From MacWhinney, B., 2015. Psycholinguistics: Overview. In: James D. Wright (editor-in-chief), International Encyclopedia of the Social & Behavioral Sciences, 2nd edition, Vol 19. Oxford: Elsevier. pp. 353–358.
ISBN: 9780080970868

Psycholinguistics: Overview

Brian MacWhinney, Carnegie Mellon University, Pittsburgh, PA, USA

Abstract

Psycholinguistics combines methods and theories from psychology and linguistics. It attempts to evaluate the psychological reality and underpinnings of linguistic rules and processes. It also seeks to link word and sentence processing to the deeper expressive processes of message construction and interpretation. Modern psycholinguistic theories emphasize the ways in which distinct areas of the brain interact in a dynamic incremental way to process language.

Introduction

Psycholinguistics is a field that combines methods and theories from psychology and linguistics to derive a fuller understanding of human language. From psychology, it inherits experimental methodology and a body of knowledge about processes in perception, memory, attention, learning, and problem solving. From linguistics, it derives detailed descriptions of specific languages, rigorous accounts of the shape of grammar, and ideas about the nature of human language.

The initial issue that motivated the establishment of psycholinguistics as a separate field of study was the problem of the *psychological reality* of linguistic concepts (Sapir, 1933/1968). In the 1960s, researchers wanted to know whether the various rules of Chomsky's new Transformational Generative Grammar (Chomsky, 1957) are actually used by humans. Although the results for this particular issue were largely negative, the core interest in psychological reality has continued unabated. To take a simple example of the issue, consider the claim that speakers of English can form the plurals of nouns by adding the suffix – *s*. This process allows us to form the plural *chandeliers* from *chandelier*. But do we actually use a productive rule to produce this plural or do we simply retrieve the plural *chandeliers* from our long-term memory as a unit? Psycholinguistic research shows that, in fact, both rote and rule are operative at various times in language production (Pinker, 1999).

This issue of psychological reality applies to all levels of language structure and usage, including articulatory phonetics, auditory phonetics, phonology, morphology, lexicon, syntax, semantics, and pragmatics. It applies to all of the constructs of linguistics, including rules, grammars, paradigms, trees, segments, words, and morphemes. When we hear words, do we break them up into their component phonemes or 'letters' or do we recognize them as wholes? When we listen to sentences, do we actually construct treelike representations of the types proposed by linguists or do we somehow extract meaning without building up formal structures? If we do use formal grammars to listen and speak, what is the exact shape of the grammars that we use?

Exploration of the psychological reality of linguistic structures immediately leads us to two related fields of study. The first is developmental psycholinguistics or the study of child language acquisition (Ambridge and Lieven, 2011). If we believe that adults form the plurals of nouns by adding – *s*, we need to consider how young children apply this rule to produce *cats*, but not *foots* or *tooths*. If we argue that children simply learn each form by rote, how can we account for the fact that they make errors like *feets* and the fact that they can produce the plural for a new word like *wug*, even without having been given that form explicitly?

The issue of psychological reality also leads us to consider the even more difficult issue of how rules of grammar might be processed in the brain. Addressing this question has led psycholinguists to explore issues in neurolinguistics (Stemmer and Whitaker, 2008) and cognitive neuroscience (Gazzaniga, 2000). When the field of psycholinguistics first developed in the 1950s, psychologists knew little about the detailed functioning of the human brain and were forced to treat it as a 'black box.' However, as our understanding of the functioning of the human brain grew during the 1980s and 1990s, it became clear that a precise understanding of the functioning of human language would have to make reference to neural mechanisms. The interactive approach to cognition (Rumelhart and McClelland, 1986) used artificial neural networks to model the processing of human language. Directly opposed to connectionism was Fodor's (1983) modular approach to cognition that emphasized the independence of separate cognitive modules for each level of linguistic structure. Researchers have attempted to test the contrasting predictions of the interactive and modular approaches using standard experimental methodology. However, this work has indicated that neither of the strong positions can be maintained (Simpson, 1994).

This article will examine research in six core areas of psycholinguistics: spoken word recognition, sentence comprehension, sentence production, message construction, crosslinguistic comparisons, and neurolinguistics. In addition to these core areas, psycholinguists are involved in the study of reading, conversational interaction, figurative language, text comprehension, aphasia, child language disorders, gesture, prosody, animal communication, and language evolution. However, our analysis here will focus on these six core areas.

