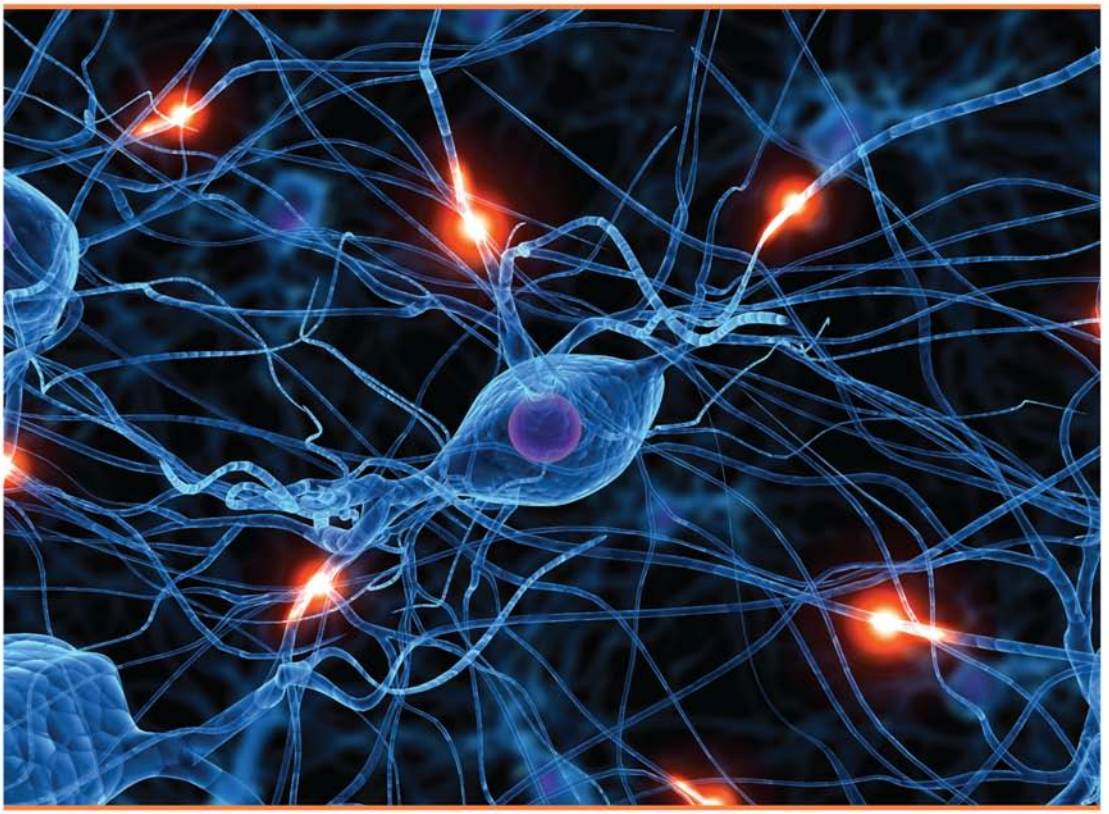
THE HANDBOOK OF PSYCHOLINGUISTIC AND COGNITIVE PROCESSES

Perspectives in Communication Disorders



Edited by

JACKIE GUENDOUZI | FILIP LONCKE | MANDY J. WILLIAMS

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Introduction

Jackie Guendouzi, Filip Loncke, and Mandy Williams

WHY THIS BOOK? SOME BASIC CONSIDERATIONS

This book is not intended to provide a definitive or extensive survey of the field of psycholinguistics; indeed, it would be impossible in a single book to cover this area comprehensively. Due to restrictions of time and space there are invariably research areas that we have not been able to include. Although this book does not require a background in psycholinguistics it does assume a basic knowledge of language and some familiarity with the field of communication disorders. Section I provides an overview of some of the theoretical approaches that have been influential in the field of psycholinguistics and cognitive processing. Although some chapters in this section focus on language processing in "normal" language, many of the authors consider what such theories and models have to teach us about communication disorders. Sections II and III of this book provide a selection of chapters that have drawn on theories from psycholinguistics and directly applied them to the context of specific communication disorders. Section IV considers theoretical approaches to language and cognitive processing in modalities (e.g., gesture) that have not traditionally been included in a book on psycholinguistics.

The field of psycholinguistics has yielded many diverse and competing theories over the years; some have dominated language research more than others. This book, however, does not take a particular stance in relation to any one theoretical framework, rather it is intended that readers draw their own conclusions as to the robustness of specific models or theories. It should be noted that many of the chapters in this book focus on Specific Language-Impairment (SLI) (Hayiou, Bishop & Plunkett, 2004) and aphasia. Both SLI and aphasia provided ideal populations for exploring language processing, because while impacting the individual's ability to use language in the past it was thought that they left other cognitive systems untouched (e.g., intelligence in SLI and comprehension in Broca's aphasia). However, as our knowledge of language processing increases this perspective is changing and, as work in this book will show, researchers in both aphasia and SLI are focusing on the role of other cognitive systems for more extensive explanations of how language develops and is processed within the brain.

It is important for the readers to approach this book with a critical eye; it is not the intention to provide answers or avoid conflicting theoretical positions. Research that explores theoretical issues or attempts to establish models is a continuing project that rarely arrives at a definitive answer. When asked why his theory had undergone so many changes (i.e., from Transformational Generative Grammar through to Minimalism), Chomsky noted that he considered his

research an on-going project (personal correspondence). Chomsky's point was that research does not necessarily reach a final conclusion, and can only improve through continual debate and revision if we are to produce robust theories.

PSYCHOLINGUISTICS: A HISTORICAL PERSPECTIVE

Psycholinguistics has always involved the art of finding models to help us understand why and how people speak, listen, read, and write. In some of the earliest reflections on language and speech, questions are raised that have kept the interest of scholars to this day. *Plato's Cratylus* (Sedley, 2003) discusses the relationship between words and their referents, an issue that has remained central both in developmental accounts of language (Piaget, 1929/1997) and its disorders and in the field of cognitive semantics (Evan & Green, 2006).

A general fascination with language, where it came from, its plasticity, and its disorders is reflected in discussions from the time of the Enlightenment on. Twentieth-century linguists explicitly trace back their line of thinking to Descartes's reasoning on the nature of ideas and mental functioning (Chomsky, 1966).

The 19th century was the time of the precursors of our understanding of the neurolinguistic underpinnings of language, starting with Gall's speculation of the brain's mental areas to Broca's and Wernicke's description of types of aphasia. Theories about localization have led to a rudimentary psycholinguistic theory, most notably reflected in the Wernicke/Lichtheim model (Caplan, 1987). This model assumed the existence of an (anatomically based) system of connections between brain centers. Problems in processing language were described as a breakdown, a deletion, or a distortion in the communication system. The Wernicke/Lichtheim classification may be considered the earliest model of internal linguistic processing, combining a brain localization approach with an information processing approach. The study of aphasia also led to the first classifications and distinctions between subcomponents of language and language processing. The terms motor aphasia, conduction aphasia, receptive aphasia, transcortical aphasia reflect an attempt to grasp both the internal organization of language and its interaction with the brain. For a century and a half, these distinctions have been a basis on which intervention rationales have been built. At the same time, already in the early twentieth century, the accuracy of these approaches was challenged and criticized.

These early neurolinguistic models served as a framework to understand language disorders in children: Until the 1970s childhood language problems were often referred to as *developmental dysphasia* (Wyke, 1978), a clear reference for a purported neuropsychological explanation of the phenomenon. These approaches initially have helped to conceptualize the relationship between language and brain.

Language as a system was the object of study of De Saussure's *Cours de Linguistique Générale*, published in 1916, This influential work marks the beginning of a strong structuralist view in language theory. Although De Saussure described language as rooted in historical "diachronic" development, he also

thought that a "panchronic" (p. 134) approach would be possible. This latter concept corresponds with today's "universal" view on language, a view that implies that explanatory models of language, language disorders, and language intervention should be valid and applicable across languages.

Today's schools of thought on language acquisition are often categorized in empiricism, rationalism, and pragmaticism (Russell, 2004). The influence of the empiricists in speech–language intervention was the most obvious in the 1950s and 1960s but remains powerful and obvious to this day. The empiricist approach apparently offers a framework that easily lends itself into concept of trainability and modifiability, which are central for interventions.

Rationalism tends to consider language as a semiautonomous self-developing system. An underlying hypothesis is that understanding the rules of languages helps to grasp language functioning and will lead to most effective interventions. In the period of linguistic structuralism, we find an interest in patterns that learners would use as reference frames to build language structures. One example here is the Fitzgerald key (1954), meant to make syntactic structures transparent and to help the student to "build" sentences according to visually laid out patterns.

In the past 20 years, the influence of linguistics on language intervention has waned. Its place is taken by a more cognitivist, emergentist, and information-processing oriented focus, as is the case for much of the entire field of psycholinguistics (Harley, 2008).

Interestingly, for a long time, the pragmaticists did not become a dominant factor in theory of speech, language, and their disorders until the 1970s, a time when interest in research areas such as early development, social interaction, and sociolinguistics started to rise. It changed the field of speech–language pathology, with a stronger emphasis on early and functional intervention, and especially involvement of communication partners.

The developments in the first decade of the twenty-first century maintain some of the old debates. However, many of the therapeutic approaches integrate and motivate multiple approaches. For example, Nelson (2000) proposes the "tricky mix approach," which strives to create multiple conditions that converge to increase learning. Nelson suggests that attention, motivation, and the right contrastive examples work together to make learning possible in typically developing children. Knowing this, the clinician's task is to recreate similar favorable conditions.

Throughout history, psycholinguistic theory and intervention have always benefited from clinical research, starting with Broca, to today's genetic studies, syndrome studies, and neuroimaging studies.

THE LANGUAGE DEBATE

In relation to the language debate, two theories had major effects on language research in the 1950s, Skinner's behaviorist model emphasizing the effects of reinforcement and environmental input (1957), and Chomsky's nativist (cognitive) approach (1957). Chomsky's work stimulated a search to discover what was going

on in the mind of the *ideal speaker* when forming a sentence. Thus the emphasis of research in linguistics shifted toward the study of a speaker's *competence* (rather than their *performance*) and the pursuit of uncovering the underlying mechanisms of language. Chomsky's work also highlighted the role of biological factors in language by suggesting a language acquisition device (LAD) innate to humans. Chomsky's subsequent critique of Skinner's *Verbal Behaviors* (1959) led to nativist approaches becoming the agenda of most linguistic programs during that period. Chomsky's work was also highly influential in driving language acquisition research at that time.

However, despite the primacy of Chomsky's work during the 1970s and 1980s, work in language acquisition has continued to explore both biological factors and environmental influences. Indeed, most current theories draw on the interaction between biological factors and socioenvironmental factors when considering how language develops across the life span. Furthermore, advances in neurosciences and computational modeling have resulted in a research agenda focusing on the notion of language as an emergent property of competing systems. However, the debate is far from over in the field of communication disorders and, as will be shown below, there is still a case in SLI for a more modular approach (see van der Lely & Marshall, Chapter 20).

THE STRUCTURE OF LANGUAGE

When studying language it is typically dissected into its component parts. However, it is important to note that this is an artificial construct; that is, the degree to which any language system (e.g., morphosyntactic, semantic) is independent of other systems is debatable. Perhaps a good analogy is that of driving in a car; in order for the car to move all the component parts and systems of the car need to be operating. In addition, a driver is required to coordinate the exercise; thus one event "driving down the road" is the sum of many interrelating and synchronized systems. However, if the car breaks down and stops moving we need to establish what system or part failed in order to repair the damage. A global failure may be due to a minor failure in the electrical system rather than engine damage itself, but in order to diagnose the problem, the mechanic has to have a working knowledge of each individual system and how it interacts with other systems.

A similar situation occurs with language; in order to produce an utterance, a variety of cognitive systems are brought into play. For example, when hearing an acoustic stimulus (e.g., a request for coffee) a listener initiates several cognitive systems; first he or she has to focus on the speaker (attention), retain the information heard (working memory), interpret the acoustic signal (auditory discrimination), parse the utterance (morphosyntactic system), and then comprehend the message (semantic and conceptual systems). In addition, there is a need to coordinate visual stimuli such as gesture and facial expressions into the interpretation of the utterance. And yet this simple action takes place in a split second of time as a holistic event and listeners are not aware of the separate systems operating to process the utterance. One is only aware that someone requested a cup of coffee.

In academic programs focusing on communication disorders, language has traditionally been studied in a way that is modular in its approach. For example, language processing is often taught within courses relating to specific disorders (e.g., motor speech disorders or child language disorders) and is typically divided up into the following areas: neurobiological correlates of language, the motor system, the phonological system, the grammatical system (morphosyntax), the semantic system (the lexicon), and pragmatics. However, as the chapters within this book will demonstrate, other equally important systems may play a major role not only in language processing, but in how we view interventions. These systems include attention, working memory, auditory discrimination, visual processing, gestures, paralinguistic features, and facial expressions. If there is a central theme to this book, it is the notion of language as an emergent property of dynamic interacting systems.

SECTION I: MODELS AND THEORIES

Models and theories drive research, yet as noted above, language processing is not often an integral part of many communication disorders programs. This may be because it is not often easy to see the connection between theory and practice, particularly in relation to psycholinguistic models. However, as Stackhouse and Wells (1997) have noted, although traditional linguistic approaches offer very detailed descriptions they do not always offer adequate explanations for the development of linguistic systems in individuals with disorders. A psycholinguistic approach to intervention in speech and language disorders "embraces the goal of explaining speech impairment" (Baker, Croot, McLeod & Paul 2001, p. 686). In their review of both Box-and-Arrow models and Connectionist models, Baker and colleagues consider the implications of such models to clinical practice and suggest that psycholinguistic approaches to understanding communication disorders will ultimately help identify more effective treatments.

As can be seen from Locke's work (Chapter 1), explanations that integrate biological factors with social and environmental factors are currently more common than the either/or explanations of the last century. Locke examines the evolution of language and raises questions relating to both social and biological needs and their role in the process of language acquisition. He suggests it may be hard to disentangle these two driving forces in the development of human language and offers explanations for gender and cultural differences within and across language use.

Interactionist approaches such as Locke's consider both the biological bases of language, and the role the child's environment plays in sculpting the brain for language. MacWhinney and colleagues (1982) suggest a functional account of language learning that proposes alternative interpretations compete online during language processing. In Chapter 2, Presson and MacWhinney elaborate on the Competition Model and show how it can offer explanations in the cases of SLI and aphasia.

Abrams and Farrell (Chapter 3) consider both age-related biological factors and social aspects of language to discuss the underlying differences in language

use in later life. They review research that has explored both comprehension and production of language in older adults and conclude with a discussion on directions for future research that might improve functional communication with older interlocutors.

Other cognitive systems such as attention and working memory play an important role in the process of both acquiring and processing language. In Chapter 4, Cowan offers an overview of both his own work and that of Baddeley (1986) to show how attention and working memory interact both with each other and with other language systems such as verbal syntax. He also raises questions relating to work (Caplan, Waters, & DeDe, 2007) that might be considered as deriving from a Chomskyan paradigm that links working memory specifically to syntax.

Advances in brain imaging techniques have led to the study of neurobiological aspects of language processing moving beyond merely describing structures that are thought to correlate with specific areas of language. In Chapter 5, Kahlaoui, Ska, Degroot, and Joanette first review imaging methods and then consider what each method can tell us about the neurobiological bases of semantic processing. Kutas, DeLong, and Kiang (Chapter 6) note that, when compared to other neuroimaging methods, electrophysiological studies are not only economical but they can provide a potential "window" on the brain's language related processing operations. Kutas and colleagues provide an overview of studies that have used Event Related Potentials (ERPs) and then consider what such paradigms reveal about normal and abnormal language processing. In Chapter 7, Friedrich compares mathematical models and artificial neural networks (connectionist models) to brain imaging techniques. In particular, she reflects on what ERP studies can contribute to our knowledge of early word learning.

As noted above, current models and theories in psycholinguistics consider how language functions as a system, particularly how individual language systems influence and, are influenced by, other systems. Many theories have drawn on what we know about neural networks and artificial intelligence to develop new models of language processing. Such research has moved away from trying to link individual centers (or modules) of the brain to specific aspects of language (e.g., lexicon, syntax), to suggest that language is subject to parallel processing within interconnected networks. Thus, rather than associating a lesion in a specific region of the brain with a particular language deficit, a connectionist approach would consider the extent to which a disturbance in one area of the network might affect other levels of the language system.

