

# TWENTY-FIRST CENTURY PSYCHOLINGUISTICS

*Four Cornerstones*



Psycholinguistics is an interdisciplinary field, and hence relationships are at its heart. First and foremost is the relation between its two parent disciplines, psychology and linguistics, one which has changed and advanced over the half century of the field's independent existence. At the beginning of the 21st century, psycholinguistics forms part of the rapidly developing enterprise known as cognitive neuroscience, in which the relation between biology and behavior plays a central role. Psycholinguistics is about language in communication, so that the relation between language production and comprehension has always been important, and as psycholinguistics is an experimental discipline, it is likewise essential to find the right relation between model and experiment.

This book focuses in turn on each of these four cornerstone relations: Psychology and Linguistics, Biology and Behavior, Production and Comprehension, Model and Experiment. The authors are from different disciplinary backgrounds, but share a commitment to clarify the ways that their research illuminates the essential nature of the psycholinguistic enterprise.

Edited by

**ANNE CUTLER**



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**ANNE CUTLER**

# 1

## The Cornerstones of Twenty-First Century Psycholinguistics

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The name says it all—psycholinguistics is a discipline which draws on multiple sources. It is simultaneously psychology and linguistics. At the heart of the discipline, therefore, is the relationship between these two fields, each of which can boast centuries of research tradition as a recognizable independent field of study. By contrast, psycholinguistics itself is relatively young. Though research in both its parent fields addressed language processing issues in earlier times, psycholinguistics as we understand it today and as a discipline with its own name has only been in existence since the mid-twentieth century.

What does it mean to be a psycholinguist? One must have interest in how language structure relates to language use. This does not exclude a primary bias to one or other of the two underlying sets of research issues. Thus a psycholinguist can be primarily a psychologist, ultimately concerned to understand and explain the mental structures and processes involved in the use of language. But to be properly a psycholinguist, such a psychologist needs also to be concerned about why language has certain universal characteristics, how it can vary in language-specific ways, and how these aspects of structure impinge upon the way language is processed. Likewise, a psycholinguist can be primarily a linguist, whose ultimate concern is with the patterning of language itself; but such a linguist needs also to be interested in patterns evident in language performance and the reasons for those patterns, and needs to be open to evidence from laboratory studies involving highly controlled

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processing tasks. Still other sets of research issues may be primary – anthropological, for instance (and now all three authors of this introductory essay are represented). But in any case, a psycholinguist is concerned with the *relationship* between language and its use.

Thus psycholinguistics may itself be defined as the study of a relationship. It is the argument of this volume that doing psycholinguistics means addressing at least four further crucial relationships which underlie research in this field. These are cornerstones of current psycholinguistics, and they form the four sections of this volume. This introductory essay is not intended just as an overview and summary of the contents of these four sections, but more as background, in the form of a general outline of how psycholinguistics works (and it includes at least some attention to areas *not* represented in the volume). One of the conclusions which this introduction will motivate is that the way in which these four relationships are important to psycholinguistics today, in the first decade of the twenty-first century, is not necessarily the way things have always been.

### PSYCHOLOGY AND LINGUISTICS

It has always been the case that most individual psycholinguists feel a primary affiliation to one or other of the parent disciplines, and unless universities worldwide see fit to establish undergraduate faculties of psycholinguistics – an unlikely eventuality, we guess – this will continue. Psycholinguists generally come to the field via courses taken either in a psychology department or in a linguistics (or language) department. It is, inevitably, very probable that a psycholinguistics course in a psychology department will convey a different way of looking at the subject matter than an equivalent course in a linguistics department. (An undergraduate textbook in psycholinguistics written by a linguist is likely to divide the subject matter into chapters on the processing of phonological, syntactic, semantic information – see e.g., Prideaux, 1984 – while a book with the same title written by a psychologist will include chapters on producing, perceiving, and acquiring language – see e.g., Garnham, 1985.)

Sometimes the difference in approach is so fundamental that it would make sense to speak of different disciplines – say, psychology of language and performance linguistics (see e.g., Cutler, 1992). Differences arise due, as described above, to a primary motivation involving questions which are fundamentally psychological (how do humans process language?) or linguistic in nature (why is language the way it is?). But it is a basic tenet of psycholinguistics that both types of questions can best be answered by drawing simultaneously on knowledge from both parent disciplines.

