exceptions to linguistic universals for language acquisition? For example, can the learner take advantage of the fact that the vast majority of languages that have verbs at the end of the sentence also have postpositions rather than prepositions, while still being able to learn a language like Persian (one of the 1% of languages that have final verbs and prepositions)?

SESSION 5

Language Design and Cognition

The last three decades have been a golden age for the experimental study of cognitive development in infants, toddlers and preschoolers. A general theme has been the relentless pushing back to ever-younger ages of demonstrations of at least the rudiments of many foundational representational capacities, capacities that were previously thought to emerge only many years later. For example, infants have been shown to predict the behavior of objects, perform numerical computations, and reason about the behavior of social agents. Participants presented evidence that hierarchical structure was present in the working memory organization of in 14-month-old infants. Evidence showed that infants use spatial and perceptual information, as well as conceptual knowledge, to parse an array into chunks, thereby increasing memory capacity. This work poses the questions: Are linguistic- and non-linguistic chunking separate processes? Can they be combined? Does language "invite" chunking prior to 14 months?

Further work continuing this line of investigation showed that preverbal infants could deduce from the different numbers of perceptually evident possible outcomes the relative probabilities of two contrasting classes of outcomes. It was argued that this demonstrated that infants already possessed the apparatus for deductive reasoning. It was further argued that reasoning from probabilities deduced from an enumeration of the different possibilities was a third alternative to the current contrast between reasoning from communicated probabilities and reasoning from probabilities induced from the experience of the corresponding relative frequencies.

This theme was continued by participants who first reviewed the evidence that numerical estimation and arithmetic reasoning is found in pre-verbal humans and non-verbal animals and that this non-verbal numerical reasoning plays an important role in human verbal reasoning about number. Recent work by Trommershäuser and Maloney was described, on the one hand, and Fuat Balci and Gallistel, on the other, showing that humans and even mice arithmetically combine intrinsic and extrinsic probabilities and pay-off magnitudes normatively in tasks where subjects must decide on an appropriate target to aim at within a 2-dimensional geometric space or a 1-dimensional temporal space. In these tasks, the choice of an optimal target requires not only a correct representation of the probabilities of different kinds of errors and different likelihoods of events and different magnitudes of consequences but also the correct arithmetic processing of the several quantities that determine the optimal target.

All presentations converged on the conclusion that a great deal of complex thought proceeds independently of language. Thus, in discussing the relation between thought and language, it is critical to have as accurate and full a characterization of non-verbal thought as possible. The domains of number, probability, space and hierarchical structure appear particularly favorable domains for such an inquiry because of the progress that has been made in understanding non-verbal thought in these domains. Impressive as this progress is, it is still very recent, and there is a vast range of questions in these domains that remain to be explored. An example of the coming together of linguistic/semantic analysis and the experimental investigation of non-verbal numerical representation is recently submitted research on the semantics of "most" by Pietrowski, Halberda, Lidz & Hunter ("Beyond truth conditions: An investigation into the semantics of "'most'"). Another relevant recent paper, also focusing on the semantics of quantifiers, is: Fox, D., & Mackl, M. (2006). The universal density of measurement. *Linguistic Philosophy*, 28, 537-586. These illustrate some of the possibilities of research on language and thought in the area of the representation of discrete and continuous quantity.

- What kind of reasoning structures are available to children early on?

- What are the non-verbal precursors of explicit logical reasoning (e.g., Boolean algebra) and how are they evident in non-verbal inference and behavior?

- How are these non-verbal reasoning and memory structures mapped into language? And how do they constrain language processing?

- The development of pragmatic knowledge and how it influences reasoning and the interpretation of language aimed at triggering reasoning. (Gary's point)

- What is the influence of domain general mechanisms (like working memory) on language?

- Turning this around, how do domain-specific reasoning (and representational structures) affect domain-general capacities and what is the role of language in mediating these effects

- What is the role of language in the development of number concepts?—with emphasis on numerical <u>reasoning</u> (reasoning about discrete quantity).

- The mapping from underlying systems for representing quantity to the use of quantifiers in language and the relation between reasoning involving quantifiers in language and more general non-verbal reasoning about quantity?