Research based on connectionist approaches have been very influential in the field of communication disorders, particularly when considering acquired disorders of language and cognition such as aphasia. In Chapter 8, Dell and Kittredge apply a connectionist approach to the context of aphasia and other communication impairments and suggest a cooperative view of language that argues for models based on interaction between processing parts. Roelofs (Chapter 9) considers vocal utterance production from the standpoint of Wernicke's classical model to the current version of the WEAVER++ model. He suggests that future research should draw on such models to develop intervention methods.

In Chapter 10, Shelley-Tremblay reviews some of the more influential and widely researched theories of semantic representation. He focuses attention on models of semantic memory, word identification, and semantic priming to assess the efficacy of local theories, feature-based theories, and distributed models.

Longworth and Marslen-Wilson (Chapter 11) examine language comprehension from the perspective of what occurs within the milliseconds it takes the brain to recognize individual words. They explore this aspect of connectivity and language processing through a clinical example and go on to suggest a neurocognitive model that contrasts with the classic model of a single processing pathway. As they suggest their model forms part of the current "Words and Rules" debate in cognitive science.

Another form of language use that has been noted in people with aphasia and other neurogenic disorders, such as dementia, is the use of formulaic language (fixed phrases). As Van Lancker Sidtis (Chapter 12) point out formulaic language has been both neglected and misunderstood. However, she claims, it has finally come into its own and they cite a growing body of recently published research studies. Van Lancker Sidtis notes that formulaic expressions operate differently to the rules of grammar for novel expressions, suggesting such forms are reliant on instantaneous rather than incremental memory processes. The study of formulaic language has implications and relevance to models of language competence, language learning, and language loss in neurological disorders.

In Chapter 13, Yates notes that single word recognition and similarity in phonological and orthographic forms are issues of cognitive psychology that have been widely studied. This area of language processing is highly relevant when we consider the issue of literacy and language processing. Yates considers models of Interactive Activation and Competition (IAC) that have been influential in examining the effects of inhibition by words that have orthographic or phonological competitors.

Phonology has been an area of psycholinguistics that has been in the foreground of research in communication disorders for some time. Given that articulation therapy has often been seen as the "bread and butter" work of speech pathology, it is hardly surprising that theories of phonology have been of interest to researchers in communication disorders. The move away from linear phonetics and phonology to nonlinear approaches (e.g., autosegmental, feature geometry, and optimality theory) has led to a great deal of research in constraint-based phonology. However, this area of psycholinguistics has been highly debated in the research arena, particularly in relation to the issue of phonological representation. Tatham and Morton (Chapter 14) consider classical phonetic approaches to speech production in comparison to a cognitive approach and examine theories that see speech as a continuous dynamic process.

In contrast, Rutter and Ball (Chapter 15) overview theoretical approaches in phonology that have moved away from the traditional notion of considering that a child stores a representation of his/her ambient language's system of sounds. Such theories suggest that we have exemplars of each sound that enables processing of speech sounds to be carried out online. Ziegler, Ackermann, and Kappes (Chapter

16) draw on neurophonetics and brain imaging to examine the processing chain from abstract phonological representations to intended motor acts (articulation). As Ziegler and colleagues note, there is considerable disagreement about the separation of phonological and phonetic encoding and therefore further research incorporating a neurological approach is needed.

SECTION II: DEVELOPMENTAL DISORDERS

Chapters in this second section draw on many of the theoretical paradigms that have emerged from psycholinguistics and apply them to specific communication disorders. The authors of these chapters develop their own current work to exemplify the relevance of using theoretical constructs to better understand particular disorders and to provide evidence-based practice.

(Central) Auditory Processing Disorder (C)APD is a highly contentious area in the field of communication disorders. No researcher would deny the existence of a central area of the brain where auditory information is processed. However, whether or not an individual can have a disorder that is specific to the central auditory processing system and thus affects language development is hotly debated issue. In Chapter 17, Shive and Bellis examine current conceptualizations of Auditory Processing Disorder and the controversy surrounding (C)APD. They discuss the diagnosis of (C)APD and the neurobiological sequalae associated with the disorder. Burns (Chapter 18) considers this issue in a broader sense focusing on temporal processing in children with language disorders. She draws on the work of Tallal and colleagues (1981) to explore the issues of bottom-up and top-down processing and their role in language interventions.

In Chapter 19, Grela, Collisson, and Arthur provide a comprehensive review of theories that attempt to explain SLI. As they suggest, the classification of SLI was originally intended to differentiate between other language related conditions (e.g., mental retardation). Grela and colleagues suggest that children with SLI are a heterogeneous population with different underlying causes to their language deficit. In contrast, the work of van der Lely and Marshall (Chapter 20) make the case for a subgroup of children with specific problems in the morphosyntactic and phonological systems. Van der Lely has labeled this group Grammatical Specific Language Impairment (G-SLI). In a book that deals with current research into language processing there will invariably be an emphasis on connectionist approaches, but there is still a need to consider research such as van der Lely's because it points to a domain specific aspect of disorders such as G-SLI.

Storkel (Chapter 21) examines a subset of properties of lexical items that are typically incorporated within both adult and child models of spoken language processing. She considers several models of the lexicon in relation to normal development before applying these theories to the case of SLI.

Howell (Chapter 22) addresses the question of whether fluency disorders can be seen as a phenomenon that is caused by a breakdown in the motor system, which is assumed to operate independently of the language system, or whether the language system is involved. His research suggests that the problem could result

from the processes by which language and speech are coupled. His theory of stuttering contrasts with two alternate theories, the covert repair hypothesis (Kolk & Postma, 1997) and the vicious cycle (Bernstein Ratner & Wijnen, 2007), theories that both draw on Levelt's model of speech production (1983, 1989).

The final three chapters in this section of the book apply theories of language processing to bilingual contexts. Armon-Lotem and Walters (Chapter 23) consider bilingual processing models before applying their approach to the contexts of bilingual SLI and schizophrenia. They suggest a way to approach assessment in cases of bilingual communication disorders and offer a way to analyze data from individual profiles to group patterns.

Bernhardt, Stemberger, Ayyad, Ullrich, and Zhao (Chapter 24) outline major characteristics of nonlinear phonology and consider the implications for clinical applications across four languages (English, Arabic, German, and Chinese). In Chapter 25, Restrepo, Morgan, and Smyk consider how SLI and bilingualism are at the crossroads of linguistic and psycholinguistic accounts of language. They discuss how bilingualism interfaces with SLI from the theoretical position of Dynamic Systems Theory and review research evidence of SLI in bilingual populations.

SECTION III: ACQUIRED DISORDERS

Chapters in this section focus on acquired disorders of language. Varley (Chapter 26) notes the historical divide between generative approaches and more diverse work in cognitive and neurobiological approaches to language disorders. She explores conceptualizations of the processes involved in speech programming, in particular, a dual mechanism model and its implications for acquired apraxia of speech.

McNeil, Hula, and Sung (Chapter 27) suggest that the traditional approach to researching and classifying aphasia has been framed within the anatomically based *centers* and *pathways* paradigm; a direct descendent of the Wernicke/Lichtheim model. They outline many attributes of aphasia that are untenable with this model and they discuss the role of working memory and particularly the executive attentional component of working memory as the source of the language impairments in persons with aphasia—constructs that are consistent with general attributes of aphasia and that are supported by the research directed toward these alternative cognitive mechanisms.

Lundgren and Brownell (Chapter 28) show how theory can be applied to clinical practice by reviewing a training program for brain injured adults that is based on Theory of Mind (see also Chapter 35). Lundgren and Brownell suggest that theory of mind performance can be differentiated from performance in other cognitive domains. In contrast, Togher (Chapter 29) examines the issue of cognitive disorganization in people with brain injuries and its effects of communication. She focuses on the heterogeneous nature of communication breakdown in brain injury and notes that theoretical advances in language processing are being translated into novel treatment approaches.

In Chapter 30, Shelley-Tremblay draws on his previous chapter outlining theories of semantic processing to provide further support for the hypothesis that many of the problems in dementia and aphasia are related not only to the representation of semantic information but also with the allocation of attention resources. He reviews ERP studies of dementia and relates their findings to the Center Surround Model (CSM). Finally in Chapter 31 of this section, Centeno examines the case of aphasia in bilingual individuals. In particular, he explores whether the monolingual and bilingual brains are organized differently.

OTHER MODALITIES

Last, but no means least, we have included a section on nonverbal aspects of communication processing, an area that has often been regarded as outside the field of language processing. This includes aspects of communication such as gesture, face processing, sign language, and augmentative and alternative communication (AAC). As McNeill and Duncan argue in Chapter 32, gesture is an integral part of the language system and should be treated as such. Indeed, gesture was likely the primary system of human communication to which later verbal forms were added.

Sign language is another area of language processing that should be included in any book relating to communication disorders. In Chapter 33, Hickok and Bellugi examine evidence from sign language to theorize on the neural organization of language, while in Chapter 34, Vermeerbergen and Van Herreweghe review the structure of sign language and examine research that explores the way in which sign language is processed.

In Chapter 35, Barnes and Baron-Cohen review theories that look at narrative in terms of the ability to ascribe mental states to others in the social world (Theory of Mind). They then present the results of a study that examined the way that individuals with and without Autism Spectrum Conditions (ASC) view film clips and produce narratives about what they have seen.

Although psycholinguists have been investigating the area of pragmatics since the 1970s, it is only recently that researchers have begun to explore this topic experimentally (see Novek & Sperber, 2004). Ryder and Leinonen (Chapter 36) draw on Relevance Theory (Sperber & Wilson, 1995) to explore the communication of children with language disorders. Although emerging from work in pragmatics, Relevance Theory is a psychological theory of communication that lends itself to experimental design.

Finally, we have also included an overview (Loncke, Chapter 37) of an area that is often overlooked in texts covering language processing, the psycholinguistics of AAC. The AAC is an area of communication that raises many questions for further research into how AAC users incorporate the language system to process other modalities of communication.

We hope this book will introduce students and new researchers in the field of communication disorders to an area we feel is an important area of language study. More importantly, we hope it will stimulate debate and encourage further

research into the topics presented here. We have tried where possible to include contributors who are leaders in their field or who have grounded their work in theory to investigate questions relating to communication disorders. It is deliberate that many of the chapters in this book have overlapping interests and we encourage readers to cross-reference the different perspectives of the authors in pursuing an understanding of this fascinating field.

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Section I

Some Basic Considerations: Models and Theories

1 The Development of Linguistic Systems: Insights From Evolution

John Locke

INTRODUCTION

About a year ago I encountered a statement that, on the surface, appeared to be eminently reasonable. It expressed the idea that linguistics may be able to grapple with evolutionary questions—a matter that has drawn new scholars at an exponential rate over the last 20 years—but not until linguists have come to a decision about what language is. One might suppose that similar thinking applies with equal force to development. How, according to the logic, can we possibly understand the development of language until we find out precisely what it is that develops?

There are at least two problems with this. The first is that it ignores the considerable merits of "reverse engineering." According to this methodology, we improve our understanding of language, and any other complex behavior, when we take it apart. Since language is a biological trait, this means, among other things, seeing how it was put together in evolution and comes together in development.

Reverse engineering contrasts sharply with the traditional approach. From the dawn of research on language development, the *leitmotif* has been to document the appearance of behaviors that seemed relevant to language or were actually linguistic. It was never clear what we might gain from knowing what these behaviors do for infants at the time of their appearance, if anything, nor was there an obvious way to find out. As a consequence, development was seen, by default, as something that "happens" to infants, not as an unfolding of new functions that contemporaneously benefit the infant and might, to some extent, be under the infant's own control.

There is, as mentioned, a second problem with the primacy of formal definition. It is a classic confrontation between internal evidence and external evidence. What if language met a series of discipline-internal tests but was later found to resist all attempts to characterize its emergence in the species and the child? Would we reject the principles of evolutionary and developmental change that have worked, with some success, for other traits, purely on the basis of the language experience; or would we argue that language is so unlike other complex traits that it emerged according to entirely different principles—ones unknown to biologists? Where

evolution is concerned, one could argue that, to some extent, this has been happening for some time and is still taking place (e.g., Chomsky, 2002).

If we are more likely to understand language by looking at its evolution and development, I think we will be unusually advantaged if we look at the interactions that have occurred, and that still occur, between these processes (Locke, 2009). Evolution and development are collaborative. They feed each other. If we treat them independently, the result can only be distortion of each process and of the faculty of language itself.

I will begin here with a brief summary of evidence that, in its totality, indicates that language is a biological trait, as Steven Pinker (1994) famously declared, not a cultural trait or the product of some form of instruction. The emergence of "language" in the infant will be seen as the development of adaptive mechanisms that take in socially and linguistically relevant behaviors—among other "duties" that they might have—store this material long enough to extract organizing principles, and use the principles to generate novel utterances. This much relates to the code of language, but development also includes the activation of rather different mechanisms that oversee the application of linguistic knowledge by, and for the benefit of, the speaker in a variety of biosocial contexts. In the next section, I will examine a view of language that is widely shared in the linguistic community, one that has been unhelpfully influenced, paradoxically, by a factor that plays no role in its development—formal instruction—and by the cultural variables responsible for instructional institutions. In the succeeding section, I will ask what actually evolved, or could have evolved, according to a selection-based account in which observable behaviors enhanced fitness. The emergence of *these evolved traits*, I will submit, requires a new theoretical framework, one that provides a biological context for the development of neurological, cognitive, and social functions, as well as linguistic ones. Life history provides such a framework, partly because it enables one to trace critical effects of evolution on development, and partly because it is receptive, in principle, to reciprocal effects of development on evolution. In the end, what is needed is a strict evolutionary ↔ developmental ("evo-devo") approach or, better, evo-devo-evo-devo …

LANGUAGE IS A BIOLOGICAL TRAIT

Language evolved in humans uniquely and develops in the young universally. A strong biological endowment was suspected a half-century ago when it was noted that infants acquire linguistic material rapidly in view of the seeming inadequacy of ambient models and the rarity of teaching or corrective feedback (Chomsky, 1959, 1980). Later, it was observed that infants appear to invent aspects of linguistic structure, as when pidgins are transformed into creoles (Bickerton, 1984) and deaf children reconstruct sign languages that have been awkwardly modeled by their nonnatively signing parents (Senghas & Coppola, 2001; Senghas, Kita, & Ozyurek, 2004). If only a portion of the language known to these individuals originated outside of their heads, then the rest, it has been assumed, must have come from the inside.

One consequence of the strong role played by *internal* factors is a course of development that appears relatively uneventful to observers, who tend to think that language, given its size and complexity, should require more *effort* than is actually witnessed. In some societies, of course, parents do direct a great deal of talk to their infants, and speak more slowly, or with exaggerated prosody; and they usually supply the names of particularly salient objects, actions, and concepts. These practices, or the disposition to engage in them, may not facilitate language learning (Hart & Risley, 1995; Nelson, Carskaddon, & Bonvillian, 1973), and may be no more helpful than merely modeling speech (Akhtar, 2005). But they cannot be essential, since infant-directed speech is rare in some societies (Ochs, 1982), and it is unusual—in any culture—for caregivers to do much that is specifically tutorial. Chomsky saw this disparity between knowledge and experience as "the most striking fact about human language." Accounting for it, he wrote, "is the central problem of linguistic theory" (Chomsky, 1967, p. 438).

For Chomsky, "knowledge" is linguistic grammar, the primary function of which is cognitive (2002). But "speech," as de Laguna advised, "must be envisaged … as performing some objective and observable function, before one can hope to discern the factors which have led to its development" (1927, p. 10). Whether she meant to exclude "language" is unclear, but the distinction is salient, for speech does things that language does not do, and cannot do. These observable functions, we may assume, relate to the ways that people *use* language.

Some might consider questions of use to be outside the purview of language scientists. Others would surely rebut this contention, claiming that pragmatics, conversation rules, and other principles of usage are among the critical components of language. This division between lexical and grammatical knowledge on the one hand, and the social and communicative applications of language on the other, is one of the issues about which evolution and development have something important to say. But there is another issue here. Since we are dealing with an evolved trait, we must assume that the function of language determined its form in evolution, and to some extent continues to do so in development (Studdert-Kennedy, 1991). Since language evolved, it should be possible to locate cases where function was responsible for something about the physical nature of speech or ways of speaking.