Notwithstanding this belief, it is very obvious that the balance between the two primary motivations has not always been exactly maintained; indeed, the relation has changed regularly across the years. There is thus no guarantee that the situation that obtains now, at the beginning of the twenty-first century, will hold till the century's end. Nonetheless, this is an exciting time for psycholinguistics.

### **Psychology, linguistics, and adult language processing**

The discipline now known as psycholinguistics is only about half a century old, and the name was assigned when the study of adult language processing attracted growing interest within experimental psychology. It is fair to say that throughout its half century of existence this branch of psycholinguistics has been immensely technology-driven. Procedures for chronometric analysis in experimental psychology were in large part responsible for the expansion of research interest to new topics such as language processing, and hence for psycholinguistics appearing when it did. From the mid-twentieth century, the tape recorder made it possible to undertake research on spoken language while satisfying the demand of experimental psychology for strictly controlled and replicable conditions. Later (from the late 1970s to 1980s), a small revolution in models of adult processing followed from the availability of computer-readable vocabularies and large language corpora. Programming techniques developed in engineering and mathematics strongly influenced the type of modeling undertaken in psychology; in particular, connectionist modeling swept through the field to take an unquestionably dominant position from the 1990s.

It is not always easy to separate the relationship between linguistics and psychology from these other influences. Still, there was a time—four or more decades ago—when linguistics clearly set the tone for adult-language psycholinguistic research. The revolution in linguistics which Chomsky initiated in the 1950s and 1960s produced a line of empirical research devoted to deriving processing predictions from linguistic models, in particular from models of the grammar. The Derivational Theory of Complexity thus proposed that the complexity of grammatical derivations of sentences in transformational grammar could directly predict the processing complexity of the same sentences. Experimental support for this proposal was found (e.g., Miller & McKean, 1964), and psycholinguists of the time also tried to tease out contrasting predictions from rival grammatical theories, and set up experiments to test them against one another (e.g., Clifton & Odom, 1966).

This period ended rather abruptly, however. The linguistic theories changed, but they changed in response to linguistic argumentation and

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not at all in response to the growing body of processing evidence. This was, understandably, not a little frustrating to those psycholinguists who had spent years gathering the relevant evidence. There then followed a time when psychological studies of language processing tried to maintain independence from linguistic theory. It is too simple to say that psychology was displeased by perceived rejection from linguistics—after all, some linguists have been less than pleased over the years over what they saw as lack of sophistication in psychology's use of linguistic proposals. But it was obvious in the 1970s that most research on language processing was not directly informed by linguistics.

This changed with the growth of research in sentence processing driven by models which were truly psycholinguistic, i.e. they were processing models which were intended as linguistic proposals (e.g., Frazier & Fodor, 1978). This line of research became important from the 1980s, and coincided with new interest in cross-linguistic comparison in adult processing—research which necessarily drew on linguistic knowledge about language-particular structural variation, if not on linguistic explanations of it. At this time there was thus the beginning of a correction of the previous asymmetry; processing evidence was both sought in linguistics and had influence on linguistic modeling. This trend continues today, with the main driving force being, however, again technological. Biological evidence, in particular evidence from brain imaging, is almost as desirable in linguistics as in psychology. The twenty-first century may yet see the first linguistic model fully motivated by processing evidence.

#### **Psychology, linguistics, and first language acquisition**

The study of child language acquisition has a longer and richer tradition than the study of adult language processing (perhaps in part because observational techniques have always been with us, and these techniques easily produce vast amounts of wonderfully informative child language data). Before the twentieth-century developments which revolutionized linguistics, the study of language acquisition was primarily the domain of psychologists. These researchers—of whom Tiedemann, Preyer, Stern and Stern, Piaget, Vygotsky are the outstanding early examples—considered language acquisition as a part of the general cognitive and social development of the child. The approach which they pioneered is continued up to present times by exponents such as Bruner, Slobin, Bowerman, and linguists who are close to this idea, for example E. Clark. There are three central characteristics of this research tradition: (a) language is viewed as just part of general development; (b) there is a strong empirical orientation; and (c) no particular linguistic framework is

relevant, so that where linguistic definitions are important, essentially categories from traditional school grammar are used.

