Psycholinguistics: History

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Our faculty for language has intrigued scholars for centuries. Yet most textbooks assume that psycholinguistics has its origins in the late 1950s and 1960s, and that nothing of note contributed to its evolution before then. In some respects this is true, in that it was only then that psycholinguistics began to proliferate as an identifiable discipline within the psychology literature. This proliferation was marked by the founding in 1962 of the *Journal of Verbal Learning and Verbal Behavior* (which subsequently, in 1985, became the *Journal of Memory and Language*). Why the original journal was so titled, and why its title presents us with a historical paradox, will become clearer as this review unfolds. The review's purpose is to consider how the present-day state of the art evolved. In so doing, it will touch briefly on ancient Greek philosophy, 19th century neuroscience, 20th century psycholinguistics, and beyond. It will

Magneto-encephalography (MEG)

MEG has only recently begun to be used in psycholinguistics. MEG has some of the advantages of both fMRI techniques and EEG techniques because it enables precise source localization like fMRI and has fine temporal resolution like ERP. It also complements ERP. Whereas ERP electrical signals can only be picked up from nerve bundles that are in particular orientations with respect to the surface of the brain, MEG magnetic field signals can be picked up from nerve bundles that are orthogonal to those giving ERP signals. For these reasons, many researchers are particularly optimistic about MEG as a psycholinguistic method used together with ERP.

One particularly interesting application has been using MEG to establish the relationship between neural representation and linguistic form. The technique depends upon what has been called **mismatch negativity**. It was observed that as the same items are repeatedly presented to subjects, so the MEG signature associated with their processing is automatically reduced (probably because of neuronal habituation). However, when a new item is presented, the signal returns to normal. This happens irrespective of any behavior on the part of the subject. Mismatch negativity can therefore be used to establish the degree to which different items are processed in the same way. The greater the resumption of the activity (i.e., mismatch negativity), the more different the neurological processing of the new item. In this way, mismatch negativity can be used in a similar fashion to priming techniques to explore the neurological representation of different aspects of a linguistic stimulus.

Summary and Conclusion

Psycholinguistic techniques differ according to the kind of variables measured and the extent to which they tap into language processing as it happens. Behavioral measures, such as eyetracking, and neurophysiological measures, such as ERP, are particularly effective for measuring the time course of language comprehension. For language production studies, picture naming and priming techniques have been especially effective.

See also: Dialogue and Interaction; Evoked Potentials; fMRI Studies of Language; Magnetoencephalography; Psycholinguistics: Overview; Reading Processes in Adults; Speech Errors: Psycholinguistic Approach; Spoken Language Production: Psycholinguistic Approach.

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consider approaches to the brain as practiced in both ancient Egypt and modern neuroscience. It will be necessarily selective, in order to make some sense of the historical developments that contributed to psycholinguistic science.

From the Ancient Egyptians to the Greek Philosophers

The earliest to write about language and the brain were the ancient Egyptians – the first to write about anything at all. A catalog of the effects of head injury (and injuries lower down the body also) exists in what is now referred to as the Edwin Smith Surgical Papyrus, written about 1700 B.C. The writer (believed to have collected together information spanning perhaps another 1000 years before) referred there to what is presumed to be the first recorded case of aphasia – language breakdown following brain trauma. However, the Egyptians did not accord much significance to the brain, which unlike the other organs of the body, was discarded during mummification (it was scraped out through the nose). They believed instead that the heart was the seat of the soul and the repository for memory, a view largely shared by the Greek philosopher Aristotle (384–322 B.C.) – a somewhat surprising position to take given that he was a student at Plato's Academy and that Plato (427–347 B.C.) believed the brain to be the seat of intelligence.