LANGUAGE IS WHAT LINGUISTS SAY IT IS

Speaking is one of the more dynamic forms of human action that one can imagine, one so dynamic that critical elements fade as rapidly as they appear (Hockett, 1960). Linguistics, however, has encouraged its followers to regard language as an object, a stable cache of knowledge about grammar that is stored in the brains of all normal individuals who are socially reared. Although Chomsky (2002) is a strong proponent of this view, one can hardly blame him for the objectification of language. He was born four years after Jespersen complained that language was being viewed as a collection of "things or natural objects with an existence of their own" (Jespersen, 1924/1963, p. 17). Later,

objectification troubled Lakoff and Johnson (1980), who commented that words and sentences were being seen as "objects that have properties in and of themselves and stand in fixed relationships to one another, independently of any person who speaks them or understands them" (p. 204). This depersonalized view of language also concerned Linell (2005), who commented that when linguists consult their intuitions on matters of linguistic practice, they encounter "an inventory of forms, and rules for generating forms" (p. 4). Recently Hermann (2008) called the language-as-thing metaphor a "systematically misleading expression." He suggested that it is time for a better metaphor, one that captures the fleeting and subjective nature of speech.

How did language come to be seen as an object? Most scholars blame literacy training (Goody, 1977; Jespersen, 1924/1963; Lakoff & Johnson, 1980; Linell, 2005; Olson, 1994). When people learn to read, they experience a cross-modal phenomenon that is on a par with hearing a taste or touching an odor. They *see words*. They also see spaces between the words in a sentence. If the language is alphabetic, they are conditioned to notice the sound symbols—hence the sounds—that make up words, and they additionally discover the spaces between these symbols. From capitalization and punctuation, their attention is further drawn to sentences and phrases.

It is instructive, I think, to consider the things that readers do *not* encounter on the printed page. They see no prosody, no voice quality, no tone of voice, no rate of speaking, no loudness, no vocal pitch, and no formant structure. As a consequence, they get little or no reliable information about the sender's identity, temperament, emotionality, attitude, social class, place of birth, height, age, sex, physical status, or hormonal status. These personal factors relate to important fitness variables such as social dominance and reproductive status, and therefore provide the raw material for evolutionary accounts of vocal communication and spoken language.

With speech literally off the page, it is not surprising that language would come to be conceptualized as whatever is left behind. But there is more, for literacy training is usually followed by 5 or 6 years of language arts instruction. Students learn the parts of speech. They are taught to recognize and correct sentences that are ungrammatical. They learn about topic sentences and paragraph structure and the importance of making sense. They become conscious of rules that they inferred in infancy and memorize others. It is a festival of linguistic prescription.

Predictably, literacy training affects the way individuals process linguistic material. In a study carried out in Portugal, subjects who were literate or culturally illiterate were enrolled in a lexical decision task. Concurrent brain scans revealed unequal activation of the right frontal opercular-anterior insular region, left anterior cingulate, left lentiform nucleus and anterior thalamus and hypothalamus in the two groups. In a separate repetition task, the illiterate subjects substituted real words for nonsense constructions 25 times more often than the literate subjects (Castro-Caldas, Petersson, Reis, Stone-Elander, & Ingvar, 1998; also see Ostrosky-Solís, Ramirez, & Ardila, 2004).

This work relates to the ways people think about and process language, but there are also huge measurement issues. Language is learned in one modality and tested in another. The result is a personal problem for good speakers who are poor readers, and a theoretical problem for scholars who wish to find out what the evolved trait of language actually entails (Locke, 2008a).

But it is not just a matter of conflicting modalities. Most standard measures of language are, in fact, evaluations of the ability to use linguistic knowledge *to solve cognitive problems* (e.g., anagrams). The relevant skills are usually classified as "metalinguistic." Individuals with metalinguistic ability are able "to deliberately reflect on and manipulate the structural features of spoken language" (Tunmer & Cole, 1991, p. 387). This ability does not naturally emerge from the biological trait of language. If untrained in literacy, normally speaking adults tend to perform poorly on metalinguistic tests (Morais, 2001; Navas, 2004; see Locke, 2008a for other references).

It is serious enough that academic training affects the way people process and use language and that scientists measure it, but instructed material forms a significant portion of the language that is *tested*. Recently, I analyzed some data collected over 90 years ago on an unusual population—the canal boat children of early 20th century England (Locke, 2008a). These children lived on boats, in constant interaction with their parents and siblings, but rarely went ashore or set foot in a classroom. Governmental concern brought about the evaluation of a number of the canal boat children using a standardized intelligence test. This instrument revealed that at 6 years, when all tests were necessarily oral, the canal boat children scored in the normal range on language measures. But as the years went by, they sank further and further below the norms on four oral subtests—language comprehension, vocabulary knowledge, sentence construction, and verbal fluency—while displaying age-appropriate abilities on nonverbal subtests. The children were not forgetting what they had learned about language, they were simply not improving at the same rate as their academic peers in the areas affected by instruction. At 12, their scores on the oral subtests approached zero. The results thus dramatized the fact that language, as tested, is heavily influenced by what children learn in schools.

All of these assessment, neuropsychological, and linguistic problems are significant, but they converge upon a hugely important biological issue. For it appears that formal training transforms language from a trait that was selected to a talent that is instructed (Locke, 2008a). A talent, according to Simonton (1999), is "any innate capacity that enables an individual to display exceptionally high performance in a domain that requires special skills and training" (p. 436). Competitive chess is considered a talent. No language scientist would assert that the faculty of human language *requires* instruction—we have already seen that it does not—but my claim here is that language, as it has come to be defined, *reflects* it. Formal instruction makes a talent out of a trait.

Having said all of this, I would not be particularly worried about these issues if my focus were the development of language in preschool children, as it once was (Locke, 1993a). But why stop studying the development of language (or anything

else) just because the child starts school? Of course we know the answer—at this age, they know enough language and are cognitively mature enough to learn to read and take classroom instruction. But an evolutionary approach is necessarily blind to cultural inventions. We will see below and in the section on life history that the trait of language continues to develop well into adolescence.

LANGUAGE IS WHAT EVOLVED

There are some 6,912 natural languages in the world (Gordon, 2005). All of them are spoken. If just one of these languages was produced in a different modality, the incidence of nonvocal languages would be about 0.0001%, but the true incidence is zero. We do not know why the vocal modality is so robust, possibly because few scholars have taken the question seriously, or even recognized that this is a question that needs to be answered (Locke, 1998a). But it is possible that when we know what caused our ancestors to "go vocal" we will be a step closer to an explanation for language itself.

In the past, the higher primates have seemed to give us very little to work with. For some time, it appeared that apes were more gestural than vocal (Locke, 2001a). Even in recent years, linguists have looked at the ape literature and found little more than "a few calls and grunts" (Newmeyer, 2003). How, under the circumstances, could language-as-mental-code have entered the heads of their successors? If we are tacitly discouraged from addressing the modality of language, the medium that contains all of the physical cues, how do we get to the object? Framed in this way, the problem seems insoluble.

Fortunately, we have about six million years to work with—the time elapsed since the *Homo* line diverged from that of the apes. In that period, there were significant environmental changes that brought about a number of different adaptations. As we will see, two that were heavily deterministic were the shift to bipedalism and increased social complexity. It is also the case that the cognitive and communicative abilities of our last common ancestors were closer to those of humans than has generally been thought. For one thing, the functional value of ape vocalization has been greatly underestimated. While linguists were busily noting the vocal poverty of apes, animal behaviorists were conducting field studies that revealed unsuspected vocal riches. It is now clear that apes' calls and grunts carry a great deal of information about the age, size, and sex of individuals, as well as their location. They also carry information about the motivational state of the individual, and his intentions with respect to aggression and sex (Seyfarth & Cheney, 2003; see review in Locke, 2009). In its totality, this literature makes it less strange to ask where the human affection for vocal communication came from, even if we are left wondering how our species, and not the apes, evolved the capacity to control and process particulated vocalization (Oller, 2004; Studdert-Kennedy, 2005).

At the other end of the evolutionary spectrum—the theoretical endpoint—it is not psychologists' and linguists' ability to use and think about language that needs to be explained, but the ability of traditionally living individuals. For them,

speaking seems to be more important than speech, the ability to joke, riddle, and tell stories more highly appraised than phonological (and grammatical) knowledge. The task, then, is to find links between the "more vocal than previously suspected" apes and the verbally artful members of traditional societies, and to ask how environmental changes produced fitness-enhancing behaviors that edged our evolutionary ancestors closer to spoken language.

In preliterate societies, language is heavily situational. This allows individuals to speak in a relatively inexplicit way (Linell, 2005). Some have difficulty thinking about the concept of "word" (Goody, 1977). Others act puzzled when asked what a word "means," possibly because words take their meaning from the context in which they are used (Malinowski, 1923). In some societies, words are thought to possess a "magical" quality (Tambiah, 1983). In none of these preliterate societies can a word's meaning be "looked up," nor can one know a word but wonder how it is pronounced.

In these societies, there are few if any schools, and no standardized language tests. Thus, what we know is what anthropologists have mentioned in their accounts. These descriptions make it clear that the communicative practices of traditionally living individuals appear neither as *language* nor *speech*. They appear as *speaking*. In these societies as with the apes, there is a special relationship between speaking and status. In a range of human societies anthropologists have noted unusual linguistic knowledge and rhetorical skill in individuals, invariably men, who have risen to positions of authority and power (Burling, 1986; Locke, 2001a; Locke & Bogin, 2006). I have speculated elsewhere that selection for vocal extravagance expanded the capacity to coordinate and control longer sequences of phonetic material, and that listeners who were able to evaluate these sequences received fitness information that others did not (Locke, 2008a,b, 2009).

There are links between speaking and sex, too. Miller's (2000) claim is that sexual selection shaped human language directly, through mate choice, and indirectly, through its effects on social status.

> Verbal courtship can be viewed narrowly as face-to-face flirtation, or broadly as anything we say in public that might increase our social status or personal attractiveness in the eyes of potential mates. Sexual flirtation during early courtship accounts for only a small percentage of language use, but it is the percentage with the most important evolutionary effects. This is the time when the most important reproductive decisions are made, when individuals are accepted or rejected as sexual partners on the basis of what they say. (Miller, 2000, pp. 356–357)

Spoken language may also have played a role in sexual selection outside of courtship by advertising various male qualities. It was through public speaking and debate that individuals were able

> to advertise their knowledge, clear thinking, social tact, good judgment, wit, experience, morality, imagination, and self-confidence. Under Pleistocene conditions, the sexual incentives for advertising such qualities would have persisted throughout adult life, in almost every social situation. Language put minds on public display,

> where sexual choice could see them clearly for the first time in evolutionary history. (Miller, 2000, p. 357)

I agree that language helped to exhibit these qualities, but it could only do so when people spoke. Then, I propose, the variables facilitative of status and sex had less to do with grammar than various aspects of speaking, including prosody, fluency, rhythm, tone of voice, rate, loudness, and humor (Locke, 2001a). But these elements would have exerted no effect had they not enjoyed some relationship to fitness variables such as dominance and attractiveness for mating.

Below, in the section on life history, I will offer proposals as to how our ancestors evolved the capacity for controlled vocalization and speech at a level of complexity that prepared them for modern language, and suggest some functions of various events or milestones in the development of language.

LANGUAGE IS WHAT DEVELOPS

Purely by cataloguing the world's languages, we find out about the range of linguistic elements that can be handled by the nervous system of young humans. But what *is* language from the *infant's* point of view? Over 40 years ago, George Miller made a simple but provocative statement. The child, he wrote, "learns the language because he is shaped by nature to pay attention to it, to notice and remember and use significant aspects of it" (1965, p. 20). When I first thought about this I wondered what "it" was from the infant's perspective (Locke, 1993a). My reaction was that "it" must refer to the things people do while talking. This vocal, facial, and gestural activity, and associated situational cues, comprise the totality of linguistically relevant stimulation (Locke, 1993b, 1994).

The process gets off to an early start. Because fetuses eavesdrop on their mother's voice, infants are born with a preference not only for her voice, but for the language she spoke during this period, even when the speaker is someone else (DeCasper & Fifer, 1980; Moon, Cooper, & Fifer, 1993). But in an astonishingly short time, the mother's tongue lays the physical groundwork for what will become the infant's mother tongue. The most obvious function at this point is indexical learning—learning about people—but it incidentally produces linguistic learning.

So does what I have called "vocal communion," a continuous state or feeling of connectedness that is maintained largely by the vocalizations of infants and caregivers (Locke, 2001b). As we will see, infants place certain kinds of vocal behaviors in this channel, and are rewarded with physical approach, handling, and other forms of care. Several of the social behaviors that predict lexical learning, including joint attention and vocal imitation, may also be associated with maternal attachment. Since quality of attachment predicts language development (van Ijzendoorn, Kijkstra, & Bus, 1995), research is needed to determine those behaviors that are functionally related to language learning and that are only symptomatic of a relationship that is independently influential.

But of course infants do not merely listen. There is a call–response aspect to vocal signaling. When mothers vocalize, infants tend to respond and vice versa. This sort of communications link resembles what Schleidt (1973) called tonic communication. When they respond, there is a tendency on the part of caregivers and infants to do so "in kind"; that is, to produce like behaviors (Locke, 1993a). One might suppose that infants are "attempting" to learn to speak. But if that is the purpose, how do we explain mothers' frequent imitations of their infants (Pawlby, 1977; Veneziano, 1988)?

It is beginning to appear that vocal imitation may be an important way of demonstrating pacifistic intent and willingness to relate, possibly even to establish the identity of the other. Several years ago, Meltzoff and Moore (1994) published a relevant paper on 6-week-old infant's imitation of an adult's facial gestures. Each of several assistants came into the lab at various times and made a distinctive gesture, then left. When they returned to the lab the next day, the same assistants entered the room. Infants responded by reproducing the gesture that the assistants had made the day before, even if they merely saw the person on the second occasion. The results thus suggested that the infants were attempting to relate to, and possibly to identify, individuals on the basis of characteristic behaviors.

These results make it possible to see the function of a particular behavior—imitation—that would otherwise merely pass as something that infants do at certain ages. If the adult were to speak instead of gesture, there is nothing here to suggest that the infant would not reproduce aspects of his speaking voice as a means of relating to or identifying him. This would make it appear that the infant was learning language, and might suggest to some observers that the infant was aware of the existence of language, and was attempting to learn it.

Infants who traffic in *speech* are likely to be credited with progress in the acquisition of *language*. But perhaps this is not altogether inappropriate. In a prospective study of normally developing children, Nelson et al. (1973) found a relationship between the sheer number of utterances recorded in a session held at 20 months and the age at which a 50-word expressive vocabulary was attained. The number of utterances also was correlated with the age of children at their 10th phrase, and with their rate of lexical acquisition and mean length of utterances. Other work indicates that lexically delayed infants exhibit fewer vocally communicative intentions per minute than normally developing children (Paul & Shiffer, 1991), and produce far fewer utterances, independent of their quality (Paul & Jennings, 1992). Similar findings have been reported by others (Rescorla & Ratner, 1996; Thal, Oroz, & McCaw, 1995).

This is consistent with a paradox about language development. Infants rarely vocalize at normal levels of frequency and complexity during the babbling stage, imitate aspects of their mother's speech, and produce isolated words—behaviors that ostensibly require no grammatical ability at all—and later stumble as they enter the domains of morphology and syntax (Locke, 1998b). Whatever problems arise at the grammatical level of language are typically forecast by deficiencies in early lexical development (Bates & Goodman, 1997), just as the rate of word

learning is predicted, to some degree, by the level of vocal sophistication and control revealed in the babbling stage (Oller, Eilers, Neal, & Schwartz, 1999).

But it gets better. Grammatical development is also linked to personality factors. Slomkowski, Nelson, Dunn, & Plomin (1992) found that a measure of introversion and extroversion at the age of 2 years was highly predictive of scores on eight different standardized language measures at the age of seven. Infants who were extraverted learned language with unusual speed. Thus, it appears that sociability and volubility—measures that are neither linguistic nor cognitive—predict the development of language even when it is defined as code.