A second and very different research tradition arose in child language studies in the second half of the twentieth century. Jakobson (1941) was an early herald of the change, though the tradition really became clarified with Chomsky's (1965) proposal of a 'language acquisition device' (LAD) which is innate and universal. In theory, this idea made acquisition a core issue in the study of the human language faculty. Work initiated by this idea created a lively second tradition (often actively hostile to the existing tradition), which in turn was characterized by (a) the idea that there is a single 'language module', innate, universal and independent of other cognitive modules; (b) often poor empirical work; and (c) strong adherence to a particular linguistic framework, namely generative grammar in its various forms.

This tradition was very influential in first language acquisition research for several decades—interestingly, even at a time when, as described above, adult processing researchers had temporarily turned their back on linguistic motivations. It is fair to say that its impact has declined considerably over the past few years. The main reason for the decline is theory-internal developments: The minimalist framework, in particular, does not motivate acquisition research. In addition, there was a diminished role for the idea of 'parameter setting'—the notion that language-specific variation can be described in terms of a universal set of parameters which allow variable values, and that children are born with the set of parameters and infer, from the language input they receive, the values which their native language requires for each parameter. This idea, crucial in this tradition of acquisition research since the early eighties, lost its impact once subsequent theoretical accounts assigned parameters to the lexicon, rather than to a core role in the grammar.

Nonetheless, the question which was the basis of Chomsky's LAD proposal and which motivated the parameter-setting account remains central in psycholinguistics: What is the interplay between language-universal and language-specific features in language development? The long tradition of cross-linguistic acquisition research in fact predates the dominance of the linguistically based tradition (see e.g., Slobin, 1985), and it continues apace, drawing both from the general developmental tradition (examples here range from cross-linguistic studies of the perceptual development of phonemic repertoires—see e.g., Werker, 1995, for an overview—to the acquisition of language-specific semantic categories—e.g., Choi & Bowerman, 1992) and also drawing from linguistic theory (especially in phonology—e.g., Peperkamp & Dupoux, 2002—and in syntax—e.g., Crain & Pietroski, 2002).

### **Psychology, linguistics, and second language acquisition**

For research on acquisition of a second language rather than the first, a different situation holds. For decades after psycholinguistics had begun as an independent discipline, researchers in second language acquisition did not reckon themselves psycholinguists at all; their field was applied linguistics. This was in large part because their work had a practical focus; its primary motivation was to improve language teaching efficacy.

Second language acquisition is not a homogeneous phenomenon, of course: First, it need not wait until first language acquisition is complete, and second, there are several ways to gain access to a new linguistic system, ranging from metalinguistic description (as in the classroom) to everyday communication (as for many foreign workers). In the history of mankind, explicit teaching of a language is a relatively late phenomenon, and untutored learning was and probably still is the most common case. Nonetheless, second language acquisition in the classroom has been the focus of most research in this area, partly because of its practical import and partly because school situations are relatively accessible to empirical manipulation—at least, more accessible than the untutored situation.

This practical focus proceeds from the twin assumptions that there is a well-defined target of the acquisition process (the language to be learned), and that acquisition can be described in terms of to what degree and in which respects this target is missed. Given this "target deviation" perspective, the learner's performance in production or comprehension is not studied in its own right, as a manifestation of language learning capacity, but in relation to a set norm; not in terms of what the learner does but in terms of what he or she fails to do.

In contrast to the motivation of this type of research in the quest for practical improvements in language teaching, empirical work on second language acquisition outside the classroom has been motivated more by linguistic considerations. Concepts such as 'interlanguage', 'learner variety', 'approximate systems' or the like (see von Steiner, 1986; Perdue, 1993; Dietrich, Klein, & Noyau, 1995) are typical of this tradition, in which Klein and Perdue (1997) have identified three key assumptions: (a) The acquisition process produces a series of varieties, in which both the internal organization at a given time as well as the transition from one variety to the next are essentially systematic in nature; (b) A small set of principles is present in all such varieties, and the actual structure of an utterance is determined by interaction of these principles with other factors (e.g., source language, characteristics of the input). Importantly, learning a new feature of the target language means reorganization of the whole variety to incorporate the new feature; the balance of the various

components of linguistic knowledge about the target language then successively approaches the balance found in native speakers' usage; (c) Learner varieties are not imperfect imitations of a "real language" (the target language), but systems in their own right. Fully developed languages are but special cases of learner varieties, a relatively stable state where the learner stops learning because there is no apparent difference between the individual variety and the environment variety.