Plato was possibly the earliest to write at length on language (where others may have spoken, but not written). Certainly, his writings were the most influential with respect to the philosophy of language and the question 'what does a word mean?' Plato, in his *Republic*, considered the meaning of words in his Allegory of the Cave (as well as in *Cratylus*). In this allegory, a group of prisoners have been chained all their lives within a cave. All they see are the shadows of objects cast upon a wall by the flames of a fire. They experience only those shadows (in much the same way that we can only experience the results of our sensory percepts), and their language similarly describes only those shadows. Plato noted that when using a word, the prisoners would take it to refer to the shadows before them, when in fact (according to Plato), they would refer not to objects in the shadow world, but (unbeknown to the prisoners) to objects in the real world. Thus, for Plato (and a host of more contemporary philosophers, from Frege to Puttnam), the true meaning of a word – its reference – is external to the person who, by using the word, is attributing meaning to it. But why should it matter what a word refers to?

The *psycholinguistic* endeavor is to uncover the mental processes that are implicated in the acquisition, production, and comprehension of language. Just as psychology is the study of the control of behavior, so psycholinguistics is the study of the control of linguistic behavior. A part of any psycholinguistic theory of mental process is an account of what constitutes the input to the mental process – that is, what information is operated upon by those processes. While Plato was of course correct that the form of the real-world object dictates the form of the sensory image presented to the allegorical prisoner, the mental processes involved in that prisoner's use of language can operate only on mental derivatives of that sensory image. There may be properties of the real-world object (such as color, texture, and density) that are not represented in their shadow-forms, and thus mental processes that might otherwise (outside the cave) develop sensitivity to those properties need never develop such sensitivities if constrained to living a life inside the cave. But while the shadows would not permit the distinction between, say, a tennis ball and an orange, the *contexts* in which the shadows were experienced, or their names heard, *would* distinguish between the two – mental sensitivities would develop, but they would not necessarily be grounded in the perceptual domain. These distinctions, between the actual world and our *experience* of the world, and between an object or word and the *context* in which that object or word might occur, led other philosophers, most notably Wittgenstein in his *Philosophical Investigations*, to propose that the meaning of a word is knowledge of its use in the language – that is, knowledge of the contexts in which it would be appropriate to utter that word, where such knowledge is shaped by experience. We return to this theme when we consider in more detail the more recent history (and possible future) of psycholinguistics.

The Earliest Empirical Studies

The pre-history of psycholinguistics (up until the 19th century) was dominated by philosophical conjecture. The term *dominated* is used loosely here, as there was no *systematic* and ongoing questioning of the relationship between mind and language, or indeed, brain and language – there was no *community* of researchers asking the questions. But modern-day psycholinguistics is dominated not by philosophy (although it had its moments), but by experimental investigations that measure reaction times, monitor eye movements, record babies' babbles, and so on. Its prehistory lacks such experimentation. This is not to say that no experiments were performed. Certainly, there were isolated cases, generally of a kind that would not

be tolerated in the modern age. Indeed, one of the most widely replicated studies (if one is to believe the historians) is a study that was carried out on at least three and possibly four independent occasions between the 7th Century B.C. and the 16th Century A.D. In each case, some number of babies were apparently brought up in isolation (except for carers who were either mute, or instructed not to speak), with the aim of the experiment being to discover what language, if any, the children would grow up speaking. The results varied. The Egyptian Pharaoh Psamtik (7th C.B.C.) was credited by Herodotus with discovering that they spoke Phrygian. The Roman emperor and German king Frederick II (1194–1250 A.D.) carried out a similar study, but all the infants died. King James IV (1473–1513 A.D.) is supposed to have performed a similar experiment on the island of InchKeith, although it is likely that this study never in fact took place (the fact that the children are reported to have emerged from their isolation speaking Hebrew is one reason to doubt the truth of the story). And finally, Akbar the Great (1542–1605), the grandfather of Shah Jahan who built the Taj Mahal, similarly failed to discover man's 'natural language' (although there is some suggestion that in this case, the infants acquired a form of signed language inherited, in part, from the infants' carers).

The 19th Century Emergence of the Cognitive Neuropsychology of Language

The first *systematic* studies of the relationship between language and brain were conducted in the 19th century. This is probably the earliest point in the history of psycholinguistics from when a *progression* of studies can be traced, with one author building a case on the basis of earlier studies coupled with newer data. The protagonists at this time were Gall, Boulliard, Aubertin, Broca, Wernicke, and Lichtheim, to name a few. None of them would be described as 'psycholinguists,' but to the extent that their work (like modern-day *cognitive neuroscientists*) informed accounts of the relationship between brain and language, they are no less a part of the history of psycholinguistics than are the linguists, philosophers, psychologists, and cognitive scientists who have influenced the field through their own, sometimes radically different, perspectives.