- How does the underlying non-verbal system or systems of quantitative and statistical reasoning and inference map into language and what is the effect, if any, of language on these non-verbal systems or reasoning?

- Are quantitative changes and individual differences in non-verbal representation of discrete and continuous quantity important in the course of development and in success in absorbing math and science reasoning in schools? And can these differences be ameliorated by training.

SESSION 6

Implications of Language for Education

The Reading-Language Connection

This talk examined several ways in which reading depends on language, from learning to read through becoming a fully competent reader.

Variations within and across writing systems:

Variations across writing systems with different organizational principles (i.e., alphabetic, syllabic, and logographic) and within alphabetic writing systems (e.g., those with shallow vs. deep orthographic mappings) relate to differences in how they are learned and how they are processed during reading. Two important principles in this area are (1) "The Language Constraint," which notes that writing systems map onto language, not meaning; and (2) "The Universal Phonological Principle," which states that all writing systems engage phonology at the smallest unit available in the writing system.

Writing systems control the details of how both phonology and meaning are obtained from the graphic forms. In alphabetic systems, phonology is activated along with orthography (i.e., letters activate phonemes) in a process characterized as "cascade style." Meaning can be mediated through phonology as part of the word identification process. In writing systems like Chinese, the character as a whole is identified and meaning is activated at the same time, following a threshold pattern. Meaning receives only diffuse activation through phonology because of the large number of homophones.

For learners who are learning to read in a second writing system, some recent findings from brain and behavior studies may support "The Assimilation-Accommodation Hypothesis," which states that learners will use L1 procedures for L2 if that is possible (an instance of assimilation). If necessary, they will learn new procedures specific to L2 (accommodation). Chinese readers, for example, are able to assimilate alphabetic reading, while alphabetic readers must accommodate to read Chinese.

Reading with alphabetic systems is affected by the nature of the orthographic mapping. Welsh, for instance, has a shallow mapping in which spelling is entirely regular and phonetic. English, in contrast, has a deeper orthographic mapping in which pronunciation is less consistent, and as a result, reading in English is more difficult to learn and takes longer to master.

Learning alphabetic reading:

There are several language-related obstacles for those learning to read an alphabetic writing system:
- In spoken language, meaning predominates over form, but that is not what the writing system is directly mapping.
- Support from the communicative and social context that is present in speech is largely absent in writing.
- Many learners have difficulty accessing the structure of language at the phonological level, which is the level that is mapped in an alphabetic system.

Recent advances emerging from behavioral and brain research on learning to read include increased understanding of the role of mechanisms related to decoding, the role of phonological awareness, the early emergence of phonology in children's writing, and the advantage of direct instruction in phonics. As people learn to read, they normally develop a "reading network" in the brain that involves increased activation in areas the support word identification and decreased activity in other brain regions. Learners with reading disability show hypoactivity in some areas of this reading circuit, which can be changed to some extent by phonological training.

Beyond learning to read:

Studies of more advanced development of reading skill indicate that word knowledge plays an important role. The "Lexical Quality Hypothesis" proposes that the representations that one has of words (how fully and flexibly specified they are in terms of orthography, phonology, semantics, etc.) determines comprehension. Higher quality lexical knowledge is better able to sustain growth in reading skill.

Empirically observed effects of lexical quality include more accurate and fluent word identification, greater resistance to word form and meaning confusions, more effective and stable learning of new words, and more facile word-to-sentence integration. These effects can be seen in both behavioral and brain measures.

Enhancing Language Development is a Matter of <u>Time</u>

This talk presented a model that has been developed through neuroscience and behavioral research over the last 30 years that looks at how infants learn how to map phonology, how they go on to map phonology into spoken language, and eventually, map language into reading. This research program seeks to understand the neurobiological and environmental influences that underlie large individual differences that are observed among children in speech, language, and reading development.

