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*Edited by Frederick J. Newmeyer*

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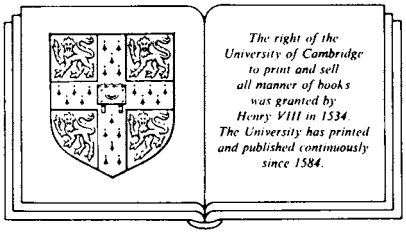


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# 1 Psycholinguistics: an overview[1]

*Michael K. Tanenhaus*

## 1.0. Introduction

Trying to write a coherent overview of psycholinguistics is a bit like trying to assemble a face out of a police identikit. You can't use all of the pieces and no matter which ones you choose it doesn't look quite right. Part of the difficulty is that psycholinguistics is concerned with three somewhat distinct questions: (1) how language is acquired during development; (2) how people comprehend language; and (3) how people produce language. The study of language comprehension and production forms one field, 'experimental psycholinguistics', and the study of language acquisition forms a separate field, 'developmental psycholinguistics'. In theory, many of the issues in experimental and developmental psycholinguistics are interrelated, but in practice there is little overlap between the two areas. As a result it is difficult to do justice to both within the same brief review.

A second problem is that contrary to what the name might suggest, psychology and linguistics have never been successfully integrated within psycholinguistics for more than short periods. Until recently, most psycholinguists were psychologists who were influenced in varying degrees by linguistics. In the last few years, an increasing number of linguists have begun to explore psycholinguistic issues. There is a fundamental disagreement about the relationship between language and cognition that more or less divides psycholinguists along disciplinary boundaries.

Linguists tend to follow Chomsky in assuming that the core of language is a specialized linguistic system or grammar which represents a sentence at a number of different levels and contains rules for relating these representations. While the linguistic system makes contact with other cognitive systems at the level of input and output, its rules and representations are

[1] I would like to thank a number of people who have shared their knowledge and insights about psycholinguistics as I was writing this chapter. Discussions with my colleagues at Rochester, Tom Bever and Gary Dell, were extremely helpful. Ginny Valian and Melissa Bowerman helped me sort through the issues in language acquisition, and Pim Levelt helped me frame the discussion of production. If I had taped these conversations, the chapter would have been improved. Thanks also to Alan Garnham for valuable comments on a draft of the manuscript and to Jane Oakhill for comments on the acquisition section.

distinct from those of other cognitive systems. According to the 'linguistic autonomy' or 'modularity' position, a theory of language performance must include among its explanatory primitives the rules and representations of the grammar. The modularity hypothesis as put forth by Chomsky (e.g. Chomsky 1980) is a theory of language competence, but it naturally translates into a perspective about language processing and language acquisition in which linguistic rules and representations form a distinct cognitive sub-system.

Psycholinguists working within the linguistic autonomy framework are guided by several assumptions. One assumption is that the structure of language can be studied independently from how that structure is used for communication. A second assumption is that sentence-level syntactic structure forms the core of the linguistic system. As a consequence these psycholinguists tend to focus on a narrow range of primarily syntactic phenomena, which are explained in terms of specialized principles of grammar. They argue that it is just these phenomena which form the core of language and the principles that explain them will thus form the basis for successful models of language processing and language acquisition.

The contrasting view, which most psychologists endorse, assigns a much less central role to the grammar. Language processing and language acquisition can best be understood within the same framework as other cognitive processes. The most radical form of this 'cognitivist' or 'linguistic minimalist' position is that the rules and representations proposed by linguistic grammars are epiphenomena of more general and basic cognitive processes (e.g. Bates & MacWhinney 1982). Linguistic minimalists generally reject the assumption that sentence-level processes, especially syntax, form the core of psycholinguistics, and they do not draw a sharp boundary between explanations of language use and language structure. As a consequence, they are often concerned with a broader range of phenomena than researchers working within the autonomy framework.