Franz Gall is perhaps better known for his work on phrenology, but he believed that language function was localized in the anterior parts of the brain. His student Jean Boulliard collected clinical evidence in support of Gall's theory, and in turn, Boulliard's student Ernest Aubertin did the same. It was at a meeting in April of 1861 that Aubertin made his beliefs plain: If a case of speech loss could be found that was not accompanied by a frontal lesion, he would give up his (and his intellectual forbearers') belief in the localization of language. In the audience was Paul Broca, after whom are named Broca's aphasia and, within the left frontal lobe, Broca's area. Broca was struck by Aubertin's empirical challenge, but at the same time realized that craniology (Gall's lasting influence on his students) could not provide the proof that was required to establish a link between language loss and cerebral localization – only anatomical inspection of the brain could do that. Coincidentally, within a few days he was presented with a patient suffering from speech loss who died a few days after that. Broca's postmortem analysis of this patient's brain (and the damage to what is now referred to as Broca's area), coupled with earlier observations made by Marc Dax (on right hemiplegia and its correlation with speech loss), but published at the same time, established the anatomical validity of the localization hypothesis. About 10 years later (in 1874), Carl Wernicke published his work on 'sensory aphasia' (deficits in the comprehension of language). This work was considerably enhanced by Wernicke's student Ludwig Lichtheim who, in 1885, produced a schematic (cf. a 'model') of how three interlinked centers in the brain are implicated in aphasia: Broca's (the 'center of auditory images'), Wernicke's (the 'center of motor images'), and a diffusely located 'concept center.' Lesions to each of these areas, or to the connections between them, produce different kinds of aphasias. Most interesting of all, his schematic enabled him to predict disorders that had not yet been described. This ability of a conceptual 'model' to make as yet untested predictions is a theme we shall return to.

The Early 20th Century Influence of Behaviorism

By the end of the 19th century, the study of language began to change, as did the study of psychology more generally. Interest in the psychology (as opposed to *philosophy*) of language shifted from being primarily (or even solely) concerned with its breakdown to being concerned also with its normal use. Wilhelm Wundt in *Die Sprache* (published in 1900) stressed the importance of mental states and the relationship between utterances and those internal states. William James similarly (at least early on) saw the advantages of introducing mental states into theories of language use (see his 1890 *Principles of Psychology*, in which several contemporary issues in psycholinguistics are foreshadowed). But the early 20th century was a turbulent time for psycholinguistics (as it was for psychology): J. B. Watson argued that psychology should be concerned with behavior

and behavioral observation, rather than with consciousness and introspection (the Wundtian approach). And whereas Wundt had argued that a psychology of language was as much about the mind as it was about language, behaviorists such as J. R. Kantor argued against the idea that language use implicated distinct mental states. For Kantor, the German mentalist tradition started by Wundt was simply wrong. Even William James turned away from Wundtian psychology. Thus, the behaviorist tradition took hold.

The late 19th and early 20th centuries were a time of great change in linguistics, too. The 19th century had seen the emergence of the Neogrammarians, a group that studied language *change*. They were interested in how the sounds of different languages were related, and how within a language, the sounds changed over time. They were less interested in what a language 'looked like' at a particular moment in time. This changed at the beginning of the 20th century when Ferdinand de Saussure brought *structure* into the study of language. He introduced the idea that every element of language could be understood through its relation to the other elements (he introduced *syntactic* distinctions that are still central to contemporary linguistics). In the 1930s, the Bloomfieldian school of linguistics was born, with the publication in 1933 of Leonard Bloomfield's *Language*. Bloomfield reduced the study of language structures to a laborious set of taxonomic procedures, starting with the smallest element of language – the *phoneme*. In doing so, Bloomfield firmly aligned the linguistics of the day with behaviorism. And just as behaviorism eschewed mental states in its study of psychology, so the Bloomfieldian tradition eschewed psychology in its study of language. The study of language was firmly caught between the proverbial rock and a hard place – between behaviorism on the one hand and taxonomy on the other. Mental states were, the argument went, irrelevant – whether with respect to psychological or linguistic inquiry.