An important early observation was that many phonological deficits are associated with slow neural processing speed. Studying the processing of speech signals from a sensory/motor systems perspective yielded the critical insight that language impaired children have difficulty perceiving and producing brief, rapidly successive signals in the *time range of tens of milliseconds*. For instance, children with language and reading problems have great difficulty sequencing two tones that are presented with an inter stimulus interval less than 350 ms; but to be able to read and spell, the child must be able to hear small acoustic differences in words at the scale of 100 ms or less. When fast acoustic changes are extended in time, the discrimination performance of language-impaired children improves significantly (and looks similar to the performance of control subjects). Temporal dynamics in this "tens of milliseconds range" turn out to characterize many aspects of language and social interaction, as well as phenomena at the level of neural circuits (such as spike timing dependent plasticity, gamma oscillations, synchronous activity, and synaptic integration).

Studies of rapid auditory processing with infants indicate that processing thresholds at 7.5 months predict language comprehension at 36 months. RAP thresholds at 6 months are also a strong predictor of developmental language delay at three years. Studies using fMRI implicate left hemisphere frontal areas in rapid auditory processing.

Some individual differences among children in language and reading are also likely to have environmental sources. For example, Hart & Risley (1995) have estimated exposure differences among different socioeconomic groups in terms of cumulative words addressed to children on the order of tens of millions of words in the first four years of life.

The model presented integrates these various data into an experience-dependent developmental model in which temporal dynamics is a crucial connecting link between circuit-level mechanisms in the brain and fundamental components of language and reading. An important mechanism in the model is the idea is that neurons that "fire together nearly simultaneously in time wire together." An assembly of cells that repeatedly fires together in this way will form a neural representation.

Interventions based on this model—in particular "*Fast ForWord*" learning technology for language and reading—have yielded impressive results. For example, game-like computer-based training exercises for children that focus on improving perception,attention and memory of rapidly sequenced auditory stimuli, lead to changes in phonological representations, which enhances oral language abilities, which, in turn, improves reading, writing, and spelling. One intervention study, for instance, demonstrated that dyslexic students make dramatic gains in real-word reading, non-word decoding, and passage comprehension following a 4-6 week program of daily computer-based training. Additional intervention studies utilizing fMRI measures also demonstrate that, following training, the brain activity of dyslexics more closely resembles that of normal readers. The ability to improve learning outcomes through training based on this model also extends to children who are not classified as having specific impairments, allowing students from generally "at-risk" populations (e.g., inner-city public school students, those learning English as a second language, title 1 students etc) to close gaps in scores on standardized language and reading assessments and high stakes tests.

This program demonstrates the value of marrying scientific research models to interventions that achieve demonstrable impacts in students' learning in a large variety of settings. Accomplishing this requires some extraordinary efforts to scale up from small research studies to programs that have the potential to have national impacts on learning outcomes. New models for collaboration among scientists, business partners, and school districts have to be developed to make such work possible. How best to create and evaluate such models is an urgent area for research in its own right.

Language, Literacy and Science Learning

The first part of this talk focused on exploring relations and issues between science learning and language and literacy development, beginning with several examples of situations in which students face conceptual difficulties in science.

The first example was drawn from elementary school children's learning about biological concepts embedded in taxonomic classification systems. The typical approach to teaching about biological categories is to offer definitions of individual categories in the form of a list of characteristic properties (e.g., mammals have fur, feed milk to their young, have a backbone, etc.). Little instruction is aimed at helping students understand the logical properties of the conceptual structure in which these concepts are embedded or how to use the inferential power of the category structure to organize and extend their knowledge. For example, if told that some novel item is a *mammal*, a student who understands how that category fits into the larger conceptual system would be able to infer that it inherits the properties of all of its superordinate categories, such as *vertebrate*, *animal*, and *living thing*. But treating the learning as a static form of vocabulary learning doesn't help students gain access to this conceptual structure.

The second example examined early elementary school children's learning about material kinds and associated language for them in a science learning context. A concept of material kinds cuts across concepts of object kinds. Items that belong to the same material kind category share important properties by virtue of their material kind, but they can also vary in many ways. For example, items made of *plastic* can be of many colors, may be light or heavy, large or small, shiny or dull, transparent or opaque. A concept of material kinds is important in early science learning: science standards expect early school-age children to understand material kinds at the macroscopic level and to connect observable material properties to different material kinds as a preparation for developing understandings of matter and material at the molecular level. However, work with kindergarten children in classrooms indicates that many do not have a clear concept of material kinds and use words for material kinds as if they labeled properties (e.g., construing "metal" as meaning shiny or of a certain color). Also of concern is evidence that children from lower socioeconomic backgrounds may be at more of a disadvantage in understanding material kinds and material kind terms as they enter school.