The history of psycholinguistics spans thirty years during which there have been radical changes in how the study of cognition is approached. When psycholinguistics was born during the 1950s, it was firmly rooted within the behaviorist tradition. There was widespread agreement that an association-based learning theory would ultimately explain the structure of language as well as how language is used and acquired. During the next decade, psycholinguistics was dominated by Chomsky's theoretical claims about the nature of linguistic knowledge, which provided a framework for the field. Psycholinguistics was at the frontier of a rapidly developing mentalist approach to cognition in which rules and representations formed the explanatory vocabulary.

During the 1970s psycholinguistics largely abandoned its ties with lin-

guistic theory, as transformational grammar was widely seen as having failed to provide a useful explanatory framework for either experimental or developmental psycholinguistics. Psycholinguistics became absorbed into mainstream cognitive psychology and ideas drawn from artificial intelligence began to provide psycholinguistics with much of its theory. Within experimental psycholinguistics, questions about the role of language structure in language processing were largely abandoned, and within developmental psycholinguistics most research began to focus on the cognitive basis of language acquisition. More recently, the debate between proponents of linguistic minimalism and linguistic autonomy has emerged again with renewed vigor as linguistics has started to become reintegrated into psycholinguistics. Finally, the recent emergence of a new subsymbolic paradigm within cognitive science is beginning to challenge many of the fundamental assumptions of psycholinguistics.

The content of psycholinguistics can be defined independently of its history and without reference to broad disagreements such as the conflict between linguistic autonomy and linguistic minimalism. However, much of the excitement in the field comes from the role that psycholinguistics plays in debates about the nature of language and its relationship to cognition. In the remainder of this chapter I will use the continuing tension between the linguistic autonomy and linguistic minimalism positions to help structure a brief overview of psycholinguistics emphasizing its historical development. Comprehension, acquisition, and production will be discussed in separate sections. Many of the influences and trends that are common to the three areas will be introduced in the comprehension section, which will be more detailed than the acquisition and production sections.

## 1.1. The birth of psycholinguistics

Modern psycholinguistics began as a cooperative venture between linguists and psychologists during the early 1950s. Linguistics and psychology had each been strongly influenced by the logical positivist tradition in philosophy. According to this doctrine, the only meaningful statements were those that derived from logic or those that could be directly tested through empirical observation. Linguistic theories of this period classified language into units of different sizes, which were arranged in a strict hierarchy or 'taxonomy.' In theory, each unit was to be derived from lower level units. Substantial progress had been made in identifying low level units such as phones, phonemes, and morphemes, and linguists were beginning to extend the taxonomic approach to syntax. The goal of American linguistics was to develop a 'discovery' procedure that could be mechanically applied to a corpus of utterances to extract the units.

Within psychology, there was a general consensus that behavior could be explained by learned associations between stimuli and responses, with reinforcement providing the glue to cement associations. 'Radical behaviorists' such as B. F. Skinner argued that psychological explanation should be couched only in terms of observable stimuli and responses, whereas 'neobehaviorists' such as Clark Hull argued for the usefulness of mediating variables that were derived from observable stimuli and responses. Most research within the learning theory tradition examined animal behavior, on the assumption that the basic laws of learning would provide the building blocks for explanations of more complex behaviors. However, during the 1950s several prominent learning theorists turned their attention to more complex behaviors, with language, or 'verbal behavior' as it was more commonly called, being one of the primary targets for explanation. In 1957, Skinner published *Verbal behavior*, which provided an in-depth analysis of language within a radical behaviorist framework. Neobehaviorist treatments of meaning were developed by Osgood, Suci & Tannenbaun (1957) and Mowrer (1960).

In 1951 the Social Science Research Council sponsored a conference that brought together several leading psychologists and linguists. One of the participants, Roger Brown, credits this conference with directly leading to the birth of psycholinguistics (Brown 1970). The proceedings of the conference outlined a psycholinguistic research agenda that reflected a consensus among the participants that the methodological and theoretical tools being developed by psychologists could be used to explore and explain the linguistic structures that were being uncovered by linguists.[2]

At the same time as behaviorist psychologists were beginning to concentrate on language, two important developments were underway that would quickly undermine a psycholinguistics based upon behaviorist principles. The first development was Chomsky's work in generative grammar. The second was the development of the information processing approach to cognition pioneered by cognitive psychologists such as Miller and Broadbent and computer scientists such as Newell and Simon. Chomsky's ideas had the more immediate impact, so we will consider them first.