The behaviorist tradition culminated (with respect to language) with B. F. Skinner's publication in 1957 of *Verbal Behavior*. Here, Skinner sought to apply behaviorist principles to verbal learning and verbal behavior, attempting to explain them in terms of conditioning theory. Verbal behavior (and *Verbal Behavior*) proved to be the final battleground on which the classical behavorists and the mentalists would clash.

The Mid-20th Century and the Chomskyan Influence

In 1959, Chomsky published a review of Skinner's *Verbal Behavior*. He argued that no amount of conditioned stimulus-response associations could explain the infinite productivity or systematicity of language. With Chomsky, out went Bloomfield, and in came mental structures, ripe for theoretical and empirical investigation. Chomsky reintroduced the mind, and specifically mental representation, into theories of language (although his beliefs did not amount to a theory of psychological process, but to an account of linguistic structure). So whereas Skinner ostensibly eschewed mental representations, Chomsky apparently proved that language was founded on precisely such representation. Some later commentators took the view that the Chomskyan revolution threw out the associationist baby with the behaviorist bathwater. Behaviorism was founded on associationism. Behaviorism was 'out,' and with it, associationism. Symbolic computation was 'in,' but with it, uncertainty over how the symbolic system was acquired. It was not until the mid-1980s that a new kind of revolution took place, in which the associationist baby, now grown up, was brought back into the fold. The intervening 20 years were typical teenage years – full of energy, punctuated by occasional false hopes that nonetheless proved essential to the maturation process.

Two years before his review of *Verbal Behavior*, Chomsky had published *Syntactic Structures*, a monograph devoted to exploring the notion of abstract grammatical rules as the basis for generating sentential structure. According to Blumenthal in his 1970 account of the history of psycholinguistics, Chomsky's departure from the Bloomfieldian school was too radical for an American publisher to want to publish a lengthy volume that Chomsky had written outlining the new approach, and only Mouton, a European publisher (and presumably more sympathetic to the tradition that Chomsky was advocating) would publish a shorter monograph based on an undergraduate lecture series he taught at MIT. In fact, this is not quite accurate (N. Chomsky, personal communication); Chomsky had indeed written a longer volume (subsequently published in 1975), and it is true that initial reactions to the manuscript were negative (but, according to Chomsky, not unreasonable), but *Syntactic Structures* was not a compromise brought about through Chomsky's search for a publisher; he had not, in fact, intended to publish it. Instead, Cornelis van Schooneveld, a Dutch linguist and acquaintance of Chomsky's who was visiting MIT and happened to edit a series for Mouton, suggested that Chomsky write up his class notes and publish them. This he did, and modern linguistics was born. Psycholinguistics became caught up, almost immediately, in its wake.

Chomsky's influence on psycholinguistics cannot be overstated. He drew an important distinction

between 'competence,' or the knowledge we have about a language, and 'performance,' the use of that language (a distinction that was reminiscent of Saussure's earlier distinction between *langue* and *parole*). Both, he claimed, arise through the workings of the human mind – a mind, which furthermore is innately enabled to learn the structures of human language (although not everyone agreed with the arguments for a language acquisition device akin to a mental organ – a concise summary of the counterarguments was written by Bates and Goodman (1999)). It is perhaps surprising that against the backdrop of *Syntactic Structures* and Chomsky's *Review of Skinner's Verbal Behavior*, a new and influential journal dedicated to research into the psychology of language should nonetheless, in 1962, give itself a title (the *Journal of Verbal Learning and Verbal Behavior*) that firmly placed it in the behaviorist tradition.

From Linguistic Competence to Psychological Performance

Chomsky's theories of grammar were theories of competence, not performance. And yet, his work on *transformational grammar* initiated a considerable research effort in the early 1960s to validate the psychological status of syntactic processing (the construction of representations encoding the dependencies between the constituents of a sentence). Many of these studies attempted to show that perceptual complexity, as measured using a variety of different tasks, was related to linguistic complexity (the so-called Derivational Theory of Complexity). However, whereas the syntactic structures postulated by transformational grammar did have some psychological reality, the devices postulated for building those structures (e.g., the transformations that formed a part of the grammatical formalism) did not. It soon became apparent that the distinction between competence and performance was far more important than originally realized – the linguists' rules, which formed a theory of competence, did not make a theory of psychological process.