The theme of children struggling to map scientific concepts to the appropriate ontological category also appears in recent work on older students' learning about concepts like light, heat, and electrical currents. Chi, Slotta and their colleagues have put forth the hypothesis that scientific concepts that are prone to robust, persistent misconceptions, such as many concepts related to force and energy, may involve an *ontological misclassification* on the part of the learner. Instead of understanding these concepts as involving emergent processes in dynamic, causally complex systems, learners may assimilate them to categories that treat them as material substances or properties. They argue that learning that involves having to reconceive the basic categorical type may involve especially challenging processes of conceptual change.

The presentation next turned to situations in which science learning may play a role in motivating and facilitating language and literacy development in children. Examples were drawn from preschool children involved in a science program in which they kept their own science journals. The science journals provide children with experience using writing and other forms of graphic representation to purposefully and accurately record observations and investigations. Children also practice "reading" back from their journals. Science learning contexts may promote the development of increasing complexity in both spoken and written language, as children try to make finer distinctions and to communicate ideas such as causal relations, comparisons, and temporal sequences.

Important research issues include investigating the similarities and differences between language and concept learning in science versus in everyday contexts or other domains. How are the language input conditions in science classrooms related to students' conceptual representations of the environment and their processes for constructing meaning? Is the language environment in science classrooms perhaps impoverished or incomplete compared to other language-rich situations —which may make new learning more difficult?

The final part of this talk focused on several issues related to building the capacity to do translational research connecting basic science on language, cognition, and learning to improving educational outcomes in school settings. Translational research involves more than conducting scientific studies in real-world settings: in entails a more fully developed process of research and development, carried out in cycles. Research approaches must also be adapted to cope in sensible ways with the complexity and variability inherent in educational settings. Finally, in order to build capacity to do translational research of national significance, we need to make investments in building the collaborative relationships, institutional bridges, and training and career pathways that can provide necessary infrastructure. Currently, the communities involved in basic and applied research, educational practice, and policy are fragmented, with little common ground.

Issues and Recommendations from Session 6

(1) Language and Reading
- Research on language and on reading has been artificially separated in many respects (funding sources, professional societies, academic departments, etc.). Similarly, there has been a separation between research involving impaired populations and other research in language and reading, even when the research is not necessarily clinical in orientation. New initiatives that would allow for the integration of the scientific study of language with the scientific study of reading—emphasizing a language to literacy continuum—would be most welcome and helpful in advancing the field. Research involving impaired populations can also inform basic science in language and reading.

- The time is ripe now to move beyond basic science focused on decoding processes. What is needed now is new research on the ways in which the linguistic system (from phonology to pragmatics) penetrates reading at higher levels of complexity. Well-developed lexical knowledge (including phonological, orthographic, semantic, and syntactic knowledge related to words) is productive and systematic and is related to both literate-like uses of spoken language and to advanced skill in

reading. To better understand skilled reading and how it is achieved, research on advanced lexical knowledge, parsing skills, and word comprehension processes is essential.

- Another research area that cuts across language and reading is looking systematically at the similarities and differences in understanding that is obtained through reading versus understanding obtained through spoken language.

(2) Learning Language and Reading in Schools
- Schools are in the business of teaching children how to read; they assume that children already have mastery of spoken language. (Indeed, a traditional view in linguistics is that children have essentially mastered their native language by the early school years and that all language learners are equally successful.) However, recent evidence indicates that there are significant individual differences in language skills among children, including differences that show persistent correlations with demographic characteristics. Many populations of American children, including but not limited to English language learners, do not have a sufficient spoken language system to support strong, smooth literacy development to high levels of skill. Research illuminating how to promote *extended* language development among school-age children and how to connect that to the development of reading skills (from basic to advanced) is much needed.