On this view, second language acquisition offers a unique window onto the human faculty for language. In untutored adult acquisition, human beings manage to copy, with varying degrees of success, the ways in which other people speak, and they do it by application of a species-specific mental capacity for language acquisition. All learner varieties are then manifestations of the human language faculty. Many learner varieties do not exploit the full potential of this faculty, for example, in terms of syntactic or morphological structure or of lexical repertoire. But note that even elementary learner varieties of Russian use more of the human language faculty's morphological potential than fully-fledged forms of the language family with the most native speakers on earth, that is, Chinese.

### Psychology and Linguistics in Section 1

The chapters in Section 1 provide views on many of the topics just mentioned. **Boland** discusses processing evidence which constrains syntactic theory in respect of the distinction between arguments and adjuncts. **Fikkert** discusses evidence from the acquisition of language-specific phonology in the light of current phonological theory. **Haverkort** contrasts linguistically and psychologically motivated accounts of grammatical impairment in aphasia. **Baayen** shows how large computer-searchable corpora can provide valuable psycholinguistic evidence. **Pickering and Garrod** discuss evidence from speaker and listener behavior in dialogue and its implications for the place of the lexicon in psycholinguistic models. And finally, **Poeppe and Embick** address the issue of how neurobiological evidence might indeed lead to new linguistic models.

## BIOLOGY AND BEHAVIOR

Psycholinguistics, as a member of the family of disciplines grouped as cognitive science, is in the twenty-first century definitely also part of that family branch now known as cognitive neuroscience. This has subsumed fields which used to be known as neuropsychology and neurolinguistics, and is faster-growing than any other area of psycholinguistics. Although

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all aspects of cognitive neuroscience are developing at an accelerated pace, there is in particular more and more interest in how language is processed in the brain. As a result, there is also more and more need for graduating psycholinguists to be familiar with techniques of brain research and the cognitive neuroscience literature. The relation between biology and behavior is thus definitely now a part of psycholinguistics; 40 years ago this may have been far less the case.

There is a sense in which cognitive neuroscience research necessarily addresses the relationship between biology and behavior, in a way that is not true of other areas of psycholinguistics; in effect, this relationship is what the field is all about, in that the principal aim is to understand how the brain operates to control and carry out all aspects of cognition.

However the relationship between biology and behavior as it concerns psycholinguistics embraces many more issues than how language is processed in the brain during comprehension or production. For instance, an important issue is the place of language processing in the functioning of the human organism as a whole. This question is represented in psycholinguistics by a growing body of research on how language interfaces with other cognitive faculties and processes.

We can, for example, talk about what we can see. For this to be possible, visual representations must be converted into linguistic representations. But these two types of representation seem to have very little in common: Visual representations are multidimensional, geometric and determinate, linguistic representations are linear, propositional and necessarily vague or general. It is actually quite unclear how these systems interface.

Visual information ties closely into spatial thinking in general, and the relation between language and spatial cognition has attracted much recent interest (see e.g., Bloom, Peterson, Nadel, & Garrett, 1996; Bowerman & Levinson, 2001; Coventry & Garrod, 2004). Take for example someone describing how to get to the railway station: What kind of coordinate systems do they use, and how does this tie in to the coordinate systems used in spatial behavior or spatial thinking? This 'frame of reference' problem has been at the centre of recent controversies (Li & Gleitman, 2000; Levinson, Kita, Haun, & Rasch, 2002; Levinson, 2003; Majid, Bowerman, Kita, Haun, & Levinson, 2004)—some researchers maintaining that the frames of reference used in language are just those used in spatial cognition, and others that while the frames of reference available to cognition are diverse, a specific language standardizes on just a few, partially constructed specifically for linguistic functions. But the main point is that we remain unclear about the nature of the interface between spatial cognition and language. For example, spatial reference

distinctions in cognitive neuroscience do not map happily onto what we know about linguistic codings of space, and considerable work will be required to bring these literatures into alignment.