Subsequently, the emphasis shifted toward examination of the psychological, not linguistic, mechanisms by which syntactic dependencies are determined (a process referred to as *parsing*). In a seminal paper published in 1970, Thomas Bever pointed out that in cases of ambiguity, when more than one structure (i.e., dependency relation) might be permissible, there appear to be consistent preferences for one interpretation rather than another. This consistency appeared to hold not only across different examples of the same kind of ambiguity, but across different people, too. Thus, despite the grammaticality of '*the horse raced past the barn fell*' (cf. '*the car driven past the garage crashed*'), the preference to interpret '*raced*' as a main verb (instead of as a past participle equivalent to '*driven*') is so overwhelming that the sentence is perceived as ungrammatical (and the preference is then said to induce a 'garden path' effect). Evidently, grammaticality and processability are distinct mental phenomena.

On the Influence of the Digital Computer

The 1970s saw enormous growth in psycholinguistics. Advances were made across a wide range of phenomena, including the identification of both printed and spoken words, the reading process, sentence comprehension (with much of the emphasis on the resolution of ambiguities of the 'garden path' kind), and the mental representation of texts. Whether there was a 'spurt' in the number of publications is contentious, because although there undeniably was such a spurt, the whole of psychology experienced the same rapid growth. It would be wrong, however, to attribute all this advancement to the influence of Chomsky. The demise of behaviorism played a part (and certainly Chomsky played a part in that demise), but so did the advent in the 1950s of the digital computer. The 'mind-as-computer' metaphor had a subtle but pervasive influence on both psycholinguistics and the study of *cognition* generally. Computer programs worked by breaking down complex behaviors into sequences of simpler, more manageable (and hence more understandable) behaviors. They relied on *symbol manipulation* and the control of *information flow*. They distinguished between different levels of explanatory abstraction (the high-level programming language, the assembly code, and the flow of electrical currents around the hardware). And perhaps most important of all to the empirical psychologist, they enabled novel predictions to be made that might not otherwise have been foreseen had the 'model' not been implemented in full; complex interactions among the components of a program were not easy to foresee.

The influences of the digital computing revolution were felt in different ways. Some were direct, with researchers building computer simulations of mental behavior (in the growing field of *Artificial Intelligence*, several language 'understanding' programs were written, some of which are still relevant 35 years later – e.g., Terry Winograd's SHRDLU program written in 1968–1970). Other influences were indirect, coming to psycholinguistics via philosophy. One such example was Jerry Fodor's Modularity of Mind hypothesis (from 1983). One simplified interpretation of

this hypothesis (it was interpreted in different ways by different researchers) was that there are two alternative ways of theorizing about the mind: one is to assume it is incredibly complex and that multiple sources of information interact in multiple ways, and the other is to assume that it can be broken down into a number of modules, each of which performs some particular function and is 'blind' to the workings of the other modules (perhaps taking as input the output of one or more of those other modules). Fodor argued that certain aspects of cognition were modular (the input systems), and certain others were not (central processes). This hypothesis had considerable influence in psycholinguistics, and for a time (the mid-1980s to early 1990s), hypotheses were evaluated according to whether they were modular or not. There seemed little agreement, however, on where one drew the boundaries (for example, was spoken language recognition a part of an input system? If it was, how could 'higher-level' knowledge of the context in which the language was being interpreted influence the modular and encapsulated recognition process? – Some argued it could not, while others argued it could). It was about this time, in seeming opposition to the trend toward *symbolic computation*, that a new computationally motivated approach to cognition emerged in the mid 1980s, apparently eschewing symbolic computation *and* modularity.