How do we make sense of these links between volubility and the lexicon, and between personality and grammar? Earlier I referred to species-specific linguistic mechanisms. Language development involves the activation of these mechanisms, but there is no evidence that the mechanisms are turned on solely by maturation or exposure to people who talk. It makes more sense to suppose that they, like other neural systems, are *pressured* to turn on. I have suggested elsewhere that the precipitating event is a storage problem, created by the accumulation of utterances that are appropriately analyzed prosodically, but underanalyzed phonetically (Locke, 1997). It has been suggested that children must have a "critical mass" of words in their expressive lexicon—perhaps as many as 70 verbs, and 400 words overall—before they discover and begin to apply the rules of linguistic morphology (Bates, Dale, & Thal, 1994; Marchman & Bates, 1994; Plunkett & Marchman, 1993).

With language presupposing the operation of mechanisms that do other things, there is naturally a question about what the language faculty can be said to include. Hauser, Chomsky, & Fitch (2002) solved this problem, to their satisfaction, by positing a broad and a narrow faculty, the former including social and cognitive mechanisms, the latter excluding them. This is a reasonable way of thinking about linguistic systems, in a logical sense, but when it comes to development a different kind of "sense" creeps in. If social factors are critical to language, then they are *critical components* in the *developmental system* that is responsible for language. Here we begin to see the problem—the difference between a developmentally and a theoretically based definition of language.

We have seen that evolution plays a role in development. It supplied the mechanisms that, with appropriate experience, carry out linguistic operations. But it has been overlooked until recently that evolution also supplied the *developmental stages in which language develops*, so that when evolution produced new and modified developmental stages, they fed back new candidate behaviors for selection.

THE EVOLUTION OF DEVELOPMENT

To evolve, genetically supported traits must offer a selective advantage. Pinker and Bloom (1990) argued that natural selection is the only way to explain the origin of language and other complex abilities. In doing so, they said little about any role that selection might have played in development. But as Hogan (1988) has pointed

out, natural selection "should operate at all stages of development, and not only on the adult outcome, since any developmental process that reduces the probability of reaching adulthood will be very strongly selected against" (p. 97). Thus, in this section I offer several new proposals relating to vocal and verbal selection as it may have operated in infancy and childhood.

There are lots of theories (or pseudotheories) of evolution in which language, like a *deus ex machina*, enters the hominin scene in the nick of time, supplying our ancestors with just the communicative tool they need to solve some pressing environmental problem. But evolution is a tinker who works from available parts. No species can manufacture a new part just because having it would come in handy.

Nor can an adult member of any species do this. No trait can evolve unless precursory forms appear during a stage of development, and *this is the only time that they can appear.* St. George Mivart hinted at this well over a century ago when he suggested that new species emerged from "affections of their generative system" (1871, p. 267). A half-century later, Walter Garstang wrote that ontogeny "creates" phylogeny. It is "absurd," he said, to think that a new trait could evolve in adults (Garstang, 1922).

In the interim, a number of respected biologists have embraced and elaborated upon Garstang's claim (Gottlieb, 2002; Gould, 1977; Northcutt, 1990; West-Eberhard, 2003; see other references in Locke, 2009). It is now understood that evolution is a two-step process (West-Eberhard, 2003). In the first step, a plastic phenotype responds to environmental variation—in development—producing novel forms that vary genetically. In the second step, selection acts on the variants. A selection-based account of language cannot be complete unless it identifies the linguistically favorable genetic variations that arise in ontogeny and the processes of selection that reinforced and expanded those variations.

If development occurs in stages, then behaviors that develop owe their existence to some feature of those stages. This implores us to look beyond the development of mechanisms that evolved and explore the *evolution of development*. I believe the case can be made that in evolution, some type of selection occurred for language—or what was to become language—at every stage of development from infancy to sexual maturity—and that each new behavior that develops serves a distinct function. I have suggested elsewhere that selection in infancy helped produce the vocal complexity and social functionality that were later reselected in the rather different biological contexts supplied by childhood, juvenility, and adolescence (Locke, 2006). But even if selection had initially applied in adolescence, the behaviors reinforced at that stage would already have to have "been there" in some form, even if they had never functioned in the new way.

To be prepared for a socially complex adulthood, there must be appropriately structured intervals for development and learning. Humans have four such stages—two more than the other primates. We also have two stages that were remodeled (Bogin, 1999a). I propose that all four of these new and remodeled stages were needed for language to evolve, and that all four are needed for the young to acquire

knowledge of language and to become fully proficient in its use (Locke, 2009; Locke & Bogin, 2006).

The approach to human life history that will be used here was developed by Barry Bogin (1988; 1999a). Much of what will be said about the individual stages is adapted from a paper coauthored with Bogin several years ago (see Locke & Bogin, 2006 for details and references).

Infancy

Infancy begins at or before birth and ends at about 30 to 36 months when, in traditional societies, weaning takes place. This stage is characterized by rapid physical growth, provision of nourishment by maternal lactation, and eruption of deciduous dentition. Human infants are more helpless than ape and monkey infants, a "deficiency" that requires a long period of continuous care.

It is thought that the initial change that produced greater helplessness was bipedal locomotion, which realigned the spine and narrowed the pelvis. This produced problems at birth for the mother and her large-headed fetus. There being a range of variation among infants, some had smaller heads at the time of birth, and these infants—and their mothers—were more likely to survive the delivery. Over time, differential rates of survival caused a shift in skull and brain development from the prenatal to the postnatal period. This increased infant dependency and need of care.

These changes *remodeled* the premodern human infancy. In doing so, they positioned it for language and other complex behaviors. For, in a number of important respects, the conditions above—in danger of being seen as design flaws—offered more and better opportunities for social, vocal, lexical, and symbolic learning (Bjorklund, 1997; Locke, 1993a, 1999).

This tendency to view helplessness and heightened care as socially and cognitively beneficial is supported by anthropological accounts, which indicate that most hunter–gatherer mothers rarely put their babies down, and then do so for no more than a few seconds. Separation cries usually evoke pick up and breast feeding. When infants cannot be carried, they are often left in the care of others (Hrdy, 2006).

Beginning prenatally, infants learn aspects of the prosodic and segmental characteristics of the ambient language. By 6 months, most infants have heard enough speech to recognize a few words and stereotyped phrases, and to experience some perceptual reorganization, a process that continues in succeeding months.

From a variety of developments in the first year or life, parents and language scientists alike conclude that infants are learning speech or acquiring language. Undoubtedly they are, but in some sense, these advances are unintended consequences. There are many reasons why helpless individuals might benefit by attending to, storing, and reproducing caregiver speech, most of which have a great deal to do with the negotiation of their own care (Locke, 1996).

In our species, weaning comes earlier than it does in the apes. It is generally held that earlier weaning would have shortened the interbirth interval, enabling

women to have more infants in their reproductive lifetime. I have proposed that this produced an increase in the number of siblings—competitors for care. This heightened competition, combined with unprecedented levels of helplessness, forced infants to explore clever new ways of using the voice to secure and maintain maternal proximity, and to monitor and "read" maternal feedback; and that, therefore, some of the vocal ability presupposed by spoken languages was asserted initially by hominin infants and reinforced by successful interactions with their parents.

According to the proposal, infants who issued more effective care-elicitation signals received more care, and were marginally more likely to live on to reproductive age (Locke, 2006). The *parental selection* hypothesis proposes that some of the vocal ability presupposed by spoken languages emerged from infancy, having been asserted initially by hominin infants and supported by interactions with their parents. This hypothesis holds that infants who issued more effective care-elicitation signals (e.g., measured or strategic levels of cry) were better positioned to receive care than infants who issued stress vocalizations noxiously or inconsolably—behaviors that invite neglect and abuse in primates generally, and forecast language-learning problems in humans. The hypothesis also envisions that infants who cooed and babbled at appropriate intervals were more likely to engage with adults, to be liked by them, to receive more sophisticated forms of care as infancy progressed, and to generate and learn complex phonetic patterns. Infants who were able to monitor adult reactions to their behaviors would have been able to discover those vocalizations that had the most beneficial effects, and thus could use structured vocalization to maximum effect.

It is also possible that syllabic and articulatory activity played a "decoupling" role (Oller, 2004), making available for recombination the discrete movements, hence the phonetic segments that make phonological systems possible (Studdert-Kennedy, 1998; 2005; Studdert-Kennedy & Goldstein, 2003). I propose that further elaboration of vocal repertoires would have occurred later in development under different pressures, potentially enhancing fitness in one or more of these stages, particularly adolescence. The result is a system flexible enough to be used for speech, and there is evidence that vocal abilities presupposed by variegated babbling are in fact adequate for infants' initial words (Vihman, Macken, Miller, Simmons, & Miller, 1985).

It is generally recognized that development is continuous, but continuity would also have played a role in evolution. I have proposed that new levels of vocal complexity, flexibility, and control that emerged from infancy were carried into later ontogenetic stages where—development being continuous and cumulative—they were reinforced and elaborated (Locke & Bogin, 2006). In the new childhood that evolved (see below), these signaling capabilities would surely have proved beneficial, for if children are to avoid hazardous aspects of their environment, they must be warned if not "instructed."

It is at this point that we begin to see the first of several sets of discontinuities. In the typical case, the close of intimacy is co-timed with evidence

that the mechanisms responsible for each of the recognized components of language-as-code—the lexicon, phonology, morphology, and syntax—are operating at some level of efficiency.

Childhood

Childhood is a uniquely human stage that is thought to have entered the *Homo* line about two million years ago (Bogin, 2001, 2003). Since chimpanzees wean at about five years, it is assumed that earlier weaning liberated about two years from infancy. This is what created childhood (Bogin, 1990). It has been suggested that the extension of childhood to its present length—which extends from about three to nearly seven years—was due, at least in part, to the increasing functionality of communicative behaviors in this stage (Locke & Bogin, 2006).

The childhood stage is peculiar to humans, having been evolutionarily inserted between the infant and juvenile stages that characterize social mammals. Childhood, according to Bogin, is defined by several developmental characteristics including: a deceleration and stabilization of the rate of growth, immature dentition, dependence on older people for food, and immature motor control. The evolutionary value of childhood is associated with the mother's freedom to stop breast-feeding her 3-year-old, enabling her to become pregnant again. This enhanced reproductive output without increasing the risk of mortality for the mother or her infant or older children, for in cooperatively breeding societies, others were available to help care for the young.

Childhood is largely defined by the long period, extending from 3 to 7 years, in which food must be provided. By seven, dentition is becoming adult-like, and with parallel increases in jaw control, it becomes possible for children to eat adult foods. Socially, childhood produces new friendships outside of the home as well as increased disenchantment with siblings. In some modern societies, 5-year-olds have social hierarchies. In these hierarchies, low-status children behave positively toward their higher status peers, without reciprocity. Children with good communication skills are likely to be popular (Asher & Renshaw, 1981; Putallaz & Gottman, 1981), whereas children with speech and language disorders are typically unpopular, and may even be victimized (Conti-Ramsden & Botting, 2004). Children with pragmatic or higher-level language processing disorders are likely to experience serious peer interaction problems (Botting & Conti-Ramsden, 2000). Delayed language predicts poor quality of friendship in adolescence; it may independently impair friendship or do so in conjunction with poor social cognition (Botting & Conti-Ramsden, 2008; Durkin & Conti-Ramsden, 2007).

As childhood draws to an end, a second set of discontinuities in native language learning occurs. One relates to the fact that languages acquired after the age of six are often produced with an accent that reflects interference from previously learned languages (Flege & Fletcher, 1992). In large epidemiological samples of midwestern American children, 6 years of age was also treated as the approximate age of native language mastery, based on standardized tests that are oriented to school performance (Shriberg, Tomblin, & McSweeny, 1999; Tomblin et al.,

1997). Thus, in one modern society, and undoubtedly far more, much of the childhood period is needed to master the basic structure and elementary vocabulary of a knowledge-based linguistic system.

But there is more to be accomplished in childhood. One advance involves verbal fluency, which continues to improve throughout this stage (Starkweather, 1987). Other developments relate to automaticity and rate of speaking (Smith, 2006). If something goes wrong with the sensory system that guides ambient learning during childhood, there is likely to be significant deterioration of speech. Clinical studies indicate that all of childhood is needed to achieve a speaking ability that can tolerate the discontinued stimulation entailed by acquired deafness (Waldstein, 1990; also see Locke & Bogin, 2006).

Some of the communicative skills arising in childhood do so in tandem with certain cognitive advances. One such development is the "theory of other minds," which typically emerges between 2 and 4 years of age (Baron-Cohen, Tager-Flusberg, & Cohen, 1993), enabling children to take the perspective of others. There is also an improvement in autobiographical memory, which usually occurs between 3 and 8 years of age (Nelson, 1996), enabling children to describe sequential events and to share memories of their own experience. This comports with the fact that childhood also sees improvement in discourse and narration (Girolametto, Wiigs, Smyth, Weitzman, & Pearce, 2001).

In recent years, there has been increased attention to pragmatics, but there are few if any accounts of language development that seriously address verbal performance. Some of the developments that occur in childhood relate to verbal competition and performance. These include joking (McGhee, 1979; Shultz & Horibe, 1974) and the use of "off the shelf" verbal routines (Gleason & Weintraub, 1976). In many cultures, jokes and riddles mark the beginning of various sorts of verbal competition (Gossen, 1976a,b; Sanches & Kirshenblatt-Gimblett, 1976).

During childhood, males tend to speak assertively to get and maintain attention and to make evident their desires, and girls tend to speak softly in order to promote interpersonal closeness and harmony (see review in Locke & Bogin, 2006). The linguistic acquisitions of infancy are thus joined, in childhood and succeeding stages, by other factors that elevate the quality of verbal expression and facilitate development of communicative skills (e.g., Sherzer, 2002).

Since it begins with weaning, childhood liberated the young from continuous maternal restraint. Naïve children's exploration of their physical environment presumably increased the need for parents to warn and instruct, giving them and other kin self-serving reasons to send honest signals. But childhood also positioned the young to know about, thus to convey information about, events occurring in the absence of others. I would suggest that childhood handed the young and their families a key ingredient of human language—displacement—in the form of new opportunities and needs to talk about things not physically present (Fitch, 2004; Hockett, 1960). It is possible that the swing period in development of native-like language abilities—6 to 8 years of age—is related to changing pressures associated with the transition to a more independent and autonomous stage of development.

In development, childhood would have given the young opportunities to integrate and automate linguistic operations, to introspect on language and to analyze it, and to develop an appreciation of rhyme, alliteration, fluency—all of which would be needed in juvenility.

Juvenility

Juvenility is the next stage of human development. In mammals generally and primates more specifically, juveniles are sexually immature but independent of others for survival. It is not unusual in traditional human societies for juveniles to find much of their own food, avoid predators, and compete with adults for food and space (see Locke & Bogin, 2006).

Juvenility begins at 7 years, with the onset of adrenarche and associate cognitive and social advances. This stage ends at 10 and 12 years in females and males, respectively. Juveniles are sexually immature but more independent of older individuals than children. Since it comes after a remodeled infancy and new childhood, the juvenile stage of our evolutionary ancestors could hardly have remained unchanged. In various species of mammals, juvenility provides additional time for the brain growth and learning that is required for reproductive success (Janson & van Schaik, 1993; Joffe, 1997). In complex human societies, it takes all of juvenility and adolescence for the development of social and linguistic skills that are needed in sexual maturity.

Although there is increased independence from family members in childhood, juvenility would have given the young opportunities to prepare themselves, while still sexually immature, for a stage in which vocal and verbal performance would play a prominent role in the competition for precious resources—particularly sex and dominance (Locke, 2001a; Locke & Bogin, 2006). Many of the language developments that occur in modern juvenility take place beyond the sentence level, in the quality of extended discourse and narratives. New abilities in pragmatics and verbal performance contribute to a variety of socially relevant activities, from gossiping to joking and storytelling.

Juvenility also accommodates additional syntactic advances (cf. Nippold, 1998), but many of the new developments affect *performance*. These include an increase in respiratory capacity, which continues into adolescence (Engström, Karlberg, & Kraepellen, 1956; Hoit, Hixon, Watson, & Morgan, 1990), and further increases in fluency and speaking rate. Changes occur beyond the sentence level too, in the quality of extended discourse and narratives (Bamberg, 1987; Burleson, 1982; Karmiloff-Smith, 1985). These advances facilitate a number of socially relevant activities, including gossip and storytelling, and contribute to successful competition and courtship as sexual maturity approaches.

Around 10 to 12 years, riddles and jokes become more important. In Turkey, boys engage in verbal duels—ritualistic insults and replies that require "skill in remembering and selecting appropriate retorts to provocative insults" (Dundes, Leach, & Özkök, 1970, p. 135). These duels occur between 8 and 14 years, bracketing the transition from juvenility to adolescence.