Word Recognition

When we listen to speech, we perceive words as following each other in clear temporal succession, like the beads on a string. However, this underestimates the extent to which words are

International Encyclopedia of the Social & Behavioral Sciences, Second Edition, 2015, 353–358

actually being blurred together by coarticulation and assimilation. Extreme examples of this blurring occur in forms such as *supchu* for 'What is up with you?' However, even nonphrasal sequences such as 'I owe you a yo–yo' show similar blurring. Even without blurring, the job of segmenting sentences into words would be a tough one. Consider a phrase such as 'my catalog value for Mark's piece.' Within this phrase, there are fragments that match a variety of other possible words, such as *mike*, *eye*, *I*, *cat*, *at*, *cattle*, *log*, *you*, *Val*, *ark*, *arks*, *are*, and *form*. The reason why we tend not to hear these alternative forms is fairly simple. If we decided to commit ourselves to having heard the word *mike*, we would end up with the nonsensical segmentation of 'mike at a log value for Mark's piece.' At each point during sentence perception, many of these alternative words are partially active in a short list of competitors. Competitors that recognize larger segments such as 'catalog' are preferred over those that recognize smaller strings or which break up larger strings into pieces, such as 'cat a log.' If a competitor leaves an unrecognized fragment, then its own recognition is weakened. These constraints work together to guarantee a maximally satisfactory segmentation. Although segmentation is primarily driven by the competition of words for matches, it is also facilitated by stress patterns, pauses, and other prosodic patterns (McClelland et al., 2006).

Segmentation relies on word recognition, but this process is also highly dynamic. Words do not have clear and invariant forms. Consonants leave no clear and invariant imprint on the auditory stream, as they are heavily blended into vowels. Because of differences in their vocal tracts, men and women produce vowels in radically different ways. Dialect differences and variations in speech level add further variability to word forms. Again, the solution to this problem involves lexical competition. For example, the sound corresponding to word like *deep* will activate a neighborhood of similar words, such as *deal*, *dean*, *peep*, or *keep*. Within this domain of rhyming forms, competition is particularly keen between words that share the same initial segments, such as *deep*, *deal*, *dean*, and *deed*. The ability of a word to dominate in this competition is a function of the strength of its match to the features of the input (Dahan et al., 2001). Apart from influences coming from a word's sound, there can also be influences from meaning. For example, hearing the word *doctor* will prime the recognition in both listening and reading of the word *nurse* (Balota, 1994).

These competitive models can be given a specific neuronal instantiation in terms of a neural network model based on self-organizing feature maps (Li et al., 2007). In these models, an unorganized, but interconnected, flat sheet of simulated neural tissue is trained to recognize a set of input words. As learning progresses, words that share features move to adjacent areas in the feature map. In our example, the words *deep*, *deal*, *dean*, and *deed* would occupy a small neighborhood on the larger map. The network operates in a winner-take-all fashion so that, when deep starts to receive the highest level of activation, it will inhibit the activation of the competitors through a series of lateral connections. Like actual cortical tissue, these maps use spatial position to represent featural structure, and they rely on lateral inhibition to sharpen the outcome of a competition.

Sentence Comprehension

In the 1960s, psycholinguists thought that the process of word recognition completely preceded the process of sentence comprehension. The idea was that we must first identify all the words in a sentence before we could feed these words to a comprehension mechanism that decided what it all meant. Much of what we have learned about language processing over the last 50 years involves the construction of a detailed rejection of this early vision. As we study how auditory processing, word recognition, and sentence comprehension operate in real time, we have come to see that language processing is both *interactive* and *incremental*.

Incrementalism

In the late 1970s, Marslen-Wilson (1975) and others showed processing keeps up with word recognition in a fully incremental or online fashion. Both word recognition and sentence comprehension attempt to keep up with speech exactly as it comes in, although sometimes there is a slight lag, particularly for sentence comprehension. You might notice this lag if you find that you are trying to read a newspaper while someone is talking to you. You hear their words, but you may not be processing exactly what they say. If someone then asks you whether you have been listening, you may be able to repeat the last seven or eight words they said, but in fact you were not really understanding the message. Rather, you were squirreling away the words in a superficial form in your short-term memory (Botvinick and Plaut, 2006), hoping not to have to actually do the work of fully comprehending the message.