An interesting way to approach some of these problems is through the study of communication in different modalities. Gestures accompanying speech, when (as often) indicating spatial directions, shapes and motions, are also driven by a frame of reference. These are more clearly dependent upon visual and spatial representations, yet they match the frame of reference used in language (Kita, 2003; Levinson, 2003), and indeed match the kind of packaging of information found in the particular language (Kita & Özyürek, 2003). More far-reaching still are sign languages, which are languages in a spatial modality. One might think that all sorts of advantages might accrue to users of a spatial language talking about space, but in fact there are also additional problems of perspective since the signs themselves are, as it were, spatial objects which can be viewed from different directions (see Emmorey, 2002, and this volume). Emmorey has been able to tie research on sign language to work on visual imagery and the underlying neuroscience (thus, for example, signers can more rapidly perform mental rotation, because their language requires special facility with this procedure).

This last finding is an important demonstration of language use exercising an effect upon cognitive processing (and abilities). It is far from the only such demonstration. For instance, bilingualism has also been shown to have far-reaching implications for cognitive processing beyond the realm of language. In a remarkably simple task from the repertoire of cognitive psychology, known as the Simon task, the subject has two response buttons, and is instructed to press (say) the left button if a red patch appears on the computer screen, the right button if a blue patch appears. Response time is slower when locations of visual stimulus and response are not congruent (e.g., the blue patch appears on the left side of the screen; Simon & Wolf, 1963). The extra cost incurred in the incongruent compared with a congruent or neutral condition is held to represent the time needed to inhibit an inappropriate response (pressing the left button), and this cost tends to increase with age. Bialystok, Craik, Klein, and Viswanathan (2004) discovered, however, that the cost is significantly reduced in bilinguals who have maintained use of more than one language throughout life; they suggested that switching between languages develops facility in inhibition of unwanted responses, such that added, quite general, benefits of cognitive control show up, even in such simple tasks. As with the mental rotation abilities of signers, we here see flow-on from use of a linguistic system—or in this case more than one linguistic system—to nominally unrelated aspects of cognition.

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However, beyond effects of language use upon cognition there is a further issue of whether (language-specific) linguistic structure may also have effects upon cognitive processing. A simplified working assumption in much of cognitive science is that semantic representations have an independent existence as conceptual representations built of categories, either innate or learned; language is then, as it were, a mere input/output device for encoding and decoding these representations. In much of psychology, 'semantic' is correspondingly equivalent to 'conceptual'. A problem for this view is that languages differ fundamentally in their semantic categories – the concepts built into their grammars and lexicons. The extent of the difference has been partly masked by the fact that psycholinguists have concentrated so much on related European languages; once one looks further afield, it becomes quite difficult to find any exact cross-linguistic matches between linguistically-coded concepts (see e.g., Levinson & Meira, 2003). Once these differences are appreciated, it becomes obvious that one must either abandon the idea that 'semantics = conceptual structure', or accept that speaking a different language might mean thinking differently, or both. This has raised the whole question of whether having language in general, and having a specific language in particular, might partially restructure human cognition.

On the role of language in general it has been suggested that language might play a crucial role in hooking up specialized mental faculties which in other species play a more modular role: Good cases can be made in both spatial and mathematical cognition for such a thesis (Spelke & Tsivkin, 2001; Spelke, 2003). On the role of particular languages, language-specific grammatical categories such as number and gender have been argued to exercise influence on cognitive processes (Lucy & Gaskins, 2001; Boroditsky, 2001; Boroditsky, Schmidt, & Phillips, 2003). Child language acquisition throws important light on these issues (see e.g., Bowerman & Levinson, 2001), as does, again, work on bilingualism (Gullberg, 2003). Recent work (e.g., Gentner & Goldin-Meadow, 2003) also suggests that language-specific semantic categories can affect thinking; again the spatial domain has played an important role here (see Levinson, 2003, for a review).

Another kind of relation between language and other aspects of cognition comes to the fore in studies of linguistic interaction. One traditional area of psycholinguistic interest has been how contextual information is used to resolve reference and ambiguity, and when and how such broader inference is intercalated with specialized comprehension processes. In linguistics, various theories about pragmatic principles and how they might guide some of these processes have been around for some time (see e.g., Sperber & Wilson, 1986; Levinson, 2000), but it is only re-

cently that these theories are being put to experimental test (see Noveck & Sperber, 2004; Hagoort, Hald, Bastiaansen, & Petersson, 2004). Another area where there is currently active interest is in conversation and dialogue. Clark (1996) proposed interesting psycholinguistic perspectives on the mental processes involved in dialogue, and more recently it has been proposed that psycholinguistic mechanisms are evolved for, and deeply attuned to, the rapid exchange of verbal information in conversational settings (see Pickering & Garrod, this volume). There is also research interest in the pre-verbal foundations for verbal interaction in infancy ('protoconversation'), which promises to illuminate basic principles in this area (Rochat, Querido, & Striano, 1999). Overall, it seems reasonable to assume that there are special cognitive abilities and proclivities that lie behind interactive language use, and which interface in complex ways with the language comprehension and production systems.