In a sense, juvenility parallels infancy. Whereas the linguistic knowledge and structure gained in infancy helps to satisfy the informational needs of childhood, juvenility provides opportunities to perfect the persuasive and attractive use of speech, and the ability to manipulate elaborate and socially appropriate utterances, which will be valued in adolescence.

Adolescence

Adolescence is the fourth stage of life history, and the second stage that is uniquely human, since the other primates proceeding directly from juvenility to adulthood (Bogin, 1999b). This stage begins at the end of juvenility and extends to 19 years, when adulthood commences. In modern humans, adolescence is announced by puberty and a simultaneous surge in skeletal growth, strengthening of friendships, and development of new relationships.

In humans, uniquely, there is a distinct skeletal growth spurt in both sexes after several years of gently decreasing juvenile growth. The onset of this spurt, along with puberty or gonadarche marks the onset of adolescence (Bogin, 1999a). Neuroendocrinological changes differentially affect the vocal tract of the two sexes, females revealing negligible changes, males displaying a significant increase in tract length and decrease in fundamental frequency, with further drops in the transition from adolescence to adulthood (Fitch & Giedd, 1999; Lieberman, McCarthy, Hiiemae, & Palmer, 2001; Pedersen, Moller, Krabbe, & Bennett, 1986; Pedersen, Møller, Krabbe, Bennett, & Svenstrup, 1990; Vuorenkoski, Lenko, Tjernlund, Vuorenkoski, & Perheentupa, 1978). The critical variable, testosterone, increases the size of the vocal folds, lowers the fundamental frequency, and changes the vibratory characteristics of the vocal folds (Abitol, Abitol, & Abitol, 1999; Beckford, Rood, & Schaid, 1985; Titze, 1989).

In adolescence—if not sooner—and certainly in adulthood, males also display lung and respiratory superiority over females (Becklake, 1999; Cook & Hamann, 1961; Hibbert, Lannigan, Raven, Landau, & Phelan, 1995; Higgins & Saxman, 1991; Schrader, Quanjer, & Olievier, 1988; Thurlbeck, 1982). Although this variable is often neglected in developmental accounts of language, even in accounts of speech, it undoubtedly has a great deal to do with speaking in a public and competitive way. In humans and a range of other species, respiratory capacity is positively correlated with body size (Engström et al., 1956; Helliesen, Cook, Friedlander, & Agathon, 1958; Stahl, 1967; Tenney & Remmers, 1963), and in the context of mate selection, this ability is likely to have been of considerable interest to ancestral females.

In men, status and dominance are linked to testosterone (Mazur & Booth, 1998), which tends to be higher in men with low vocal pitch (Dabbs & Mallinger, 1999; Pedersen et al., 1986). It comes as no surprise, then, that men with low-pitched voices are judged by female listeners, from vocal samples, to be more dominant and attractive (Collins, 2000; Collins & Missing, 2003; Feinberg, Jones, Little, Burt, & Perrett, 2005; Puts, Gaulin, & Verdolini, 2006). Women also *prefer* male voices that are low in pitch (Collins, 2000; Oguchi & Kikuchi, 1997), a preference that appears

to be enhanced by estrogen (Feinberg et al., 2006; Puts, 2005). Male university students with low voices report slightly more sexual partners than other men (Puts et al., 2006), and baritone opera singers report having more affairs than tenors (Wilson, 1984). In hunter–gatherer societies, men with low voices report fathering more children than men with higher voices (Apicella, Feinberg, & Marlowe, 2007). These findings could be taken to mean that vocal pitch is a fixed trait, but of course men are able to manipulate their voices, and do so when it could alter their perceived dominance (Puts et al., 2006).

Earlier I mentioned rising group size and rising social complexity as a spur to increased brain size and linguistic behavior. If these pressures applied with unusual force during any one of the stages of life history, adolescence—when the draw of the group is especially strong—would surely be that stage. It is therefore interesting that recent imaging research is now indicating that adolescence, to a surprising degree, is a time of renewed brain development. The volume of cerebral gray matter sharply decreases from childhood to adolescence, evidently due to dendritic pruning, and there are large increases in white matter, caused by myelination, increases in axonal size, and glial proliferation (De Bellis et al., 2001; Giedd, 2005; Giedd et al., 2001; Shaw et al., 2006). This pattern of exuberant growth and pruning is relevant to arguments that adolescence conferred reproductive advantages on our ancestors, partly by giving the young additional opportunities to acquire social and sexual skills before reproducing (Bogin, 1999a,b).

Adolescence provides opportunities to learn the pragmatic and performative skills that are needed to converse and to narrate (Dorval & Eckerman, 1984; Nippold, 1998). It also offers opportunities to learn slang, idioms, and other formulaic expressions, which contribute to group solidarity and enhance the ability to perform, possibly by increasing fluency and rate of speech for that material (Kuiper, 1996). Other performance skills that develop in adolescence include refinements in gossiping, joking, arguing, negotiating, and persuading; and in the rate of speaking (Walsh & Smith, 2002). All these skills stand to impress peers and facilitate the achievement and maintenance of social relationships.

I have emphasized adolescence as an innovative stage with reproductive advantages. The reason, in part, relates to the benefits and pressures associated with group life. Dunbar (1993) has argued that group pressures played a role in the evolution of language. It is reasonable to suppose that the benefits of group affiliation, and the achievement of personal identity and autonomy, have motivated adolescents to invent vocal and verbal behaviors, thereby reinforcing any improvisational abilities carried forward from previous stages. Modern adolescents do not merely learn additional linguistic features and rules of usage. They also modify material learned earlier, and invent new words and constructions. But the changes are not merely lexical. "The relatively high degree of phonological innovation in the adolescent age group," wrote Eckert (1988), "is an indication that the development of adolescent social structure provides a major impetus for phonological change" (p. 197).

Development of other secondary sexual characteristics, and a sharp increase in height and weight, also occur in adolescence. These physical changes are

paralleled by an intensification of preexisting friendships, and the development of new relationships. The new affiliations, and membership in peer groups, facilitate intimacy and mutual support (Whitmire 2000). Adolescence draws to a close with the attainment of adult stature and the biosocial skills needed for successful reproduction. Typically, this occurs at about 19 years of age in women and 21 to 25 years in men (Bogin 1999a, 2001).

CONCLUDING REMARKS

If development occurs in stages, then behaviors that develop owe their existence to some feature of those stages. This implores us to look beyond the development of mechanisms that evolved and explore the evolution of the developmental stages themselves, asking which of many biological factors are responsible for the induction of linguistic systems.

The stages of life history have unique and coherent properties. These properties provide the context for a range of social and cognitive developments, including language. This suggests that there are linguistic discontinuities at stage boundaries. Several have been identified here, but there are likely to be a great many others.

In research on language development, there is a tendency to focus on infancy and childhood, probably because it is during these stages that knowledge of words and grammatical rules is acquired. This accords well with implicit views of language as an object. But knowledge of language enables one to speak, thus to act in social situations, and to express oneself in social groups. By adopting human life history as our theoretical framework, one is encouraged to ask about the contribution of each developmental stage, from infancy and childhood through juvenility and adolescence, and it is during these later stages that this second (social) view of language becomes more salient.

It is for these reasons that developing individuals who speak in accepted ways should experience far more social success than those who do not, and there is no shortage of evidence that this is so. However, the causes of social acceptance (and rejection) at sexual maturity are not as closely linked to linguistic knowledge and structure as to vocal and verbal performance. Clearly, the relevant *speaking skills*—the perceptible and, from a causal standpoint, proximate behaviors—presuppose prior accomplishment in all areas of language, however inconspicuous these accomplishments might be initially.

Until now, research on language development has emphasized acquisition of a lexicon and linguistic grammar, but other advances in maturation, learning, and consolidation are necessary for the young to speak informatively, attractively, and persuasively, thus competitively. If in evolution, as now, these developments occurred during a stage that follows childhood, communicative ability in *preceding* stages would have been important. In a treatise on the embryological development of the chick, Caspar Friedrich Wolff wrote, "each part is first of all an effect of the preceding part, and itself becomes the cause of the following part" (Wolff 1764, in Hall 1999, p. 112). Since development is continuous, one supposes that infants and children who achieved effective use of sound-meaning signals

precociously carried some form of the relevant control behaviors into juvenility and adolescence. The result, on a continuity hypothesis, would have been other exceptional skills in the use of spoken language. These would have facilitated attainment for status, sex, and additional resources, enhancing reproductive success while strengthening the precursory behaviors that had persisted, in some form, from earlier stages.

I have suggested that studies of language development can benefit from a new model—one that explores synergies between evolution and development. Such a model encourages us to think in new ways about development and to explore new issues. These include the fitness-cue value of various components of spoken language. If elements of speech were selected, they may now be supported by special-purpose mechanisms. To the degree that they are, the behaviors enabled by these mechanisms may enjoy a different developmental course than other behaviors.

It is clear that we need a functional account of vocal imitation, one that parallels work on facial and manual activity, and its necessity to develop greater understanding of the proximal mechanisms that are at work in infants' learning of vocal and symbolic activity. Before infants become aware of the communicative value of linguistic material, they absorb and accommodate to it, but on what motivation?

Where the faculty of language is concerned, the biological trait that evolved was the ability to speak, and yet there are no standardized tests of speaking. As a consequence, we have no way to measure the relationship of language-as-code and the ability to speak, where speaking is sensitive to performance variables of the sort mentioned above. There is room for a great deal of research here.

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2 The Competition Model and Language Disorders

Nora Presson and Brian MacWhinney

INTRODUCTION

To understand language disorders, we need to contrast disordered language processing with normal language processing. In one sense, this is easy to do. We see that people with language disorders struggle with articulation, lexical access, syntactic structure, comprehension, and other language functions. But simply observing these behavioral differences is not enough. To understand the dynamics of communication disorders we need to articulate a processing model that explains in mechanistic terms how and why disordered processing differs from normal processing. Moreover, because communication abilities continue to develop throughout the life span, the model must also consider properties of language acquisition.

The Competition Model (MacWhinney, 2008a) addresses this challenge by providing a functionalist account of how languages are learned across the life span and how they are processed in real time. Three decades of research based on this model have shed light on aspects of first language learning, second language learning, bilingual processing, developmental language disorders, and language loss in aphasia.

The fundamental claim of the model is that alternative interpretations compete online during language processing. To probe these various competitions, researchers have used multifactorial experimental designs to measure the process of cue competition. As summarized in MacWhinney (2008a) and elsewhere, the predictions of the model have been uniformly supported across three decades of research involving 15 different languages (MacWhinney & Bates, 1989). In this chapter, we will focus on the ways in which this model can help explain behavioral and neural patterns of language disorders.

Readers of this volume are well aware of the many challenges involved in studying language disorders. Perhaps the biggest challenge is that these disorders come in so many alternative forms. Given the complexity of language, there are good reasons to expect that the patterns of language disorders should be at least as diagnostically complex as disorders of any other sophisticated biological system (such as the immune or the circulatory system). We know that the human brain is an extremely complex object (Buzsaki, 2006) and that no two human brains are totally alike. Rather, our brains differ substantially in terms of size, connectivity, and microstructure. Language is a complex and distributed process overlaid on

this individually variable and complex system. Although language is a species-specific ability, the detailed shape of that ability involves many mutations across millions of years that have promoted a gradual and continual growth in communication skills (MacWhinney, 2008b). These changes have impacted dozens of traits relating to the size of the brain, patterns of neural connectivity, styles of neural processing, gestural expression, and the structure of the vocal apparatus.

Given this immense complexity, we might wonder how one could even begin to understand language disorders. Fortunately, language itself provides two powerful searchlights for our exploration. The first is that language use is grounded on social convention. This means that, no matter how variable our brains, we all learn to use the same socially shared system for communicating meaning. To illustrate this, Quine (1960) compared language use to the structure of hedges in a formal garden. Viewed from the inside, each hedge has its own idiosyncratic branching structure. Viewed from the outside, all of the hedges have the same straight edges. Social convention serves as the metaphorical gardener, making sure that each of us uses language in accordance with tightly specified patterns. No matter how individualistic our intentions or divergent our thought patterns, we all must end up conforming to the same grammatical rules. These core linguistic patterns are called "cues" in the Competition Model, and studies in that framework show that cues are acquired bit by bit during childhood. However, by adulthood, normal native speakers have acquired and coordinated all the relevant cues, weighing each cue by its normative strength. In this way, ensuring a common communicative system, normally developing speakers end up with nice, straight hedges.

There is also a second way in which language properties facilitate our exploration of language disorders. By its very nature, language rests on at least six separable data-processing systems: audition, articulation, lexicon, syntax, perspective switching, and mental model construction. A modular view of language (Fodor, 1983; Pinker, 1997) views these systems, and others, as executing in isolation and as represented in discrete local neuronal regions. This model suggests that we might expect to find easily distinguishable neural patterns in patients with language disorders.

In contrast, the Competition Model views these separable systems as interconnected and interactive (McClelland, 1989). From the viewpoint of the Competition Model, developmental language disorders should arise primarily from disturbances in the connections between these partially separable systems, rather than damage or malformation of particular areas. At the same time, we must recognize that some disorders, particularly in the aphasias, can arise from malformations, including lesions, within specific brain areas.

WHY USE A PROCESSING MODEL?

Some have argued that specific linguistic deficits are the basis for language disorders (Rice & Wexler, 1996). In some of these accounts, deficits are associated with specific brain areas that are damaged in aphasia (Caplan, 1992). In other accounts,

the deficit is linked to some specific mutation that is thought to impact language functioning (van der Lely & Stollwerk, 1996). However, analyses have often oversimplified the actual patterns of disruptions in the linguistic system. Language is a complex process, consisting of many component skills. Semantic, lexical, phonological, and syntactic information must be processed online to produce or comprehend language. Viewing language as a dynamic interaction between many local brain areas is consistent with the available neuroanatomical and behavioral data (Bookheimer, 2002). One classic contrast emphasizes the role of Wernicke's area for lexical processing and the role of Broca's area for syntactic processing. Work in neuroimaging (Booth et al., 2001; Just, Carpenter, Keller, Eddy, & Thulborn, 1996) has supported aspects of this analysis. This work has shown that there is language task differentiation in neural tissue.

Why, then, would we suggest that research go beyond mapping particular competencies to specific disorders (such as SLI) or anatomical injuries (as in aphasia)? First, evidence suggests that even specific damage can exert broad and varying effects on language functioning (Bates, Wulfeck, & MacWhinney, 1991). The reverse is also true; similar symptoms in language production and comprehension can be elicited from different types of damage (Bates, Wulfeck, & MacWhinney, 1991). More fundamentally, it is a mistake to think that local areas operate in a simple and uniform way when involved with other areas online. Neuroimaging with fMRI can underestimate the dynamic real-time flexibility and complexity of the system. A processing approach, on the other hand, emphasizes the potential for systemwide deficits to stem from varying or multiple causes. Moreover, as Quine's analysis suggests, the specific symptoms of a language disorder will depend on how the linguistic processing network is configured. For example, because different languages are represented differently, we would expect noticeably different patterns of impairment in different languages. These observations underline the importance of a processing approach to communicative disorders.

AN INTRODUCTION TO THE COMPETITION MODEL

The Competition Model provides a processing account for both comprehension and production. In order to map form to meaning during comprehension, or meaning to form in production, a language user must use a set of cues specific to that language. Each of these cues has a certain *validity*, or general usefulness of a cue in the input. More specifically, we can think of cue validity in terms of the dimensions of *reliability* and *availability*. The availability of a cue is the degree to which it is accessible in the input. The reliability of a cue is the probability with which a cue leads to correct usage or understanding.

The original framing of the Competition Model (Bates & MacWhinney, 1982) relied exclusively on the concepts of reliability and availability. At that time, we viewed competition in terms of its final results, such as sentence role interpretation, often revealed in decisions made after subjects had finished hearing whole sentences. However, once experimenters began making online measurements of processing (Kempe & MacWhinney, 1998; MacWhinney & Pléh, 1988), it became

clear that additional dimensions needed to be included in the model. This additional variance was described in terms of *cue cost*, a measure of the processing effort needed to make use of that cue during comprehension or production. Among the factors affecting cue cost, the most notable is *working memory load* (Gupta & MacWhinney, 1997; King & Just, 1991). Other factors include *detectability* and *systematicity*. For cues to compete, they must be maintained together for the short-term, necessitating some working memory or attentional focus mechanism. This integration is important because it plays a large role in predicting the effects of disorders in language.