The Late 20th Century Emergence of Connectionism: Statistical Approaches to Language

In 1986, David Rumelhart and Jay McClelland published *Parallel Distributed Processing*. This edited volume described a range of *connectionist*, or *neural network*, models of learning and cognition, and marked a 'coming of age' for connectionism. It was, for many researchers in psycholinguistics, their first introduction to a wide range of research in this emerging field. Of particular interest were the facts that 'knowledge' in connectionist networks is encoded as patterns of connectivity distributed across the neural-like units, and 'processing' is manifest as spreading patterns of activation. These networks can learn complex associative relations largely on the basis of simple associative learning principles (based primarily on work published in 1949 by Donald Hebb, a student of Lashley's). Various algorithms exist to set the 'strengths' of the connections between the units automatically, so that a given input pattern of activation across some set of units will spread through the network and yield a desired output pattern across some other set of units. Indeed, multiple input-output pairings can be learned by the same network. Importantly, and in contrast to the ideals of the behaviorist traditions, neural networks can develop internal representations.

Several connectionist models had profound effects on developments in psycholinguistics. TRACE, for example, developed by McClelland and Jeff Elman in the 1980s, was a model of spoken word recognition that formed the focus of empirical research for a good 20 years after its inception. But TRACE did not learn anything – it was hardwired. An extremely influential model that *did* learn by itself was described by Elman (1990), who showed how a particular kind of network could learn the dependencies that constrain the sequential ordering of elements (e.g., phonemes or words) through time. In effect, it learned which kinds of word could follow which other kinds of word (hence, it was a *statistical model*, because it encoded the statistics of the language it was trained upon). Interestingly, it developed internal representations that appeared to resemble grammatical knowledge; words that occurred in similar sentential contexts came to evoke similar internal representations (that is, internal patterns of activity when the word was presented to the network) – and because words of the same grammatical category tend to occur in the same sentential contexts, different 'clusters' of words emerged, with each cluster representing a different category of word.

Not surprisingly, the entire connectionist enterprise came under intense critical scrutiny from the linguistics and philosophy communities, not least because it appeared to reduce language to a system of statistical patterns, was fundamentally associationist, nonmodular, and eschewed the explicit manipulation of symbolic structures (because the internal representations that emerged as a result of the learning process were not symbolic in the traditional sense). Within the context of the symbolic-connectionist debate there developed what became perhaps one of the longest surviving disputes in contemporary psycholinguistics; between those that believe that word formation (e.g., the formation of 'walked' from 'walk,' 'ran' from 'run,' and 'went' from 'go') is driven by knowledge of *rules* and *exceptions* to those rules, and those who believe it is driven by *statistical regularity* (which can apparently capture, in the right model, both the regularly and irregularly formed words). The debate shows little sign of abating, even 20 years later.

Critics notwithstanding, statistical approaches to language (both with respect to its structure and its mental processing) are becoming more prevalent, with application to issues as diverse as the 'discovery' of words through the segmentation of the speech input, the emergence of grammatical categories, and even the emergence of meaning as a consequence of

statistical dependencies between a word and its context (cf. Wittgenstein's views on the meaning of words). Empirically also, the statistical approach has led to investigation of issues ranging from infants' abilities to segment speech and to induce grammar-like rules to adult sentence processing. The reason that such approaches have proved so appealing is that statistics are agnostic as to the nature of the real-world objects over which the statistics are calculated – thus, the fundamentally same algorithm can be applied to sequences of phonemes, words, or sentences. Their implementation within a neural network is similarly agnostic – the same network and the same algorithms that enable that network to induce the appropriate statistics can be applied to many different domains. Connectionism opened up experience-based learning to a range of psychological domains, not just the linguistic domains. And experience-based learning was attractive not least because it required fewer assumptions about the existence of innately specified domain-specific faculties (and in a multi-authored volume published in 1996, Jeff Elman teamed up with a variety of developmental psychologists to argue that connectionism was attractive precisely because it enabled a new perspective on how innate constraints on learning and neural structure might be an important component of human language acquisition (Elman, 1996)).