- We need to study sources of individual differences *as well as* the shared capacities that characterize most human learners. Sometimes relatively small differences in knowledge or processing lead to large differences in outcomes. We need research that will help us understand variance—where is it coming from, how is it related to basic mechanisms of learning, and what variables are predictive of later outcomes? (We are starting to see examples of variables measured in infancy that are predictive of outcomes years later.)

- Improving language and reading outcomes in education also entails developing ways to communicate to teachers a research-based understanding of how human cognitive systems develop and function. Too often courses designed for teachers in development teach basic Piaget and sociocultural theory, but very little about contemporary research in cognitive and conceptual development, cognition and learning, or language and reading from a learning and processing point of view.

(3) Bringing Language & Literacy into Relation with Learning in Other Domains in Schools
- Development of language and literacy skills continues well into the later grades and impacts students' learning and development in other areas. Language skill also broadens into larger *communication* skills, involving discourse requirements of various domains and handling and evaluating information in complex communication systems. Oral discourse (e.g., argument and evidence in science) and textual sources become much more complex in the higher grades and place greater demands on the learners' skills in both comprehension and production.

- Similarly, there is a need to connect and extend research in language and literacy into these more complex situations in order to provide a scientific foundation for making teaching and learning more effective. For example, studies in early language learning have developed ways to conceptualize and study how various kinds of inputs interact with learning and processing mechanisms to lead to systematic growth. Can these approaches be developed and applied to more complex language and literacy learning and to varied conceptual domains?

- We need to extend research on the interpenetration of conceptual representations and language to more complex learning domains that are important in education. How do language growth and conceptual growth interact across a variety of domains?

(4) *Understanding and Improving L2 Learning*
- Improving L2 learning and literacy is an urgent issue for millions of Americans. We now know more about the capabilities of infants learning more than one language. But many English language learners (or, more generally, second language learners) are beyond the age at which new languages are so readily learned. What are the learning mechanisms (cognitive, linguistic, and other) that can compensate for age-related declines in language acquisition abilities? Do adults potentially bring other skills that can support language learning? How can auditory representations be reorganized? What constitutes effective and efficient practice that helps more learners reach fluency? We need basic science to understand the development of learning trajectories. Are they the same for L2 as L1? Given a better understanding of learning trajectories, it is easier to design learning programs and environments to support progress along those trajectories.

(5) *Building Knowledge and Capacity for Effective Translational Research*
- Recent debates over prescriptions for how to conduct research aimed at improving learning in school settings have been heated and polarized. What has been missing from these debates is actual research on what *are* effective, efficient, and ecologically appropriate models for carrying out translational research and for developing researchers with the necessary sets of skills. Models imported from other fields (such as clinical drug trials that move from basic chemistry to pharmaceuticals) may not constitute best practices for relating basic research in learning and development to education. We need to understand what models there *might be* that can bridge back and forth between basic scientific research in language, learning, and cognition on the one hand, and the design and validation of learning resources, environments, and practices in educational settings on the other. Then we need to implement and evaluate those models in systematic ways.

- At the same time, it is important to build capacity to conduct translational research by developing pathways by which professional researchers can gain the knowledge and skills necessary to bridge back and forth between basic research communities and educational settings. Similarly, we need new models for creating sustained, mutual collaborations between research and practice communities that can provide the necessary infrastructure for carrying out translational research on a scale that could have national impact.

D. APPENDIX

Opportunities and Challenges for Language Learning and Education
September 5-7, 2007
National Science Foundation

Schedule:

Wednesday, September 5
4:00 PM – Refreshments
4:30 PM –
- *Welcome* (David Lightfoot AD/SBE)
- *Goals of Workshop* (Soo-Siang Lim)

5:00 PM – *Plenary session* - (David Lightfoot, SBE/OAD, Lila Gleitman and Patricia Kuhl)
6:00 PM – *Dinner and group discussion*

Thursday, September 6
LEARNING AND THE DEVELOPING BRAIN

First language learning and the prospects for bilingualism are known to look different at different points in the lifespan. The first two sessions discuss the mechanisms underlying language learning and their domain specificity. The session also compares monolingual and bilingual language learning.