Apart from some such marginal cases of short-term buffering, we process incoming material incrementally, both lexically and conceptually. Take as an example the sentence, 'The boy chased the baboon into the bedroom.' As soon as we hear *the* and *boy*, we immediately begin to relate them to each other. We then relate this unit to the following verb *chased*. Milliseconds after hearing *chased*, we begin to construct an interpretation of the activity in which there is a boy doing some chasing. By the time we hear *baboon*, we can begin to sketch out the figure that the boy is chasing. We do not need to wait until we have heard all the words in the sentence to begin to extract these meanings. In this sense, sentence processing is both interactive and incremental – we tend to make decisions about material as soon as it comes in, hoping that the decisions that we make will not be reversed. Although processing is incremental, it only builds as much structure as it needs in order to keep words related. The real job of comprehension is delayed until more of the message is heard.

Garden Pathing

There are times when the initial decisions that we have made take us down the garden path. A classic example of garden-path processing occurs with sentences such as 'The communist farmers hated died.' It often takes the listener awhile to realize that it was the *communist* that died and that it was the *farmers* who hated the *communist*. Inclusion of

a relativizer to produce the form, 'The communist that farmers hated died' might have helped the listener sort this out. A somewhat different example is the sentence, 'The horse raced past the barn fell.' Here, we need to understand 'raced past the barn' as a reduced relative clause with the meaning 'The horse who was raced past the barn.' If we do this, the appearance of the final verb *fell* after *barn* no longer comes as a surprise.

Garden paths arise when a word or suffix has two meanings, one of which is very common and one of which is comparatively rare (MacDonald et al., 1994). In a sentence like 'The horse raced past the barn fell' the use of the verb 'raced' as a standard transitive verb is much more common than its use as the past participle in a reduced passive. In such cases, the strong meaning quickly dominates over the weak meaning. By the time we realize our mistake, the weak meaning is fully suppressed by the strong meaning and we have to try to comprehend the sentence from scratch. A classic garden-path example from Lashley (1951) is the sentence 'Rapid righting with his uninjured left hand saved from destruction the contents of the capsized canoe.' When this sentence is read aloud, listeners find it extremely difficult to understand the second word as *righting* rather than *writing*.

Lexical Effects

Current models of sentence processing emphasize the extent to which lexical and syntactic ambiguities of individual words trigger competing syntactic structures (MacWhinney, 1987; Trueswell and Gleitman, 2004). For example, there are two readings of the sentence 'Flying planes can be dangerous.' The planes can be either dangerous to their pilots and passengers or dangerous to onlookers down on the tarmac. Both interpretations of the participle *flying* are fairly strong. Because the two readings are of similar strength, they can compete with each other and no garden pathing arises. Another example of this type is 'He bought her pancakes,' in which *her* can be either the possessor of the pancakes or the recipient of the pancakes. Both meanings are strong and can compete with each other during sentence processing, yielding a clear ambiguity.

Sometimes lexically based expectations can be fairly complex. Consider these sentences in which the verbs *criticize* and *apologize* set up contrasting expectations:

John criticized Mary, because she hadn't delivered the paper on time.
John apologized to Mary, because he hadn't delivered the paper on time.
John criticized Mary, because he hadn't delivered the paper on time.
John apologized to Mary, because she hadn't delivered the paper on time.

Processing of the first two sentences is quick and easy, because the gender of the pronoun matches that of the expected agent. However, the processing of the second pair is more problematic because the gender of the pronoun forces the selection of an unexpected causal agent of the criticism or the apology (McDonald and MacWhinney, 1995).

Modularity

Although processing on individual linguistic levels is highly incremental, the interaction between levels is not immediate. During the first 300 ms after hearing a word, we attend primarily to its auditory shape, rather than the degree to which it fits into some grammatical context. Take as an example the sentence 'The sailors took the port at night.' Here the word *port* could refer to either the wine or the harbor. We can ask subjects to listen to sentences like this while watching a computer screen. Directly after subjects hear the word *port*, we can present one of these three words on the computer screen: *wine*, *harbor* and some control word such as *shirt*. If we do this, we will find that the recognition of both *wine* and *harbor* is facilitated in comparison to the control word *shirt*. If we change the sentence to something like 'The sailors drank the port at night,' we might expect that the context would bias the subject to respond more quickly to *wine* than to *harbor*, because one is not likely to drink a harbor. However, there is evidence that both *wine* and *harbor* are facilitated in comparison to the control word *shirt*, even when the context tends to bias the *wine* reading of *port*. This facilitation is fairly short lived and the contextually appropriate reading soon becomes dominant.