Neural networks can be criticized for being (among other things) too unconstrained – they can, in principle, do more than might be humanly possible – but the opposite criticism, that they are too small and do not necessarily 'scale up' is another criticism that is often heard. Neural networks as currently implemented are just the 'medium' on which are offered up the statistics. To misuse a common adage, the proof will be in the pudding, not in the plate that serves it up. There is little doubt, from the historical perspective, that although the emergence of connectionism has offered a powerful theoretical tool, its emergence has also polarized sections of the psycholinguistic community, between 'connectionists' on the one hand, and 'symbolists' on the other. This polarization is not unique to psycholinguistics, however, but pervades the study of cognition more broadly. And as if to further muddy the theoretical waters, the beginning of the 21st century has seen renewed interest in yet another (no less controversial) paradigm – one that grounds language (and cognition) in action.

The Early 21st Century and the Grounding of Language in Action and the Brain

Traditional theories in cognition suppose that the job of the perceptual system is to deliver to the cognitive system a representation of the external world. The job of the cognitive system is then to reconstruct, mentally, that external world. This reconstruction subsequently forms the basis for 'commands' sent to, for example, the motor system. Cognition thus mediates between perception and action. An alternative approach, termed 'embodied cognition,' is that cognition and action are encoded within the same representational medium. Cognition is thus rooted in the same motoric and sensory representations that support interaction with the external world. Or, put another way, cognition is grounded in the same neural substrates that support sensory-motoric interaction with the external world. One consequence of this view is that language, a component of cognition, should, like the other components of cognition, be studied in the context of (i) the interactions it causes between the hearer and the world, and (ii) the neural substrates that support those interactions. Coincidentally, the 1990s saw a boom in research into the neural substrate of language, in part due to the increased availability of neuroimaging technologies (predominantly *PET* and *fMRI,* with *EEG* and more recently *MEG* also proving influential). It also saw increased research into the relationship between language and action. Taken together, these two streams of research provided increasing evidence for embodied cognition.

With respect to imaging, a variety of studies demonstrated what Lichtheim had alluded to a century earlier – that concepts are not represented in some discrete location within the brain, but are distributed across different regions. For example, words whose meanings implicate tool use (e.g., 'hammer') activate regions of the brain responsible for controlling motoric action (during the use of the tool) and other regions involved in the recognition of object form (during perception of the tool). Color words (e.g., 'yellow') and words referring to non-manipulable artefacts (e.g., 'house') do not activate motoric areas to the same extent, but they do activate regions close to those implicated in form perception and, for color words, color perception. Importantly, there is no single region that is primarily active; rather, words and concepts activate complex patterns of activity that are distributed and overlapping within different parts of the brain that are known to have (other) motoric and sensory functions. The meanings of (at least some) words do appear, then, to be grounded in those neural substrates that support sensory-motoric interaction.

About the same time that increased attention was focusing on neuroimaging, new techniques for studying language and its effects on *action* were also being developed. One of these involved the monitoring of eye movements as participants listened to

commands to manipulate objects in front of them, or as they listened to descriptions of events that might unfold within the scene before them (one can view language-mediated eye movements as central to the relationship between language and action, because eye movements signal overt shifts in attention, and because attention to something necessarily precedes (deliberate) action upon it). It was found that eye movements were closely synchronized with processes implicated in both spoken word recognition and sentence processing, and that much could be gleaned about what kinds of information were recruited at what point during a word or sentence in order to interpret the unfolding language with respect to the scene in front of the participant (it is not without some irony that in L. N. Fowler's famous Phrenology bust, from about 1865, the faculty for language is located just below the left eye). Another technique involved measuring motoric responses to different kinds of linguistic stimuli – for example, words or sentences referring to movements toward or away from the body were found to interfere with responses in a judgment task (e.g., 'does this sentence make sense?') that involved moving a finger toward or away from a response button. A range of studies, some involving TMS (Transcranial Magnetic Stimulation – a method for either temporarily stimulating or suppressing a part of the brain, such as parts of motor cortex) have confirmed this motoric component to language comprehension.

It is noteworthy, with respect to the embodiment approach to cognition, that some of its basic tenets have been around since the earliest days of (contemporary) psycholinguistics. Winograd's SHRDLU program, for example, viewed the meaning of a word such as 'place' or 'lift' as that part of the program that caused placing or lifting – language comprehension within that program was grounded in sensory-motoric representation – and as such, SHRDLU followed in the Wittgenstinian tradition of treating meaning as use. Similarly, it is noteworthy that although most of the neuroimaging of language has been carried out independently of theories of embodied cognition, much of the work converges on the same theme – that aspects of language are represented in the same representational substrates that control our sensory-motoric interactions with the external world.