### **Biology and Behavior in Section 2**

The chapters in Section 2 reflect the variety of ways in which the relationship between biology and behavior can be relevant in psycholinguistics. **Stromswold** reviews the evidence on genetic factors in language performance. Three chapters deal with how language is processed in the brain: **Scott** treats the perception of speech, **Hagoort** the problem of syntactic unification, and **Thompson-Schill** the necessity for selection as part of linguistic processing. The latter two chapters form an interesting contrast in that both deal with the role of Broca's area, which, however, **Hagoort** approaches from the point of view "How does the brain perform this function?" while **Thompson-Schill's** point of view is "How can we most accurately characterize what Broca's area does?" Finally, **Morgan** discusses how modality-general versus modality-specific effects offer insight into the relationship of biology and behavior in language use, via evidence from the acquisition of sign language.

## **COMPREHENSION AND PRODUCTION**

For many, in fact most of the years that psycholinguistics has existed, it was almost a truism to bemoan the predominance of research on comprehension over research on production. The reasons for this asymmetry were obvious: In any experimental science, control over the conditions in which an experiment is conducted is paramount, and control over stimuli presented for comprehension is trivially easy to achieve while control over language production seems at first glance nigh on impossible. How can one conduct an experiment on spontaneous speech production and

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yet constrain the speech that is produced? Speakers cannot be simply instructed what to say, for that would remove the central components of the spontaneous production process (not to mention that it would also involve comprehension of the same linguistic material). For decades, this problem stood in the way of laboratory studies of language production. Despite early ingenious use of sentence completion (Forster, 1966) and picture-naming techniques (Oldfield & Wingfield, 1964), language production research relied to a large extent on an indirect view of the production process: inferring the normal processes of operation from observation of the breakdown of those processes. Thus major milestones in the study of language production include views from slips of the tongue (Fromkin, 1973; Garrett, 1975) and language breakdown in aphasia (Coltheart, Patterson, & Marshall, 1980).

Research on language comprehension, in contrast, streamed ahead; visual word recognition, based mainly on evidence from lexical decision and word naming, became a minor industry in itself (Seidenberg, 1995), as did the study of syntactic processing, which also relied principally on visual presentation and timing of reading, either via tracking of eye movements or other less fine-grained measures (Tanenhaus & Trueswell, 1995). From the 1970s on, spoken language comprehension (made empirically more tractable by the development of computer-based speech analysis, storage and presentation techniques) also gradually grew in importance. Word recognition became almost as well-studied in the auditory as in the visual modality, though in sentence processing research visual presentation still predominated over auditory presentation.

So dominant was comprehension research in psycholinguistics that it was possible for an Annual Review of Psychology overview article on "Experimental Psycholinguistics" to begin: "The fundamental problem in psycholinguistics is simple to formulate: What happens when we understand sentences?" (Johnson-Laird, 1974).

This too has changed. Experimental research on language production, and especially the production of spoken language, has undergone a revolution in the past two decades. Levelt and colleagues pioneered techniques for studying the production words and phrases (Levelt, 1992), Bock and colleagues did the same for sentence production (Bock, 1995) and even more importantly these advances have been embedded within a strong background of theoretical explanation. Active competition between models of speech production (see e.g., Dell, 1986; Dell & O'Seaghdha, 1992; Levelt, 1992; Roelofs, 1992) has prompted a stream of empirical tests of the models' predictions, making research on production at last competitive with research on comprehension.

Thus the relation between comprehension and production research, which was very asymmetric in the earlier years of psycholinguistics, is no longer so. This means that the way is now open to models of both processes together. Clearly comprehension and production are closely connected in the speaker-hearer; a model of language use from both perspectives would seem an obvious next step. Curiously, however, there have been very few initiatives of this sort.