This type of result indicates that, in the first fraction of a second after hearing a word, we rely most strongly on auditory cues to guide our processing. This is not to say that context is not present or not being used as a cue. However, during the first fraction of a second, we need to focus on the actual auditory form in order to avoid any 'hallucinatory' effects of paying too much attention to context too soon in processing.

Sentence Production

There are many similarities between sentence comprehension and sentence production. In both activities, we rely heavily on the words in our lexicon to control syntactic structures. Both activities make use of the same patterns for determining grammatical structures. The most important difference is that, during sentence production, we are in full control of the meanings we wish to express. In comprehension, on the other hand, we are not in control and have to follow the ideas of others.

The production of sentences involves at least four processes (Levelt, 1989). The first process is message construction. This process takes our goals and intentions and builds up a thread of ideas to be articulated. The process of lexical access then converts these ideas in worded forms. The third process uses positional patterning to order words into phrases and clauses. The fourth process activates a series of verbal gestures through articulatory planning. As in the case of comprehension, these four stages are conducted not in serial order, but in parallel, interactively and incrementally. Even before we have finished the complete construction of the message underlying a sentence, we begin the process of articulating the utterance. Sometimes we find out in the middle of an utterance that we have either forgotten what we want to say or do not know how to say it. It is this interleaved, incremental, online quality of speech production that gives rise to the various speech errors, pauses, and

disfluencies that we often detect in our own speech and that of others.

Speech errors come in many different forms. Some involve simple slurring of a sound or retracing of a group of words. Others provide more dramatic evidence of the nature of the language planning process. Some of the most entertaining speech errors are spoonerisms, which owe their name to an English clergyman by the name of William Spooner. Instead of 'dear old queen,' Spooner produced 'queer old dean.' Instead of 'ye noble sons of toil,' he produced 'ye noble tons of soil.' Instead of 'I saw you light a fire in the back quad, in fact you wasted the whole term,' he said 'I saw you fight a liar in the back quad, in fact you tasted the whole worm.' These errors typically involve the transpositions of letters between words. Crucially, the resulting sound forms are themselves real words, such as *liar*, *queer*, and *worm*. The tendency of these errors to produce real words is known as the 'lexical bias' in speech errors and indicates the extent to which the lexicon itself acts as a filter or checker on the articulatory process.

Another illuminating group of errors is named after a character named Mrs. Malaprop in the play *The Rivals* by Sheridan. Some examples of malapropisms include *Judas Asparagus* for *Judas Iscariot*, *epitaphs* for *epithets*, or *croutons* for *coupons*. Some malapropisms arise when uneducated speakers attempt to produce unfamiliar words, but many of these errors are true slips of the tongue. In a malapropism, the two words have a similar sound, but a very different meaning. The fact that speakers end up producing words with quite the wrong meaning suggests that, at a certain point during speech planning, the output processor handles words more in terms of their phonological form than the meaning they express. It is at this point that malapropisms can occur.

When two words end up directly competing for a single slot in the output articulatory plan, the result is a lexical blend. For example, a speaker may want to describe both the flavor and the taste of some food and end up talking about its *flaste*. Or we might want to talk about someone's *spatial performance* and end up talking instead about their *perfacial performance*. These errors show the extent to which words are competing for placement into particular slots. When two words are targeting the same slot, one will usually win, but if there is no clear winner there can be a blend.

Another remarkable property of speech errors is the way in which grammatical markers seem to operate independently of the nouns and verbs to which they attach. Consider an exchange error such as 'The floods were roaded' for 'the roads were flooded.' In this error, the plural marker – *s* and the past tense marker – *ed* go to their correct positions in the output, but it is the noun and the verb that are transposed. This independent behavior of stems and their suffixes indicates that words are being composed from their grammatical pieces during sentence production and that grammatical markers contain clear specifications for their syntactic positions.

Sigmund Freud believed that slips of the tongue could provide evidence for intrusions from underlying anxieties, hostilities, and worries. From this theory, arose the notion of a 'Freudian slip.' We now know that the majority of speech errors are not of this type, although there are some that can be viewed as intrusions from the context. For example, if a speaker is discussing some activities surrounding a local barber, he might say 'He made hairlines' instead of 'He made headlines.' Even rare examples of this type of contextual influence seldom point to underlying hostilities or neuroses.