Over the years, as the model has been extended to an increasingly wider range of phenomena in both first and second language learning, it has been necessary to add additional processing dimensions. The current version of the model, called the Unified Competition Model, provides a singular account of both first and second language learning. The Unified Model retains competition as the core mechanism by which form and meaning are mapped in comprehension and production. The model is described in terms of seven additional dimensions of cognitive processing that modulate this core process of competition, as illustrated in Figure 2.1.

In the Unified Model, competition arises between alternatives within specific cortical *maps*. The relevant maps represent cortical areas that encode patterns, across six areas language processing: audition, articulation, lexicon, syntax, perspective taking, and mental models. These maps are broadly tied to specific brain areas in the model: auditory cortex for audition, motor cortex for articulation, Wernicke's area for lexicon, Broca's area for syntax, dorsolateral prefrontal cortex for perspective taking, and more dorsal areas for mental models. In addition, morphological usage coordinates processing in posterior lexical areas and anterior syntactic areas. In lexical representation, there is a further distinction between localized phonological representations and distributed semantic representations. For details regarding the emergence and connectivity of lexical maps please consult Li, Zhao, and MacWhinney (2007).

The strength of a given competitor within a map is determined by its resting strength and the additional activation it receives from other items from *connectivity* both within and between brain areas. For example, the competition between

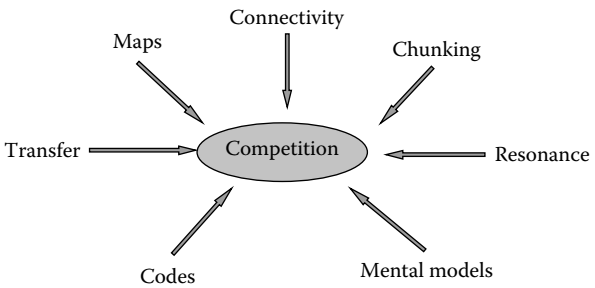

FIGURE 2.1 The Unified Competition Model. (For further details see MacWhinney, B., *Handbook of Cognitive Linguistics and Second Language Acquisition*. Mahwah, NJ: Lawrence Erlbaum Associates, 2008a. Reprinted with permission.)

the two readings of *port* in (1) and (2) can be resolved by connections to other lexical items (*captured* and *drank*). However, the competition between the two readings of *raced* in (3) and (4) is determined by syntactic patterns that extend beyond single lexical items.

1. The sailors captured the port at night.
2. The sailors drank the port at night.
3. The horse raced past the barn.
4. The horse raced past the barn fell.

The dimension of *connectivity* likewise influences the ways in which local areas communicate with each other. For example, the lexical cortex in Wernicke's area must be connected in some way to the motor cortex that produces articulatory output. The study of speech errors has shown that the lexicon maintains a function that assures that output forms are at least whole words. To do this, there must be some reciprocal connection between motor and lexical brain areas.

Within local maps, items that occur together frequently can become unified into *chunks*. For example, the phrase *as they say* functions as a single lexical item that is functionally equivalent to *reportedly.* Other chunks operate on the phonological level. For example, in Japanese, there are only 70 possible syllables and each of these, such as *na*, *ko*, or *ku* operate as single chunks. In syntax, chunks have a more flexible structure. For example, a phrase such as *what I really wanted to say was* can be processed as the same syntactic chunk that would produce *what I really meant to say was.*

The patterns of connection between local areas are further influenced by *resonance* in neural activation. During processing, attentional areas in the frontal cortex (Botvinick, Braver, Barch, Carter, & Cohen, 2001) maintain resonant activation in the local maps. This type of online resonance is particularly relevant to the study of language disorders, because it implements both the process of working memory and that of gating, which are necessary to language models. Working memory operates by maintaining a pattern of activation in an area or across areas. Gating operates in speech production to allow a candidate pattern in the output buffer to actually be produced (Levelt, 1989). Both of these aspects of resonance rely heavily on accurate timing of gating during production and preservation of material while it is still needed for sentence processing. If this connectivity is poorly wired or if resonance is inaccurate, errors in timing result, and the whole complex process of language production can fall apart.

Resonance also operates during language learning to consolidate new forms and chunks in memory. For example, when we read a new word, we represent that new word in terms of resonance between sound, meaning, and orthography. The hippocampus and other subcortical areas provide temporary support for these resonant connections (Wittenberg, Sullivan, & Tsien, 2002). The smooth functioning of resonance involves precise activation between corresponding linked areas. For example, a given lexical item in auditory cortex is linked to a corresponding representation in articulatory/motor cortex. This mapping between the two

areas retains the fundamental property of resonance: auditory features must be mapped in a traceable way onto articulatory features. Another pathway of resonant connection links lexicon and syntax. Words that occupy a certain position in the lexical map also operate in similar ways in the syntactic map, and connectivity between the two areas is necessary. If these patterns of connection between areas are jumbled or disordered, it will be difficult to achieve smooth control of this type of resonance.

The Unified Model includes three additional dimensions. Two of these dimensions—transfer and code selection—are primarily important for the study of bilingualism and second language learning. The final dimension, mental model construction, is relevant primarily for those speakers with conceptual communication disorders (Craig & Evans, 1993). Mental model construction includes skills such as perspective shifting, theory of mind, imagery, and narrative construction. Problems with mental model construction have often been implicated in disorders such as autism (Pelphrey, Morris, & McCarthy, 2005), schizophrenia (Rochester & Martin, 1979), and Williams Syndrome (Karmiloff-Smith et al., 1997).

PREDICTIONS OF THE MODEL

Having reviewed the seven dimensions that control competitive processing in the Unified Model, we can now return to the original question. Specifically, how can a processing model add to the understanding of language disorders and treatment of patients diagnosed with those disorders? There are two main possibilities. First, understanding the greater systemwide features of these disorders can increase our ability to predict patient behavior. Second, this increased predictive power can influence how treatment can be designed and evaluated.

Research in communication disorders addresses three main theoretical questions: (1) To what degree can we characterize impairments as localized versus global? (2) Are the problems encountered by patients exclusively linguistic, or are domain-general cognitive processes also affected? (3) How much of language is "hard-wired"; that is, genetically specified and available independent of experience and learning? Let us examine how the Unified Model addresses each of these questions.

LOCALIZED VERSUS GLOBAL IMPAIRMENT

Reacting against his failure to locate the *engrams* of memory, Karl Lashley (1951) proposed that all cognitive functioning is global. However, given what we now know about the details of neural connectivity (Schmahmann et al., 2007; Van Essen, Felleman, DeYoe, Olavarria, & Knierim, 1990), it is difficult to deny that different neuronal areas have different functions. However, this functional differentiation does not invalidate the concept of global cognition. In the case of language impairments, we can think of language processing in terms of the performance of an acrobat who is simultaneously juggling across seven separate dimensions. At any given moment, there is a contribution from attentional areas, lexical processing, links from lexicon to syntax, and often

elaboration of a mental model. If processing in any one of these coordinated areas suddenly crashes or breaks down, then the larger process is disrupted. In the case of normal speakers, the juggler is so skillful that this seldom happens, and when it does, there is a quick recovery. In a speaker with impairments, problems in any area can impact the whole system. Because of this, the Unified Model places an emphasis on overall patterns of cognitive *cost* or cognitive *load*. If stress to the system causes failure primarily in a highly vulnerable or costly area of language, then, within a language, there should be a common tendency *across disorders* for similar structures and processes to be harmed. That is, aphasics and SLI patients should be similar in *which* elements of language are impaired, either in comprehension or production. Moreover, a similar pattern of these impairments (albeit to a lesser degree) might be produced with normal language users under cognitive load. We will see that findings from Broca's and Wernicke's aphasics, as well as SLI patients, show support for this Competition Model prediction.

An important piece of evidence for the systemic properties of language disorders comes from nondisordered individuals under cognitive load. First, we know that marked increases in cognitive load can impair normal comprehension (Just & Carpenter, 1992). Moreover, varying the type and quality of cognitive load creates a performance profile in normal college students that closely resembles the one found in aphasics (Dick et al., 2001). Because we know there is no *systematic* physiological or genetic damage to the language system in these control participants, results like these support a model of language as a broad, complex, resource-intensive system that depends on smooth coordination between diverse local resources.

Moreover, aphasics and SLI patients have similar deficits in the specific elements of language that are impaired, both in comprehension or production. Most importantly, this prediction shifts the emphasis in language disorders from specific competency deficits (e.g., inflectional morphology in Broca's aphasics) and moves it to the *cause* of those deficits (i.e., less reliable, less frequent, more costly parts of the system, such as inflectional morphology are more vulnerable to deficits across the board). The resemblance between the areas of language affected under cognitive load and those affected in SLI is a good example of the ways in which processing models can illuminate the study of language disorders.

The Competition Model does not suggest there are no differences among different disorders. On the contrary, these dissociation help us understand the detailed functioning of chunking, connectivity, maps, and resonance within the framework of the Competition Model.

SPECIFIC LANGUAGE IMPAIRMENT

Specific language impairment is a disorder that is defined by normal cognitive function combined with markedly poor performance on language tasks. As such, the disorder is a logical testing ground for hypotheses about the domain-generality of language as well as possible genetic origins of grammatical competence.

Specific Language Impairment and *FOXP2*

Some researchers have argued that SLI is a genetic disorder resulting in a phenotypically unified competence deficit. For example, the Extended Optional Infinitive Model (Rice & Wexler, 1996) proposes that SLI is centrally a failure to develop verb agreement, delaying competent syntactic production. Similarly, the G-SLI model (van der Lely, 2005) proposes that there is at least some subgroup of SLI patients whose essential deficit is in grammatical processing; more specifically, there must be impairment in grammar but not in word learning, phonology, or working memory. However, we suggest that full application of these models depends on assumptions that lack strong biological evidence and general plausibility.

The strongest phrasing of these arguments includes each of three main tenets: (1) the cause of SLI is genetic in origin, (2) the deficits seen in SLI are fundamentally domain-specific, and (3) SLI has a common set of diagnostic criteria based on linguistic competence that mark the fundamental difference between SLI and comparison individuals. Let us examine each of these tenets.

Is the Cause of SLI Genetic in Origin?

In order to characterize SLI as a disorder with a single genetic cause, several inferences are needed. First, the argument requires an identifiable genetic source of the disorder. For example, in the KE family (Marcus, 2001), the disorder is linked to a dominant mutation on the *FOXP2 gene*.

What is known about *FOXP2*, however, does not lend itself to such an easy explanation. First, the fact that the gene exists in large concordance across species (Enard et al., 2002) makes it is necessary to differentiate what part of the *FOXP2 gene* is uniquely human. Second, a large-scale study of 270 four-year-old language-impaired children from a general population sample of 18,000 children (Meaburn, Dale, Craig, & Plomin, 2002) did not find the hypothesized *FOXP2* mutation in any participants. Therefore, there must be some alternative etiology that leads to language impairment, beyond a simple mutation in *FOXP2*.

Moreover, mutations of *FOXP2* in patients are also associated with small-scale orofacial motor control. Thus, behavioral deficits in these individuals extend beyond functional language processing to motor control (including motor control that is necessary for speech). Vargha-Khadem, Watkins, Alcock, Fletcher, and Passingham (1995) note that the disorder in affected members of the KE family "indicates that the inherited disorder does not affect morphosyntax exclusively, or even primarily; rather, it affects intellectual, linguistic, and orofacial praxic functions generally" (p. 930). Given the complex range of deficits, it is unclear how a mutation in this area could yield a phenotypically unified disorder such as that proposed by van der Lely, Rosen, and McClelland (1998).

This is not to say that such specific and mutation-based disorders are impossible; indeed, sickle cell anemia is a clear case of a disorder that is both phenotypically identifiable and genetic in origin. However, this example makes it clear that the

level of specificity involved in describing such a disorder is much higher than that currently used in SLI. Genetic specification of the "one gene, one mutation" variety is unlikely. A more complex model, involving interactions between genetic factors, seems more probable. Recently, Vernes et al. (2008) traced the down-regulation of *FOXP2* on *CNTNAP2*, a gene that encodes a neurexin that influences cortical development. Looking at a British database of 847 individuals from families with at least one child with SLI, this group then focused on nine *CNTNAP2* polymorphisms. Each of these nine had a significant association with nonword repetition scores. The most powerful association was for a haplotype labeled ht1 linked to a lowering of nonword repetition scores by half a standard deviation. This same pattern is also heavily associated with autism. This new research illustrates the growing contribution of genetic analysis, as well as the complexity of genetic interactions involved and the ways in which they impact the formation of connections between areas in early brain development.

Van der Lely has emphasized the extent to which she can identify a highly specified subgroup of SLI language users. However, attempts to replicate this selection specificity (Bishop, Bright, James, Bishop, & van der Lely, 2000) have not succeeded. Moreover, even if such a distinct subtype were identified, and even if there were some statistical association between that disorder and some genetic mutation or set of mutations, we would still need a cognitive or neural model by which the mutations could be linked mechanistically to the disorder in question.

Are SLI Deficits Domain-Specific?

Claims of specific competence deficits in children with SLI have been used to support nativist views regarding the "faculty of language" (Hauser, Chomsky, & Fitch, 2002). The idea is that the specificity of this disorder implies that language learning and processing depend on a separate linguistic module, rather than on domain-general processes, and that damage to the module causes highly specified symptoms as hypothesized in SLI. However, the comorbidity of nonlinguistic task difficulties for children with SLI (Barry, Yasin, & Bishop, 2006) calls this interpretation into question.

Many studies have found deficits in nonlinguistic tasks in SLI patients, seemingly disputing the definition of SLI as an exclusively linguistic (or exclusively grammatical) disorder. The findings that SLI patients have impaired phonological short-term memory (Evans & MacWhinney, 1999), that the KE family and others have comorbid motor problems (Vargha-Khadem et al., 1995), and other trends toward cross-domain SLI symptoms are supportive of a richer understanding of SLI than that which restricts the impairment to one grammatical competency.

Finally, in a gating task of word identification from incomplete auditory data, an SLI group took longer to produce the correct response consistently (Mainela-Arnold, Evans, & Coady, 2008). These findings suggest a prolonged process of competition in SLI lexical processing. Such data help connect a potential perceptual deficit with the accompanying processing impairment.

Is SLI Exclusively a Deficit of Linguistic Competence?

Van der Lely and Christian (2000) describe the difference between processing models and competence deficit models as the difference between whether or not "impaired input processes and processing capacity cause SLI" (p. 35). That is, within a competence deficit model, any negative effects that stem from SLI should be restricted to the linguistic domain, and basic cognitive capacity (such as working memory) should remain within the normal range. More concretely, these competence models of SLI predict that genetic changes cause domain-specific effects, and that those effects consist of competence deficits such as the Extended Optional Infinitive stage. However, there is real variability in the symptoms and deficits showed by SLI children, and multiple cognitive limitations could be the source of these varied deficits.

First, as noted earlier, SLI is characterized by a variety of comorbid impairments (Norbury, Bishop, & Briscoe, 2002), such as phonological and oro-facial motor control disorders. The data from the KE family of language-impaired individuals are characterized by just such comorbidity (Bishop, 2002). Motor control problems, while clearly implicated in deficits in language production, do not fit the profile of a uniquely human mutation-based impairment in grammatical usage, as in a competence model. Van der Lely et al. (1998) differentiate between these comorbid impairments and the root cause of SLI by selecting participants who fall within normal range in these other language-related skills. This exclusion certainly increases the likelihood that there is a common etiology for the impairment in the grammatical SLI subgroup. However, there is no room in such a model to explain the nonlinguistic deficits of the many individuals excluded during this process. Unless there is some plausible explanation for the rest of these SLI subtypes, it is difficult to accept a model dependent on restricting any variance in the patient population.

Second, the competence impairments that serve as *cause* in models such as Rice and Wexler (1996) and van der Lely et al. (1998) could in fact be the *result* of impairments in processing, which need not be domain specific. For example, the Competition Model account would suggest that at least some children with SLI have problems with long-distance neural connectivity. Such problems could have a particularly strong impact on the coordination of information between posterior lexical areas and anterior syntactic areas. These problems would not impact linguistic competence, but rather the speed and accuracy of processing during interactive communication between these two separate areas. This emphasis on the vulnerability of between-area communication is in accord with the Competition Model emphasis on processing cost. According to the Competition Model, the SLI patient is performing a complex task with limited cognitive resources, and the limitation of those resources creates predictable and consistent negative effects for the most resource-intensive aspects of language processing.