Epilogue

And that, broadly speaking, is where the field is now. In the space available, it is impossible to document all the trends that have influenced contemporary psycholinguistics, and which have influenced not just what kinds of language behavior we study (e.g., language breakdown, normal language use, ambiguity resolution, and so on), but also how we study those behaviors (through studying aphasis, neuroimaging, language-mediated eye movements, and so on). And we have still to see the full influences of connectionism, statistical learning, embodied cognition, and the neuroscience of language. What we can be sure of is that the boundaries between the study of language and the study of other aspects of cognition are wearing thinner (the eye movement research mentioned above is at the interface of language and vision, for example). No doubt there are already developments in 'neighboring' fields of study (e.g., the computational sciences and non-cognitive neurosciences) that will also have an impact, but have yet to emerge as quantifiable influences on psycholinguistics. For example, researchers are already using computational techniques coupled with detailed neuroanatomical research on the neural structure of the brain to attempt to understand the kinds of 'computation' that distinct parts of the brain may be capable of. Such research promises greater understanding of the brain's ability to learn, represent, and deploy language. And although the history of psycholinguistics is relevant to understanding where the field is today, perhaps of greater interest is where the field will be tomorrow.

Acknowledgments

This article is a substantially expanded version of a short, 1500-word section on the history of psycholinguistics that appeared as part of a broader review of issues in psycholinguistics (Altmann, 2001). The reader is referred to this paper for in-depth review of (some of) the topics that constitute the field of psycholinguistics. The author would like to thank the publishers of this article for donating his fee to the charity Médecins sans Frontières, and Silvia Gennari for advice on topics ranging from Plato to neuroimaging.

See also: Cognitive Science: Overview; fMRI Studies of Language; Human Language Processing: Connectionist Models; Human Language Processing: Symbolic Models; Language, Visual Cognition and Motor Action; Modularity of Mind and Language; Psycholinguistics: Overview; Sentence Processing.

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Psycholinguistics: Overview

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Emergence of Psycholinguistics in the Late 1950s and 1960s from the Chomskyan Revolution

Although the study of language has been part of psychology from its earliest years, including for example in the work of Wilhelm Wundt, the father of psychology, a distinct field of psycholinguistics emerged in the late 1950s largely in response to the impact of Chomsky. In the preceding decades, notably in the United States, psychology had been dominated by the behaviorist approach of researchers such as B. F. Skinner. They treated language as a form of verbal behavior, which, like all other behavior, they believed was governed by simple stimulus–response associations. Chomsky demonstrated the shortcomings of the behaviorist approach in explaining the productivity of language and its complexity, and his work, notably *Syntactic structures* (1957), provided a major impetus for a new kind of psychological investigation of language. This was driven by an interest in the mental representation of language in general and syntactic structures in particular (*see* **Psycholinguistics: History**).

Psychology since the demise of behaviorism has again been concerned with understanding the way that people accomplish various information-processing tasks. In the field of psycholinguistics this means a concern with the cognitive processes by which a string of sounds in an utterance, or marks on a page, are processed to identify individual words and sentences, and how this emerging structure becomes mentally represented as a meaningful concept. The goal of this process is to derive models that account for how people achieve this so rapidly and successfully, given what we know about the general limitations of human cognitive processing. To oversimplify: the psychologist is concerned with **how** the linguistic units are processed and represented; the linguist is concerned with the description of the structures that emerge from any such processes.

Research Topics in the Early Years of Psycholinguistics

In its early years psycholinguistics reflected the concerns of linguistics and the central role of syntax. Psychologists such as Miller and Isard (1963) showed that the syntax influences the way people interpret sentences, and even how many words people can remember from a string of words that make no sense. More words are remembered from a 'sentence' like 'Accidents carry honey between the house' than from strings with no syntactic structure such as 'On trains hive elephants the simplify.' The focus on

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