Message Construction and Perspective

The basic goal of both sentence comprehension and sentence production is the linking of spoken forms to underlying conceptual meanings. In the 1970s, psycholinguists thought of these conceptual structures in terms of links between simple sentences or propositions. These propositions represented relations that had no clear relation to the actual physical perspective of the speaker. More recently, work in philosophy, robotics, psychology, cognitive linguistics, and cognitive neuroscience has recast this view of meaning structures in terms of dynamic activities that are linked to the embodied perspective of the speaker.

Consider what occurs when a speaker relates a fable, such as the story of the Tortoise and the Hare. In this story, there are basically three perspectives, one for the tortoise, one for the hare, and one for the narrator. The narrator says, 'the hare decided to rest.' At this point, the narrator is taking the perspective of the hare and describing the hare's actions from that perspective. Next, the narrator shifts to the perspective of the tortoise and describes how he passes the sleeping hare. These various shifts and blends of perspective are important aspects of all narrative structures. However, we can see their impact everywhere in language. For example, if we want to point out that there is a dent in the side of the refrigerator, we may use the impersonal construction, 'someone knocked a dent in the refrigerator' or we may use the pseudopassive, 'the refrigerator got a dent knocked into it.' In the impersonal we are forced to point a finger at an unspecified perpetrator of the deed. In the pseudopassive, we background or deemphasize the doer of the activity, focusing instead on the result. These choices all reflect variations in perspective.

Another choice we make is between alternative perspectives on a single action. For example, we could describe a picture by saying 'the girl gave a flower to the boy.' In this case, we are taking the viewpoint or perspective of the girl and describing the activity of giving from her perspective. Alternatively, we could say, 'the boy got a flower from the girl.' In this alternative form, we view the action from the perspective of the recipient. Depending on whether we choose to view the action from the viewpoint of the giver or the receiver, we will use either the verb *give* or the verb *get*. Language is full of choices of this type and sentence production can be viewed as involving a continual competition between choices for perspectives. The selection of pronouns is determined by the need to link up referents to earlier perspectives. Shifts from the present tense to the past also reflect movements in perspective to various points in time.

Crosslinguistic Comparisons

All languages have sound segments, syllables, words, phrases, and sentences. In all languages, processing is online, incremental, and interactive. However, languages differ markedly in the particular grammatical contrasts they choose to mark and

the devices that they use to mark them. In languages like Warlpiri or Hungarian, word order is remarkably flexible. In languages like Navajo or Eskimo, a single complex word may express what English does in a seven-word sentence.

Psycholinguistic comparisons of processing in different languages (MacWhinney and Bates, 1989) use a simple common task to examine the effects of radically different structures. In one type of experiment, subjects listen to a sentence such as 'The eraser is pushed by the cat' and have to point to a picture that shows who is the actor. Consider a comparison of these sentences from English and Spanish:

The lion kisses the cow.
El león besa la vaca. (The lion kisses the cow).

A major difference between these two languages revolves around the use of variable word orders. In Spanish, it is possible to invert the word order and produce 'la vaca besa el león' while still meaning that the lion is kissing the cow. This inversion is even clearer if the particle *a* is added to marker the direct object as in these variant orderings in which the two nouns are moved into different places around the verb *besa*.

El león besa a la vaca.
A la vaca besa el león.
Besa el león a la vaca.
Besa a la vaca el león.

These differences between English and Spanish can be traced to the relative cue validities of word order and object marking in the two languages. In English, it is virtually always the case that the noun that appears before the verb is the subject of the sentence. If the verb is an active verb, the preverbal noun is almost always the actor. This means that the cue of preverbal positioning is an extremely reliable guide in English to assignment of the actor role. In Spanish, there is no such simple rule. Instead, the best cue to assignment of the actor role is the presence of the object marker particle *a*. If one of the nouns in a two-noun sentence is marked by *a*, then we know that the other noun is the agent or subject.

Other languages have still other configurations of the basic cues to sentence interpretation. For example, Hungarian makes reliable use of a single case-marking suffix on the direct object. German uses the definite article to mark case and number. The Australian language 'Walpiri' marks the subject with a variety of complex case markings. Navajo places nouns in front of the verb in terms of their relative animacy in the Navajo 'Great Chain of Being' and then uses verbal prefixes to pick out the subject. These languages and others also often rely on number agreement between the verb and the noun as a cue to the subject. English also requires subject–verb agreement, but this cue is often missing or neutralized. In languages like Italian or Arabic, subject–verb agreement marking is extremely clear and reliable.