Third, there is substantial evidence that the SLI diagnosis can be further subdivided based on whether the impairment in language competence extends to receptive as well as expressive language use (Evans & MacWhinney, 1999).

It is difficult to see how a competence account alone can explain this further dissociation. However, the Competition Model can account for this asymmetry as a result of differences in connectivity. Varieties of SLI that are exclusively expressive function much like Broca's aphasia. In typical speakers, Broca's area serves to gate the firing of lexical items during production. In expressive SLI, as in Broca's aphasia, disruption in the connectivity between Broca's and Wernicke's areas interrupt the smooth gating of lexical items for production. This gating is only important during production and is not involved in comprehension. In the case of receptive-expressive SLI, then we would expect to see a different, more general problem of information exchange between brain areas, affecting connections between Broca's area, DLPFC, Wernicke's area, and attentional areas generally.

APHASIA

These issues can be further explored by considering aphasic patients. Aphasia arises when a brain lesion from trauma or stroke produces a linguistic impairment. Traditionally, aphasia has been divided into three main categories: Broca's, or nonfluent aphasia; Wernicke's, or fluent aphasia; and anomia, or problems with word finding. Additional types include global and conduction aphasia. Because the etiology of aphasia is much clearer than that of SLI, and because the injuries are easier to map, aphasia provides a useful counterpoint to SLI. In SLI, the functional deficits are well-defined but etiology remains unclear. In aphasia, the opposite is true.

Although aphasia has a clear etiology, lesion site is not a strong predictor of symptom pattern. Two patients with lesions in very different areas will often have similar linguistic profiles. Similarly, patients with lesions in the same area often end up with very different profiles in language performance. Moreover, if a person with Wernicke's aphasia is impaired in grammaticality judgment in a way that resembles a person with Broca's aphasia, this does not necessarily mean that Broca's and Wernicke's areas perform the same processing tasks, or that they are neurally identical. Rather, it means that grammar is a complex computational task with certain high-risk components that can be impaired in similar ways through damage to various parts of the language network. In this way, aphasia often teaches us more about the nature of the language processing system than it does about the brain.

Crosslinguistic studies of aphasia (Bates et al., 1991) have illustrated and validated this approach. There is a rich literature demonstrating differences between Broca's aphasics who are native speakers of different languages. For example, the use of agreement in aphasic patients whose native language is Italian is relatively less impaired than in comparison patients whose native language is English. This result is predictable in a Competition Model framework, given the strength of agreement cues in Italian compared to English. In both Broca's and Wernicke's aphasics, obligatory structures such as SVO word order in German and Italian patients are preserved. These structures are also the most valid, least

costly (as defaults in the language), and most highly frequent. Similarly, when Turkish speakers become aphasic, they still maintain the use of SOV word order, which is the standard in Turkish. As Elizabeth Bates would say, "You can take the Turks out of Turkey, but you can't take the Turkish out of the Turks." Overall, this research shows that the major determinant of cue survival in aphasia is the relative strength of the cue in the language of the aphasic.

The status of competence accounts in aphasia is similar to its status in SLI. In SLI, competence accounts look to a simple causal association between a damaged component (such as a specific mutation) and a language deficit. In aphasia, these accounts also require that a specific lesioned local area or module be the root cause of the aphasic disability. In both cases, the competence approach fails to consider the broader context of the language system, wherein levels of processing (semantics, syntax, lexicon, audition, comprehension) interact within a distributed functional neural network of brain areas (Bookheimer, 2002).

In the Competition Model analysis, the effects of lesions must be understood in terms of the damage inflicted on both grey matter and white matter. Damages to grey matter impact the content of the representational maps that are at the core of the system. In one view, these maps could be viewed as encoding specific linguistic competence. However, when grey matter is damaged, there is usually accompanying damage to the white matter that connects the local map with other processing regions. Thus, actual patterns of aphasia relate not just to the processing in local maps, but also disorders in connectivity and processing that occurs as two or more maps attempt to work in synchrony.

Gupta, MacWhinney, Feldman, and Sacco (2003) showed that, in children who had had early focal lesions, learning was quantitatively delayed in word learning, nonword repetition, and serial recall tasks. Although the level of performance was impaired overall, the relation between measures of verbal working memory and word learning was maintained, and those relations were similar to the control group. These data are consistent with the finding that children with focal lesions are able to achieve functional language use, although their overall reaction times are often slower than that of controls (MacWhinney, Feldman, Sacco, & Valdes-Perez, 2000).

A similar, and perhaps even more striking, finding comes from Wilson and Saygin (2004). They report evidence in direct contradiction to models that hypothesize that Broca's area is the unique site for comprehension of maximal trace projections (Grodzinsky, 2000). In Wilson and Saygin's study, *all patient groups*, including anomics, shared a general impairment pattern, although the quantitative performance of the patients varied, as expected. These results show that a number of injuries to the language network can create similar performance profiles. These data fit well with the analysis of the Competition Model.

Finally, data suggest that nonaphasic patients with left-hemisphere lesions have sentence comprehension and free word recall deficits compared to similar right-hemisphere lesion patients (Vallar, Papagno, & Cappa, 1988). The left hemisphere patients had lexical and syntactic deficits, as well as a decrement in verbal long-

term memory. Consistent with the view of language as a complex and distributed system, the varied lesion sites all had some broad effect on linguistic *processing*, as demonstrated through varied behavioral measures.

SUMMARY AND CONCLUSION

This chapter has presented ways in which the Competition Model can be useful in understanding SLI and aphasia. The Competition Model framework suggests that there are multiple pathways that can produce SLI. As we have argued, impairment in processing capacity can result in symptoms that reflect weakened "vulnerable" linguistic structures. Such a processing deficit, however, could have multiple causes, consistent with accounts of decreased verbal working memory (Gathercole & Baddeley, 1993), phonological processing impairment (Tallal & Piercy, 1974), and orofacial motor impairment (Vargha-Khadem et al., 1995). In this sense, SLI can be viewed as linked to an *endophenotype* (Gottesman & Gould, 2003) in which a complex set of genetic variations produce a phenotypically consistent cognitive outcome. The current literature suggests that at the core of the SLI endophenotype is a set of individual variations that can influence the operation of verbal working memory. We must note that verbal working memory is not a single cognitive process. On the one hand, the six local cortical maps that support language each maintain some type of local memory through competitive activation patterns. However, this local activation is not enough to effectively control higher levels of language processing. Once an item is activated locally, it must receive additional support from other areas and it must also trigger activation in other areas.

For example, a word such as "more" may maintain activation in the posterior lexical area. This activation constitutes a certain level of local memory. However, this item must then activate Broca's area to trigger combination with a noun, as in "more campers." Once this phrase links up with a verb, as in "more campers visited the park," activation then spreads to frontal areas that encode perspective (MacWhinney, 2008c) and overall mental models. The distributed and interactive nature of this information flow requires smooth white matter connections between each of the areas involved in processing. This suggests that an SLI endophenotype involves disruptions that interrupt the timing or accuracy of this information flow.

This approach suggests that we should not imagine working memory as a discrete neural storage area. As Mainela-Arnold et al. (2008) write:

> Current developments in connectionist modeling and neuroscience suggest that what has been referred to as working memory capacity may be comprised of global competition of activation in large-scale neural networks with a top-down attentional bias from prefrontal cortex (PFC) circuits. (p. 390)

This is consistent with other domain-general models of working memory function (Schneider & Chien, 2003).

The Unified Competition Model is designed to interface with perceptual and memory processes and integrates working memory buffers at each level of processing. In this way, the model is aligned with cognitive models such as ACT-R (Anderson & Lebiere, 1998) that maintain local buffers. These accounts fit behavioral data that show competition and interference at multiple levels in online language processing. Because language depends on the integration of multiple inputs to produce either intelligible outputs or comprehension, describing the precise nature of this coordination is crucial for neurally grounded language models. By mapping connections between language areas with diffusion tensor imaging (DTI; Schmahmann et al., 2007), or by using functional connectivity analyses (MacDonald, Just, & Carpenter, 1992), we can provide further articulation of this account.

Although the Competition Model emphasizes the structural integrity of language, it also emphasizes the complexity of neurolinguistic processing. Although we expect a wide variety of lesions or endophenotypes to produce similar symptom patterns, we also expect that careful scientific work can eventually separate out the relative contributions of the six separate local processing regions and the complex patterns of white matter connections between them. We also expect that some symptom patterns will arise not from lesions, but from poor mappings between resonant areas and cellular-level problems with neuronal firing and consolidation. In this sense, we would agree with van der Lely (2005) when she notes "it is only by identifying pertinent … phenotypes that we can illuminate functionally specialized cognitive systems" (p. 53). There are many contrasts that are illuminative in this way; for example, some aphasics are expressive (fluent), while others are nonfluent. Some subjects have affected prosody and labored articulation, whereas others do not. Similarly, in SLI, some subjects have reduced working memory and others are closer to normal. However, we do not want to use these dissociations to link impairments to modules. Rather, we need to look at the overall dimensions of cue strength and cue cost as the linguistic backdrop against which processing limitations should be measured. Only by collecting a rich set of measures of performance in both experimental and naturalistic contexts can we achieve clearer understandings of the various ways in which this integrated system can be impaired. Language, though unique in the types and complexity of the necessary calculations, is in the end a cognitive process, and this simple fact leads to a more complete understanding of language disorders.

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3 Language Processing in Normal Aging

Lise Abrams and Meagan T. Farrell

INTRODUCTION

Older adults' ability to perceive, comprehend, and produce language has been an area of interest to researchers in recent years. One of the core questions under study has been whether aging affects the processing of language universally or only in specific ways. In general, an asymmetric pattern emerges, where older adults experience greater difficulties when producing language compared to comprehending it (e.g., Burke, MacKay, & James, 2000). In particular, word-retrieval problems are some of the most noticeable and frustrating language difficulties reported by older adults (e.g., Lovelace & Twohig, 1990). Although these difficulties are much less significant than the profound language impairments found in clinical disorders such as aphasia, they nonetheless have important consequences for older adults' ability to communicate. For example, difficulty retrieving someone's name during a conversation can result in negative perceptions of older adults' competence, both from the listener and the speaker (e.g., Cohen, 1994; Hummert, Garstka, Ryan, & Bonnesen, 2004; Kemper & Lacal, 2004; Ryan, See, Meneer, & Trovato, 1994). This negative perception of aging is misleading, as there are positive aspects of aging, such as consistent increases in vocabulary that occur across the life span (e.g., Verhaeghen, 2003).

The purpose of this chapter is to review the literature on language processing in healthy older adults, with a particular focus on the cognitive processes underlying language and the circumstances that lead to impairments in older adults' language comprehension and production. This chapter begins with a brief review of theories of cognitive aging, as they relate specifically to language processing. The remainder of the chapter discusses research-based findings regarding language processing in old age, covering comprehension and production of both oral and written language as well as language use in conversational settings. We conclude with some discussion about our own directions for future research and suggestions for enhancing the ability to communicate with older adults.

THEORIES OF COGNITIVE AGING

Salthouse (1988) suggested that there was a paucity of theories of cognitive aging in comparison to the number of empirical findings at that time. In the two subsequent decades, a number of theoretical explanations have been proposed to

explain age-related changes in language processing. Generally, these theories can apply to other aspects of cognition besides language, but for the purposes of this chapter, we have highlighted their relevance to language processing specifically. Brief descriptions of each theory and some corresponding empirical evidence are given below.

Working Memory

Working memory is a limited-capacity memory system that temporarily holds and manipulates information as we perform cognitive tasks (e.g., Baddeley, 1986). Some theorists suggest that older adults suffer overall decreases in working memory capacity, the amount of information that can be held at a given time (e.g., Craik, 1983; Salthouse, 1991). An alternative viewpoint is that aging is accompanied by changes in processing efficiency in working memory, not necessarily capacity (e.g., MacDonald & Christiansen, 2002). In this view, older adults have less efficient processing, such as slower spreading of activation throughout the networks of the language system, which in turn constrains the amount of information that they are able to process concurrently. Regardless of the cause of working memory deficits in old age, older adults do have greater difficulty with language tasks that are dependent on working memory, such as the production and comprehension of complex grammar or semantically difficult content (e.g., Kemper, 1987, 1992; Kemper & Kemtes, 1999; Kemper & Sumner, 2001; Kemper, Thompson, & Marquis, 2001; Obler, Fein, Nicholas, & Albert, 1991; Zurif, Swinney, Prather, Wingfield, & Brownell, 1995). For example, Kemper and Sumner (2001) reported that several measures of grammatical complexity were positively correlated with traditional working memory span measures, including reading span and digit span.

Inhibition Deficits

Another explanation for age-related changes in language processing comes from inhibition deficit theory (e.g., Hasher, Lustig, & Zacks, 2007; Hasher & Zacks, 1988). In this theory, aging weakens inhibitory processes, which are responsible for regulating the information that enters and leaves working memory. The main consequence of older adults' inefficient inhibitory processes is that irrelevant information gains entry into working memory, is not deleted, and thus creates interference. Inhibition deficits have been used to explain various impairments in older adults' perception and comprehension of language, such as older adults having greater difficulty understanding speech when background speech or noise is present (e.g., Pichora-Fuller, Schneider, & Daneman, 1995; Tun, O'Kane, & Wingfield, 2002) or when there is competition from similar-sounding words (e.g., Sommers, 1996; Sommers & Danielson, 1999). Older adults also have greater difficulty ignoring visually distracting information during reading (e.g., Connelly, Hasher, & Zacks, 1991; Li, Hasher, Jonas, May, & Rahhal, 1998). Difficulties with inhibition have also been used to explain some age-related

deficits in language production, such as older adults producing more speech that is off-topic (e.g., Arbuckle, Nohara-LeClair, & Pushkar, 2000; Gold, Andres, Arbuckle, & Schwartzman, 1988).

General Slowing

Theories of general slowing propose that age-related deficits in language processing are due to slowing of component processes (e.g., Birren, 1965; Cerella, 1985; Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 2000). Specifically, processing speed, the speed at which older adults execute cognitive operations, may be too slow to accomplish a task in a given amount of time (e.g., Salthouse, 1996). Age-related declines in processing speed have been used to explain older adults' deficits in time-limited tasks, such as comprehension of speeded speech (e.g., Wingfield, 1996; Wingfield, Poon, Lombardi, & Lowe, 1985). Processing speed deficits have also been used to explain some of older adults' difficulties with sentence comprehension, such as a reduction in the use of contextual information to help resolve ambiguity (e.g., Dagerman, MacDonald, & Harm, 2006). Although general slowing theories have been applied to some language tasks, they generally are used to explain older adults' performance on a much broader range of cognitive tasks (e.g., Salthouse, 1985).

Transmission Deficit Hypothesis

The Transmission Deficit Hypothesis offers the most specific mechanism to explain the asymmetric effect of aging on language processing, where certain aspects of language processing, namely semantic representations and retrieval, are actually well-preserved into late adulthood, relative to phonological and orthographic representations (e.g., Burke et al., 2000). In this framework, linguistic information is stored as nodes in a vastly interconnected network separated into multiple systems, including a semantic system for word meanings, a phonological system for sounds, and an orthographic system for spellings (MacKay, 1987; MacKay & Abrams, 1998). As people age, the strength of connections between these nodes becomes gradually degraded throughout the entire network (Burke & MacKay, 1997; MacKay & Abrams, 1996; MacKay & Burke, 1990), which influences the speed and amount of activation that is transmitted between nodes. The architecture of the network leaves the phonological and orthographic systems particularly vulnerable to age-related transmission deficits because it relies on single connections between the semantic representation of a word's meaning and the word's phonological/orthographic form. Evidence in support of the Transmission Deficit Hypothesis comes from an age-associated increase in tip-of-the-tongue (TOT) experiences, a temporary inability to produce a word despite knowing its meaning (e.g., Burke, MacKay, Worthley, & Wade, 1991; White & Abrams, 2002), more frequent slips of the tongue (e.g., MacKay & James, 2004), and increased spelling errors (e.g., Abrams & Stanley, 2004; MacKay & Abrams, 1998; Margolin & Abrams, 2007).