9:00 AM – 10:30 **Session 1: Cognition and the Infant Brain**

*Key questions***:**
- What is the status of the "domain-specificity" debate regarding language development at the initial state and as learning progresses?
- What is the evidence for "critical" or "sensitive" periods for language learning and what are the contributions of maturation, learning, or both to this phenomenon?
- Does the machinery for acquiring language build on inherited mechanisms for acquiring other aspects of cognition, and if so, how?

Speakers:
9:00 AM – Elissa Newport (University of Rochester) — Language learning and invention over the lifespan
9:20 AM – Discussion
9:30 AM – Gary Marcus (New York University) — Language learning and domain specificity
9:50 AM – Discussion
10:00 AM – Patricia Kuhl (University of Washington) — Neuroplasticity for language in infancy
10:20 AM – Discussion

10:30 AM – Break

10:45AM – 12:15 PM **Session 2: Bilingualism and Early Second Language Acquisition**

Key questions:
- How does language learning differ in monolinguals and multilinguals?
- What is the role of cognitive development in shaping language acquisition? Does exposure to two languages alter cognitive skills?
- What can bilingualism and early second language learning tell us about cognitive and neural plasticity?
- Do bilinguals have two language systems or one? Does the answer depend on which level of representation is under discussion (lexical semantics, syntax, phonology)? And whether we are talking about comprehension, production or linguistic representations?

Speakers:
10:45 AM – Nuria Sebastian-Galles (University of Barcelona) — Early bilingualism and the limits of plasticity
11:05 AM – Discussion
11:15 AM – Jesse Snedeker (Harvard University) — Starting Over: Early second language acquisition in internationally-adopted preschoolers
11:35 AM – Discussion
11:45 AM – Janet Werker (University of British Columbia) — Speech perception in infant bilinguals-to-be
12:05 PM – Discussion

12:15 PM – 1:30 PM – Lunch

INPUT AND INVENTION

Language learning is obviously strongly dependent on the information available in the environment. The third and fourth sessions ask what happens to learning when the available information is radically reduced from the normal case; or when the properties of the database differ strongly, as in acquiring typologically disparate languages.

1:30 PM – 3:00 PM **Session 3: Effects of Limitations on Input and Invention**

Key questions:
- What is the theoretical leverage gained by the fact that children acquire language when the input is severely impoverished or when pertinent modalities are compromised?
- In what regards (if any) can we say that the trajectory of language learning is immutable?
- How closely related are the mechanisms of language learning and language change?

Speakers:
1:30 PM – David Corina (University of California-Davis) — How the brain processes language and gesture in the manual modality
1:50 PM – Discussion
2:00 PM – Susan Goldin-Meadow (University of Chicago) — Making language out of gesture
2:20 PM – Discussion

2:30 PM – Ann Senghas (Barnard College) — The contribution of successions of learners to the formation of language
2:50 PM – Discussion

3:00 – 3:30 – Break

3:30 PM – 5:00 PM - **Session 4: Cross-linguistic Differences and Syntactic Inference**

Key questions:
- What features of language are universal, and what features vary across languages?
- What does the pattern of variation imply about the abstractness of people's grammatical knowledge and its relationship to other mental faculties?
- How does abstract grammatical patterning facilitate the drawing of inferences in language acquisition?
- How does grammatical patterning affect the drawing of inferences in the online parsing of languages?

Speakers:
3:30 PM – Mark Baker (Rutgers University) — Constraints on syntax and universal design features
3:50 PM – Discussion
4:00 PM – Jeff Lidz (University of Maryland) — Acquisitional universals in syntax development
4:20 PM – Discussion
4:30 PM – John Trueswell (University of Pennsylvania) — Languages vary, parsing is universal
4:50 PM – Discussion

5:00 PM – *Dinner*

Friday, September 7

IMPACT OF LANGUAGE ON OTHER COGNITIVE SYSTEMS

In the final sessions we turn the issues on their head(s), asking how language learning may influence nonlinguistic aspects of cognition. The 5th session discusses possible effects of the (specific) language learned on foundational aspects of knowledge (particularly, numeric and spatial organization). The 6th session discusses mutual implications of language and literacy growth; and the potential for usefully translating research findings into large-scale applications in classrooms and public cultural institutions such as museums and zoos.