When a monolingual speaker comes to learn a second language, the learner needs to fundamentally retune his or her sentence-processing mechanism. First, the learners need to acquire a new set of grammatical devices and markings. Second, they need to associate these new devices with the correct cue validities. Third, they need to reorganize their expectations for particular sequences of cues and forms. Initially, the learner simply transfers the cues, cue validities, and habits from the first language to processing of the second language. Over a period of time, the cue validities change smoothly, until they eventually match that of the native monolingual (MacWhinney, 2012).

Neurolinguistics

Recent advances in Cognitive Neuroscience have had a major impact on psycholinguistic research. Increasingly, researchers are asking not just when and how linguistic processes interact, but also where and how processing occurs in the brain. The bulk of this work has used the neuroimaging methods of functional magnetic resonance imaging (fMRI) and event-related potential (ERP). Other methods include diffusion tensor imaging (DTI), structural MRI, lesion studies, near-infrared spectroscopy (NIRS), mismatch negativity (MMN), and single-cell recordings during surgery. Using these various methods, researchers have begun to piece together a new vision of language processing in the brain. This new account provides important roles for many cortical and subcortical regions. Frontal areas such as the dorsal lateral prefrontal cortex (DLPFC) and the anterior cingulate cortex (ACC) are seen as playing a role in the type of attentional switching needed for perspective shifting and code switching in bilinguals (Roelofs, 2011). Midbrain structures such as the striatum and basal ganglia are implicated in the development of language fluency (Ullman, 2004). A linked system of temporal and frontal areas is involved in both auditory and articulatory processing of sounds (Hickok, 2009). Studies show that the superior temporal sulcus (STS) controls many aspects of lexical processing, although other temporal areas also have some involvement. Increasing detail from DTI and other methods (Bookheimer, 2007) has shown that inferior frontal cortex or Broca's area has multiple areas for semantic, syntactic, and phonological processing, each with detailed connections through white matter tracts to other areas. The study of articulatory control in stutterers (Howell, 2011) points to a role for between-area connectivity in producing timing errors in phonological and lexical access.

The work attempting to identify areas involving aspects of language processing has shown how difficult it is to peg a function to a single area. Instead, it is becoming clear that language processing works in terms of dynamic interactions across multifunctional areas organized into flexible neural circuits (Anderson, 2010; MacWhinney, 2009). As we begin to understand the dynamic nature of these interactions, we will be able to construct a much more accurate understanding of how language is processed in the brain.

Summary

In this article, we have examined six core issues being addressed by psycholinguists. These areas are central to the study of psycholinguistics, because they allow us to evaluate the psychological reality of linguistic formalisms. The interaction between psycholinguistics and linguistic theory has been intense, reciprocal, and dynamic. We have learned that language processing is interactive and incremental in regard to

word recognition, sentence comprehension, sentence production, and message construction. We know that crosslinguistic differences in processing are closely related to differing levels of reliability for the cues involved and the ways in which structures impose demands on verbal memory capacity. Some versions of linguistic theory have moved to adapt to some of these findings from psycholinguistics (Pollard and Sag, 1994). However, a satisfactory resolution of the core issue of the psychological reality of linguistic structures has not yet been obtained.

See also: Functional Brain Imaging of Language Processes; Second Language Acquisition; Sentence Comprehension, Psychology of; Speech Errors, Psychology of; Speech Perception; Speech Production, Psychology of; Word Order; Working Memory, Neural Basis of; Working Memory, Psychology of.

Bibliography

Ambridge, B., Lieven, E., 2011. Child Language Acquisition: Contrasting Theoretical Approaches. Cambridge University Press, New York.

Anderson, M., 2010. Neural reuse: a fundamental organizational principle of the brain. Behavioral and Brain Sciences 33, 245–313.

Balota, D.A., 1994. Visual word recognition: the journey from features to meaning. In: Gernsbacher, M. (Ed.), Handbook of Psycholinguistics. Academic Press, San Diego, CA.

Bookheimer, S., 2007. Pre-surgical language mapping with functional magnetic resonance imaging. Neuropsychological Review 17, 145–155.

Botvinick, M., Plaut, D.C., 2006. Short-term memory for serial order: a recurrent neural network model. Psychological Review 113, 201–233.