LANGUAGE COMPREHENSION

Current theories of cognitive aging need to account for the observation that while some language functions are maintained or even improved throughout most of late adulthood, other capacities are significantly corrupted by the cognitive aging process. This age-linked asymmetry in linguistic abilities is classically demonstrated by the comparison of input- to output-side language processes (Burke et al., 2000; James & MacKay, 2007). We focus first on input processes, which refer to the perception of speech sounds and letters and comprehension at the word, sentence, and discourse level. Aging appears to have a less deleterious effect on input-side processes, although some deficits do emerge.

Sensory/Perceptual Versus Cognitive Deficits

A common cause of deficits in older adults' comprehension of language is sensory and perceptual deficits. With respect to vision, older adults experience declines in visual acuity, retinal blurring (e.g., Artal, Ferro, Miranda, & Navarro, 1993), a reduction in the accuracy of voluntary saccadic eye movements (e.g., Scialfa, Hamaluk, Pratt, & Skaloud, 1999), and reduced light transmitted to the retina (e.g., Scialfa, 2002). These changes in vision have consequences for visual language processing, such as a reduction in the speed and accuracy of recognizing words and reading text (e.g., Akutsu, Legge, Ross, & Schuebel, 1991; Scialfa, 2002; Steenbekkers, 1998). Similar sensory and perceptual declines occur in the auditory system, where aging is frequently accompanied by presbycusis, or pure-tone hearing loss characterized by the loss of higher frequencies (e.g., CHABA, 1988; Cheesman, 1997; Frisina & Frisina, 1997; Willott, 1991). These age-related auditory changes can lead to poorer identification of individual sounds and words, even in ideal listening situations (e.g., Humes, 1996).

However, when younger and older adults are equated on hearing ability, age differences sometimes still emerge, suggesting that higher-level cognitive deficits may also contribute to age-related impairments in spoken language processing (e.g., CHABA, 1988; Frisina & Frisina, 1997; Schneider & Pichora-Fuller, 2000; Wingfield & Tun, 2001). Specifically, reductions in processing resources described earlier, such as working memory capacity, processing speed, or inhibitory control, have been proposed to explain age differences in spoken language processing (see Sommers, 2008, for a review). Support for this view comes from studies showing that increasing or decreasing the cognitive demands on speech perception and comprehension determines the degree of impairment that older adults experience. For example, older adults show exacerbated declines under listening conditions that increase the amount of resources required for successful perception and comprehension, such as background noise (e.g., Frisina & Frisina, 1997; Pichora-Fuller et al., 1995; Tun, 1998; Tun & Wingfield, 1999), accelerated speaking rates (e.g., Gordon-Salant & Fitzgibbons, 1999; Stine, Wingfield, & Poon, 1986; Wingfield, Peelle, & Grossman, 2003), multiple people talking at once relative to a single talker (e.g., Sommers, 1997; Sommers & Danielson, 1999; Tun & Wingfield, 1999),

or unfamiliar talkers (e.g., Yonan & Sommers, 2000). Conversely, circumstances that reduce the cognitive demands of spoken language processing facilitate older adults' performance, often more so than younger adults. For example, older adults' speech perception is improved by presenting words in highly predictive or semantic contexts (e.g., Frisina & Frisina, 1997; Pichora-Fuller et al., 1995; Sommers & Danielson, 1999; Wingfield, Aberdeen, & Stine, 1991; Yonan & Sommers, 2000), when speaking rates are slower (e.g., Wingfield & Ducharme, 1999; Wingfield, Tun, Koh, & Rosen, 1999), or when prosodic and syntactic information is provided (e.g., MacKay & Miller, 1996; Wingfield, Lindfield, & Goodglass, 2000).

Word-Level Comprehension

Despite the additive effects of hearing loss and cognitive declines, the majority of healthy older adults maintain an ability to successfully communicate in a variety of settings (e.g., Wingfield & Grossman, 2006). One explanation is that older adults may be able to make use of environmental and contextual cues as a compensatory strategy to offset their sensory, perceptual, and cognitive changes (e.g., Craik, 1986; Humphrey & Kramer, 1999; Sommers, 2008). Alternatively, older adults may be able to employ effective top-down strategies that make use of preserved semantic knowledge, which appears to resist the age-related degradation observed in other domains of cognition (e.g., Burke et al., 2000; Burke & Shafto, 2008; Kemper, 1992; Thornton & Light, 2006). Since input-type lexical processes rely on the ability to link current linguistic information onto existing semantic knowledge, many aspects of language comprehension remain markedly intact among older adults, at least at the single-word level (e.g., Burke & MacKay, 1997; Thornton & Light, 2006).

Semantic priming studies, which examine how word meanings are processed and organized in the semantic network, have demonstrated that older adults experience the benefit of semantic priming at least to the same degree as younger adults (e.g., Balota, Watson, Duchek, & Ferraro, 1999; Burke, White, & Diaz, 1987; Faust, Balota, & Multhaup, 2004; Howard, McAndrews, & Lasaga, 1981; Lazzara, Yonelinas, & Ober, 2002; Tree & Hirsh, 2003; White & Abrams, 2004). Individuals are faster to identify a target word (e.g., DOCTOR) when it is preceded by a semantically related prime (e.g., NURSE), compared to an unrelated word (e.g., TABLE), and the degree of facilitation from the semantic prime is comparable for younger and older adults (see Laver & Burke, 1993 for a meta-analysis). Similarly, both age-groups benefit equivalently from exposure to contextually related sentences prior to single-word comprehension tasks (e.g., Burke & Yee, 1984; Stine & Wingfield, 1994). Furthermore, older adults are equally if not more accurate in making decisions about the lexical status of linguistic stimuli, such as decisions about whether visually presented items are actual words or not (e.g., James & MacKay, 2007).

In sum, although age-related sensory declines restrict the speed with which older adults are able to comprehend lexical items, there seems to be little or no change in their ability to process and organize the meanings of words. The

findings that older adults perform consistently well on these comprehension tasks are likely the product of a superior vocabulary and a dense semantic network, which continues to grow throughout most of adulthood.

Sentence and Discourse Comprehension

The picture is somewhat more complex when considering older adults' comprehension at the sentence and discourse level. Unlike the observed pattern in word-level comprehension, older adults do show impairment in comprehension and retention of sentences and longer texts (e.g., Johnson, 2003; Kemper & Sumner, 2001; see also reviews by Burke & Shafto, 2008 Kemper, 2006; Thornton & Light, 2006; Wingfield & Stine-Morrow, 2000). Age differences in comprehension have largely been attributed to declines in component cognitive processes like working memory (e.g., De Beni, Borella, & Carretti, 2007; Margolin & Abrams, 2009; Stine-Morrow, Soederberg Miller, Gagne, & Hertzog, 2008). Sentence and discourse comprehension requires processing current linguistic input and integrating it with previously read material in order to create a cohesive representation of the text. As a result, older adults are more vulnerable to syntactically complex or ambiguous sentences (e.g., Kemper, Crow, & Kemtes, 2004; Kemtes & Kemper, 1997; Zurif et al., 1995) and prefer segmenting text into smaller chunks in order to offset the demands on working memory (e.g., Wingfield et al., 1999). However, difficulties with processing negation during sentence comprehension do not seem to increase with age (Margolin & Abrams, 2009).

Most comprehension measures used in research rely on readers' memory for the text; as a result, older adults' impairments in comprehension may more accurately reflect age-related declines in episodic memory (e.g., Burke & Shafto, 2008) and not a decline in reading ability. Furthermore, older adults may be able use their superior vocabulary and semantic knowledge to counteract processing deficits during the comprehension of discourse. A reader's *situation model* refers to his/her global representation of the text. It is created and constantly updated while reading to include information about the shifts in time and space, character and theme development, as well as to incorporate the textual information with preexisting knowledge structures (e.g., van Dijk & Kintsch, 1983; Zwaan, Magliano, & Graesser, 1995; Zwaan & Radvansky, 1998). Situation models differ from *surface level* and *textbase* representations, which are data-driven and exist independent of the reader's knowledge (e.g., Stine-Morrow et al., 2008). Surface-level representations consist of the individual meaning of words and the syntactic structure of sentences. At the next level, the textbase captures the semantic meaning explicitly provided in the text and links multiple concepts. Older adults demonstrate an intact ability to construct mental representations of discourse and update situation models as necessary during reading (e.g., Morrow, Stine-Morrow, Leirer, Andrassy, & Kahn, 1997; Radvansky, Copeland, & Zwaan, 2003; Radvansky, Zwaan, Curiel, & Copeland, 2001), despite impaired memory and comprehension for surface and textbase information.

Older adults may actually depend more on self-constructed situation models during reading because they are able to utilize existing knowledge when forming

representations. As a result, older adults may not remember specific details (likely to be asked on typical comprehension measures) but will have preserved understanding of the global meaning or gist of the text. For example, older adults' memory for situation model information was superior to younger adults for passages about history (e.g., Radvansky et al., 2001) as well as narratives (e.g., Radvansky et al., 2003). Recently, Stine-Morrow et al. (2008) compared the reading abilities and strategies of younger and older readers using individual sentences, scientific expository texts, and narratives. Resource allocation was measured as a function of the amount of time readers spent on text features thought to reflect surface-level, textbase-level, and discourse-level processing. Collapsed across genre type, they found that compared to younger adults, older adults allocated more resources to surface-level processes (increased reading times for low-frequency and multi-syllabic words) and textbase processes (increased time spent on the introduction of new concepts) when reading individual sentences. However, these differences were diminished by contextual facilitation, as age differences disappeared for narrative texts and were less pronounced for the expository texts. Stine-Morrow et al. (2008) proposed that older adults may compensate for obvious processing deficits, such as declines in working memory capacity, by relying on superior knowledge-based processing and preserved contextual understanding, as well as by allocating additional resources as needed.

SPOKEN LANGUAGE PRODUCTION

In contrast to the input side, the output side of language requires the activation and retrieval of phonological information (for spoken language production) and orthographic information (for written language production). Comparisons of input- and output-side processes demonstrate significantly greater age-related deficits on production tasks, relative to comprehension tasks (e.g., Burke et al., 2000; James & MacKay, 2007; MacKay & Abrams, 1998). Tasks of production typically involve lexical retrieval, in spoken or written form.

Tip-of-the-Tongue (TOT) States

On some occasions, word production fails and results in a TOT state, a temporary and often frustrating inability to retrieve a known word (e.g., Brown & McNeill, 1966). TOT states increase with aging, both in the laboratory and in everyday life (e.g., Abrams, 2008; Brown & Nix, 1996; Burke et al., 1991; Burke, Locantore, Austin, & Chae, 2004; Cross & Burke, 2004; Evrard, 2002; Gollan & Brown, 2006; Heine, Ober, & Shenaut, 1999; Maylor, 1990), despite older adults having larger vocabularies (e.g., Verhaeghen, 2003). TOT states are thought to reflect phonological encoding failure after the selection of an appropriate word. The inability to retrieve phonology (and result in a TOT) increases with age, presumably because aging reduces transmission of excitation to phonological representations (MacKay & Burke, 1990), a difficulty that seems to derive from atrophy in the left insula (Shafto, Burke, Stamatakis, Tam, & Tyler, 2007). Consistent with this explanation,

compared to younger adults, older adults can retrieve less phonological information about the TOT word, such as number of syllables or first and last letters (e.g., Burke et al., 1991; Brown & Nix, 1996; Heine et al., 1999; James & Burke, 2000), and they are less likely to have an alternate word during a TOT state, an incorrect word that involuntarily comes to mind and often overlaps phonologically with the TOT word (e.g., Burke et al., 1991; Heine et al., 1999; White & Abrams, 2002). TOT states are more likely to occur for low- than high-frequency words (e.g., Vitevitch & Sommers, 2003), and proper names have the greatest susceptibility to TOT states, especially in old age (e.g., Burke et al., 1991; Evrard, 2002; James, 2006; Rastle & Burke, 1996).

Research has shown that activation of phonological representations thought to cause TOT states can be achieved by prior production of words that share phonology with the TOT word (e.g., James & Burke, 2000; see Abrams, Trunk, & Margolin, 2007a for a review). For example, James and Burke (2000) showed that after pronouncing a list of words that included *abstract*, *indigent*, *truncate*, *tradition*, and *locate*, people were less likely to have a TOT for *abdicate*. Pronouncing phonologically related words during a TOT can also help to resolve the TOT, resulting in retrieval of the intended word (e.g., Abrams & Rodriguez, 2005; Abrams, Trunk, & Merrill, 2007b; Heine et al., 1999; James & Burke, 2000; Meyer & Bock, 1992), and the initial syllable is the key to TOT resolution in both age groups (Abrams, White, & Eitel, 2003; White & Abrams, 2002). There are some age-related changes in the ability to resolve TOT states following phonologically related words, but the deficits are specific to older adults in their late 70s and 80s. Adults in their 60s and early 70s show an increase in resolving their TOT states following phonologically related words to the same degree as younger adults (e.g., Heine et al., 1999; James & Burke, 2000; White & Abrams, 2002), whereas adults in their late 70s and 80s have significantly less or no TOT resolution following phonologically related words (e.g., Heine et al., 1999; White & Abrams, 2002).

Recent research has documented instances where phonologically related words do not facilitate TOT resolution. Abrams and Rodriguez (2005) discovered that phonologically related words only help to resolve TOT states when these words are from a different part of speech as the TOT word. For example, when in a TOT state for the noun *bandanna*, reading *banish* (a verb) helped to resolve the TOT state, but reading *banjo* (a noun) did not. Abrams et al. (2007b) found that adults aged 61–73 showed a similar pattern, while adults aged 75–89 not only did not benefit from reading *banish,* but their retrieval of *bandanna* was worse after reading *banjo* compared with an unrelated word. These findings suggest that similar sounding words in the same grammatical class as the TOT word may compete with the TOT word for production and that these potential alternative words become more competitive for retrieval as we age.

Picture Naming

The suggestion that older adults have an increased difficulty in activating the connections between words and their phonology is also supported by research on

picture naming. Studies requiring older adults to produce the names of visually presented pictures have shown that older adults name objects less accurately and more slowly than younger adults (e.g., Feyereisen, 1997). However, age deficits in picture naming are not always found in individual studies (e.g., Goulet, Ska, & Kahn, 1994). One possible explanation is that older adults' larger vocabularies give them greater familiarity with the rarer picture names than younger adults, which then masks the age-linked decline in picture naming that would have appeared if both age groups were equally familiar with the words (e.g., Schmitter-Edgecombe, Vesneski, & Jones, 2000). Furthermore, similar to research on TOT states, there are differences within the older adult group, namely that many of the age differences in picture naming are found only when older adults reach their 70s (e.g., Barresi, Nicholas, Connor, Obler, & Albert, 2000; Connor, Spiro, Obler, & Albert, 2004; MacKay, Connor, Albert, & Obler, 2002; Morrison, Hirsh, & Duggan, 2003; Nicholas, Obler, Albert, & Goodglass, 1985).

Another use of picture naming studies has been to measure the influence of distractors, but there are virtually no studies with older adults. The only published study of which we are aware is Taylor and Burke (2002), who examined picture–word interference effects in younger and older adults as a function of auditory semantic and phonological distractors presented either before or after the picture appeared. Relative to unrelated distractors, interference (slower latencies) emerged when semantic distractors preceded the pictures, and older adults showed greater interference than younger adults. In contrast, facilitation (faster latencies) occurred when phonologically related distractors were presented after the picture, and this facilitation was equivalent for both age groups. These findings are consistent with the idea that older adults have a more elaborate semantic network, which results in greater priming to related concepts and subsequently more interference. Conversely, the lack of an age difference in degree of phonological facilitation suggests that presentation of phonologically related words strengthens the transmission of excitation to all connected words and that this "priming" process remains stable with age, a claim supported by research in other production tasks (e.g., James & Burke, 2000; White & Abrams, 2004).

Speech Errors

Compared to TOT states and picture naming, there is considerably less research on aging and speech errors. Speech errors provide us with an understanding about how language production is planned and how this planning can sometimes go awry and lead to errors in articulation. The patterns of speech errors that emerge have given researchers insight into the mechanisms that underlie speech production more generally. Two classes of errors that have been studied in aging include slips-of-the-tongue and dysfluencies. A slip-of-the-tongue occurs when a speaker rearranges one or more sounds across words to be produced, such as *darn bore* instead of *barn door*, or swaps entire words, for example, *I'm writing a mother to my letter* instead of *I'm writing a letter to my mother.* Similar to other forms of speech production, a word's frequency appears to influence the likelihood of