9:00 AM – 10:30 PM – **Session 5: Language Design and Cognition:**

Key questions:
- Does speaking a specific language alter or refine our notions of quantity and spatial relations?
- More generally, does the acquisition of linguistic representations that vary cross-lnguistically have implications for nonlinguistic reasoning throughout life?

Speakers:
9:00 AM – Luca Bonatti (International School of Advanced Studies, Trieste, Italy and University of Paris VIII) — Language and reasoning

9:20 AM – Discussion
9:30 AM – Lisa Feigenson (Johns Hopkins University) — Numerical cognition and language
9:50 AM – Discussion
10:00 AM – Randy Gallistel (Rutgers University) — Language and numbers
10:20 AM – Discussion

10:30 AM – 10:45 AM – Break

10:45 AM – 12:15 PM - **Session 6: Implications of Language for Education**

Key questions:
- How centrally do domain-general information handling capacities influence the acquisition and efficiency of reading?
- How centrally does underlying language skill influence the acquisition and efficiency of reading?
- How centrally do linguistic and orthographic variation influence the acquisition and efficiency of reading?
- How do language and literacy skills interact with teaching and learning in other domains (e.g., science)?
- How can we better understand and improve the process for conducting translational research with the aim of improving educational practice and student learning?

Speakers:
10:45 AM – Chuck Perfetti (University of Pittsburgh) — The reading-language connection
11:05 AM – Discussion
11:15 AM – Paula Tallal (Rutgers University) — Auditory processing and reading skill
11:35 AM – Discussion
11:45 AM – Chris Massey (University of Pennsylvania) — Language and education
12:05 AM – Discussion

12:15 PM – 1:30 PM – *Working Lunch with visit from Dr. Kathie Olsen, Office of the Director (invited)*

1:30 PM – 3:00 PM – *Breakout Sessions*
3:30 PM – *Closing Discussion*
4:00 PM – *Workshop ends*

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Initial set of questions and starting points for discussions:

Cognition and the Infant Brain
- What is the status of the "domain-specificity" debate regarding language development at the initial state and as learning progresses?
- What is the evidence for "critical" or "sensitive" periods for language learning and what are the contributions of maturation, learning, or both to this phenomenon?
- Does the machinery for acquiring language build on inherited mechanisms for acquiring other aspects of cognition, and if so, how?

Bilingual and Early Second Language Acquisition
- How does language learning differ in monolinguals and multilinguals?
- What is the role of cognitive development in shaping language acquisition? Does exposure to two languages alter cognitive skills?
- What can bilingualism and early second language learning tell us about cognitive and neural plasticity?
- Do bilinguals have two language systems or one? Does the answer depend on which level of representation is under discussion (lexical semantics, syntax, phonology)? And whether we are talking about comprehension, production or linguistic representations?

Effects of Limitations on Input and Invention
- What is the theoretical leverage gained by the fact that children acquire language when the input is severely impoverished or when pertinent modalities are compromised?
- In what regards (if any) can we say that the trajectory of language learning is immutable?
- How closely related are the mechanisms of language learning and language change?

Cross-linguistic Differences and Syntactic Inference
- What features of language are universal, and what features vary across languages?
- What does the pattern of variation imply about the abstractness of people's grammatical knowledge and its relationship to other mental faculties?
- How does abstract grammatical patterning facilitate the drawing of inferences in language acquisition?
- How does grammatical patterning affect the drawing of inferences in the online parsing of languages?

Language Design and Cognition
- Does speaking a specific language alter or refine our notions of quantity and spatial relations?
- More generally, does the acquisition of linguistic representations that vary cross-lnguistically have implications for nonlinguistic reasoning throughout life?

Implications of Language for Education
- How centrally do domain-general information handling capacities influence the acquisition and efficiency of reading?
- How centrally does underlying language skill influence the acquisition and efficiency of reading?
- How centrally do linguistic and orthographic variation influence the acquisition and efficiency of reading?

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- How do language and literacy skills interact with teaching and learning in other domains (e.g., science)?
- How can we better understand and improve the process for conducting translational research with the aim of improving educational practice and student learning?