Of course, it may turn out to be the case that there are such fundamental differences between the input and the output side of language processing that it makes no sense to connect the modeling efforts. The speaker's task is after all quite different from the hearer's task. The speaker begins with (supposedly) certainty about a message to be conveyed, and the process of speech production consists in converting that message into an appropriate articulatory form. The hearer begins with uncertainty about the message; the process of speech perception consists of testing hypotheses about the components of the speech signal in order to recover encoded message. These differing tasks may have far-reaching implications for the architecture of the respective processing systems. McQueen, Dahan, and Cutler (2003) have argued, for example, that continuous and graded flow of information (allowing multiple competing hypotheses to be continuously compared, re-weighted or discarded) makes sense in comprehension but has no obvious counterpart in production; in production, instead, the certainty of the initial state seems to motivate a more obvious role for discrete units of encoding. Moreover, these units may be units which simply have no direct relevance in perception. Thus there is evidence that syllables play a role in the production process (Cholin, 2004), which is entirely reasonable because syllables are articulatory units, and the units in terms of which speech timing is described; coordination of timing is the essence of speech production. Reconstruction of that timing does not necessarily benefit the listener, however, and reconstruction of units such as syllables is rendered entirely unnecessary by the continuous use of acoustic-phonetic information which characterizes speech recognition. Where syllables do play a role in perception it is an indirect role, for example, in the postulation of lexical boundaries (Content, Kearns, & Frauenfelder, 2001).

Thus psycholinguistics may never achieve an integrated model of language production and perception, because there may be no such integration—the two-way model may be no advance on separate models of the one-way processes. However, we won't know till we try.

### Comprehension and Production in Section 3

In Section 3, the chapters by **Vigliocco and Hartsuiker** and by **McQueen** deal with the architecture of the language processing system, comparing production and comprehension but taking a view primarily from production (**Vigliocco and Hartsuiker**) or primarily from comprehension (**McQueen**). **Schiller** discusses how monitoring one's own speech involves the comprehension system in the production process. **Ferreira and Swets** show how nonstandard syntactic forms arise in production and are dealt with in comprehension, thereby illuminating the relation of the two processes; **Sebastián-Gallés and Baus** show how this relation can be very different in a second language from in a first, and how this has implications for our understanding of second language acquisition; and finally, **Emmorey** discusses how language use in a spatial modality informs the relation between perception and production.

### MODEL AND EXPERIMENT

Methodologically, psycholinguistics has been fashioned more by psychology than by linguistics, because it has been since its outset an experimental discipline. Of its two parent fields it was, then, psychology which offered an experimental research tradition to draw on. In any experimental discipline, of course, the relation between theory and experiment must be got right, and this is not as easy as it might seem.

Too much modeling is not theory-driven; the model is built in whatever way can be gotten to work, irrespective of whether the resulting inevitable implications for theory are motivated by experimental evidence. This ultra-pragmatic approach to model construction is, for instance, responsible for the inability of human speech science to reach a rapprochement with speech engineering (in which the aim is development of techniques for automatic speech recognition and speech synthesis), despite at least a quarter of a century of determined attempts to learn from each other. Engineers need to have techniques that work, and at the moment the techniques which work best for computer implementation vary in obvious ways from the processes which speech scientists believe human language users employ. Speech scientists find it difficult to accept that engineers do not wish to implement immediately every advance in knowledge about human processing; engineers wish that speech science would provide knowledge in some form that would prove useful, because advances in computer speech processing have slowed to a frustrating succession of tiny increments; but they are generally unwilling to take the steps necessary to implement insights from human processing, that is, build a different kind of model. This would require

starting from a basis of reduced recognition performance, which would run counter to the pragmatic imperative.

Computational models of language processing in psychology have to some extent suffered from the same form of pragmatism. The goal of a working computational model was so seductive that many sacrifices—in the form of compromise implementations of model components in a way that would work though it was demonstrably implausible from a psychological point of view—were made to ensure that this goal was achieved. Nonetheless the contribution of modeling to psycholinguistic research has been profound. In the previous section we pointed out that the motor behind the rapid increase in research on language production in recent years was the existence of strong and testable models of the production process. In the same way, models of comprehension have been responsible for driving empirical expansion. Spoken-word recognition has been a field which was highly model-driven, from the earliest days of non-computational models specific to the processing of spoken words (Marslen-Wilson & Welsh, 1978) through the explosive development of computational models beginning with TRACE (McClelland & Elman, 1986). That this development was scientifically productive is perhaps attested in the remarkable degree of agreement achieved by computational models of spoken-word recognition in the late 1990s, in which all available models agreed on the notions of multiple lexical activation and inter-word competition (the models still disagreed on other issues, of course, notably the incorporation of feedback links from logically later to logically earlier stages of processing; and this period of relative unanimity now appears to be coming to an end). Other areas of comprehension research such as visual word recognition or sentence processing have not experienced such a period of intense research activity leading to rapprochement; but both these subfields have a longer history of active research and have amassed a great variety of modeling initiatives. It is instructive, though, to compare research on the processing of spoken words with research on the processing of spoken sentences; there are as yet no strong models of the latter process, which is perhaps why the dominant research methodology in sentence processing is study of reading rather than of speech.