Chomsky, N., 1957. Syntactic Structures. Mouton, The Hague.

Dahan, D., Magnuson, J., Tanenhaus, M., Hogan, E., 2001. Subcategorical mismatches and the time course of lexical access: evidence of lexical competition. Language and Cognitive Processes 16, 507–534.

Fodor, J., 1983. The Modularity of Mind: An Essay on Faculty Psychology. MIT Press, Cambridge, MA.

Gazzaniga, M. (Ed.), 2000. The New Cognitive Neurosciences. MIT Press, Cambridge, MA.

Hickok, G., 2009. The functional neuroanatomy of language. Physics of Life Reviews 6, 121–143.

Howell, P., 2011. Language–speech processing in developmental fluency disorders. In: Guendozi, J., Loncke, F., Williams, M. (Eds.), The Handbook of Psycholinguistic and Cognitive Processes: Perspectives in Communication Disorders. Psychology Press, New York, pp. 435–462.

Lashley, K., 1951. The problem of serial order in behavior. In: Jeffress, L.A. (Ed.), Cerebral Mechanisms in Behavior. Wiley, New York.

Levelt, W.J.M., 1989. Speaking: From Intention to Articulation. MIT Press, Cambridge, MA.

Li, P., Zhao, X., MacWhinney, B., 2007. Dynamic self-organization and early lexical development in children. Cognitive Science 31, 581–612.

MacDonald, M.C., Pearlmutter, N.J., Seidenberg, M.S., 1994. Lexical nature of syntactic ambiguity resolution. Psychological Review 101 (4), 676–703.

MacWhinney, B., 1987. The competition model. In: MacWhinney, B. (Ed.), Mechanisms of Language Acquisition. Lawrence Erlbaum, Hillsdale, NJ, pp. 249–308.

MacWhinney, B., 2009. The emergence of linguistic complexity. In: Givon, T., Shibatani, M. (Eds.), Linguistic Complexity. Benjamins, New York, pp. 405–432.

MacWhinney, B., 2012. The logic of the unified model. In: Gass, S., Mackey, A. (Eds.), The Routledge Handbook of Second Language Acquisition. Routledge, New York, pp. 211–227.

MacWhinney, B., Bates, E. (Eds.), 1989. The Crosslinguistic Study of Sentence Processing. Cambridge University Press, New York.

Marslen-Wilson, W., 1975. Sentence perception as an interactive parallel process. Science 189, 226–227.

McClelland, A., Mirman, D., Holt, L., 2006. Are there interactive processes in speech perception? Trends in Cognitive Sciences 10, 363–369.

McDonald, J.L., MacWhinney, B.J., 1995. The time course of anaphor resolution: effects of implicit verb causality and gender. Journal of Memory and Language 34, 543–566.

Pinker, S., 1999. Words and Rules: The Ingredients of Language. Basic Books, New York.

Pollard, C., Sag, I., 1994. Head-Driven Phrase Structure Grammar. Chicago University Press, Chicago, IL.

Roelofs, A., 2011. Modeling the attentional control of vocal utterances: from Wernicke to WEAVER+. In: Guendozi, J., Loncke, F., Williams, M. (Eds.), The Handbook of Psycholinguistic and Cognitive Processes: Perspectives in Communication Disorders. Psychology Press, New York, pp. 189–208.

Rumelhart, D.E., McClelland, J.L., 1986. Parallel Distributed Processing. MIT Press, Cambridge, MA.

Sapir, E., 1933/1968. The psychological reality of phonemes. In: Mandelbaum, D. (Ed.), Selected Writing of Edward Sapir. University of California Press, Berkeley, CA, pp. 46–60.

Simpson, G.B., 1994. Context and the processing of ambiguous words. In: Gernsbacher, M. (Ed.), Handbook of Psycholinguistics. Academic Press, San Diego, CA.

Stemmer, B., Whitaker, H. (Eds.), 2008. Handbook of the Neuroscience of Language. Academic Press, New York.

Trueswell, J., Gleitman, L., 2004. Children's eye movements during listening: evidence for a constraint-based theory of parsing and word learning. In: Henderson, J., Ferreira, F. (Eds.), Interface of Language, Vision, and Action: Eye Movements and the Visual World. Psychology Press, New York.

Ullman, M., 2004. Contributions of memory circuits to language: the declarative/procedural model. Cognition 92, 231–270.