The greater methodological strength in the psychological side of psycholinguistics has led to the interplay of model and experiment in psycholinguistics involving primarily models from psychology. This is not to say that there have not been models which are truly psycholinguistic, informed simultaneously by both research traditions; such models exist, especially in the area of sentence processing (with the Minimal Attachment model of Frazier & Fodor, 1978, as an outstanding

example). Purely linguistic theory, however, has not been directly responsible for empirical surges in psycholinguistics in the way that psychological theory has.

But there are changes in the model-experiment relationship in psycholinguistics and its associated fields, as there are changes in all the relationships we have discussed above. Recent developments have been both retrograde—for example, the adoption of essentially psychological modeling notions in linguistics which in a way parallels the adoption of linguistic notions in psychology some four decades ago—and progressive—for example, the emergence of linguistic traditions in which empirical testing is seen as an essential component of theoretical development.

As an example of the former, consider the remarkable current popularity in linguistics of exemplar-based models of word processing (e.g., Bybee, 2001; Jurafsky, Bell, & Girand, 2002; Pierrehumbert, 2002). Although such models originated in psychology (Nosofsky, 1986), they have not been widely adopted in that field (in which for spoken-word processing Goldinger [1998] remains the single common citation). This situation is reminiscent of 1960s psycholinguistics not in this respect, however, but in the unfortunate fact that the sophistication with which linguists have embraced ideas from psychology is no better than was the case the other way round at that time. In brief, there are phenomena which seem to demand an exemplar-based solution (frequency effects on lexical form, for example), and these phenomena are given wide exposure, while phenomena which speak strongly against exemplar models (generalization of new phonological features across the lexicon, for example) are ignored. Since the two classes of phenomena together cannot be accounted for by a radical exemplar model or by a radical abstractionist model, the time is ripe for a new hybrid model of word processing. We predict that such a model is more likely to be developed from the psychological side of the field.

As an example of the latter, progressive, development, consider laboratory phonology, a fairly recent movement in which the experimental tools of phonetics and to some extent psycholinguistics are brought to bear on questions of phonological theory. These, as Pierrehumbert, Beckman, and Ladd (2000) argue in their account of laboratory phonology's genesis and rationale, may be questions springing from any of a number of current theoretical approaches in phonology. Laboratory phonology is not a theoretical school, but a methodological approach which, they maintain, raises the level of scientific contribution possible in phonology.

### Model and Experiment in Section 4

The authors in Section 4 do not share a single disciplinary background (**Roelofs**, **Norris** and **Pitt and Navarro** are psychologists, **Crocker** a linguist, **Fitch** a biologist) but they do share a commitment to explicit modeling in theory development. **Roelofs** lays out a case for long-term investment in a model which can gradually become better (putatively closer to the true state of affairs) as it is refined by continual testing. **Norris** stresses the interplay that is necessary between theory, model, and empirical research. **Pitt and Navarro** describe techniques for determining how best to test between alternative models of the same processes. **Crocker** argues that the modeling enterprise should be rooted in an initial analysis of the demands of the processing task which is being modeled. **Fitch**, finally, spells out four computational distinctions and their implications for models of psycholinguistic processing.

Obviously, many chapters in Sections 1 through 3 also had much to say about the relationship between models and experimental research. The chapters in Section 4 likewise relate to psychology and linguistics (**Pitt and Navarro**; **Crocker**), production and comprehension (**Roelofs**, **Norris**), biology and behavior (**Fitch**). It is perhaps inevitable, given the nature of psycholinguistics, that there are elements of our four cornerstone relationships in all four sections of the book. For now, though, we hand the job of tracking them all down over to the reader.

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