## 1.2. **The Chomskyan revolution**

There are at least three distinct ways in which Chomsky's ideas have shaped psycholinguistics: (1) Chomsky's criticisms of behaviorist treatments of

[2] The proceedings were edited by Osgood & Sebeok (1954) and published as a supplement to *The International Journal of American Linguistics* and reprinted in 1969 by Indiana University Press.

language and his view of the appropriate goals for linguistic theory played a major role in the development of cognitive science; (2) Chomsky's formulation of the logical problem of language acquisition has provided a framework for developmental psycholinguistics; and (3) Chomsky's theory of transformational grammar guided much of the first decade of research in experimental psycholinguistics.

### 1.2.1. Chomsky's methodological contribution

Chomsky rejected the discovery procedure as an unrealistic and scientifically inappropriate methodological goal for linguistics. He argued instead that linguistics should evaluate theories according to their explanatory power. These theories should account for the native speaker's tacit knowledge of sentences, or 'linguistic competence,' rather than the regularities observed in a recorded corpus of utterances. Linguistics was thus properly viewed as a branch of 'theoretical cognitive psychology' (Chomsky 1968). Chomsky argued that in order to model competence, linguists would have to abstract away from linguistic performance, which was affected by nonlinguistic factors such as attention and memory limitations.

Chomsky mounted a multifaceted attack on behaviorist explanations of language. He argued persuasively, if not conclusively, that natural language has properties that cannot be described by the class of formal languages (finite-state languages) that are, in principle, compatible with behaviorist assumptions. He also argued that behaviorist accounts of linguistic meaning and linguistic structure were plausible only in so far as they used scientific notions such as stimulus and response in a non-scientific metaphorical way. When these terms were defined operationally, the explanations were clearly incorrect (Chomsky 1959). Chomsky also argued that behaviorist learning theories did not provide adequate explanations of language acquisition by the child. Chomsky's critiques of behaviorist models focussed on Skinner's radical behaviorist analysis. However, Chomsky's arguments were quickly extended to neobehaviorist models by his students and colleagues. For instance, Fodor (1965) presented a detailed critique of Mowrer and Osgood's accounts of meaning. And, Bever, Fodor & Garrett (1968) challenged the adequacy of neobehaviorist accounts of language and cognition.

Bever *et al.*'s argument illustrates the flavor of these attacks on behaviorism. They pointed out that all behaviorist models accept the methodological constraint that all explanatory elements in a psychological theory must be derivable from potentially observable stimuli and responses. They dubbed this constraint the 'terminal meta-postulate' (TMP). However, no model that adheres to the TMP can generate all and only the strings pro-

duced by a mirror-image language, i.e. the language produced by the rules in (1):

(1) a. X→aXa
b. X→bXb
c. X→O

The problem is that producing strings of a mirror-image language (e.g. abba, aa, bb, aabbaa) – which people can quickly learn after exposure to a few instances of grammatical and ungrammatical strings – requires a device that can keep track of what sequence of symbols was used early in the string, so that the sequence can be reproduced to complete the mirror image. The symbol X in (1) serves this function. There are numerous devices that will do the job (e.g. a push-down stack), but postulating such devices which clearly have no counterparts in stimuli or responses violates the TMP (Anderson & Bower 1973).

### 1.2.2. Language acquisition

Although Chomsky never put forward a serious model for language acquisition, his logical analysis of the problem has provided a framework for the field (see Gleitman & Wanner 1982). Chomsky argued that the linguistic input to which the child was exposed was too impoverished for him to induce the mapping between meanings and linguistic forms. Thus the child must begin the acquisition process with some innate linguistic knowledge that constrains the set of candidate grammars. Chomsky proposed that certain 'linguistic universals' constrained the 'hypotheses' that the child needed to consider and he restricted the notion of 'explanatory adequacy' to linguistic theories that provided an account of these universals. Chomsky's emphasis on the theoretical importance of language acquisition, his presentation of the simple fact that children acquire language as an intellectual puzzle, and his strong nativist claims all helped to create an atmosphere of intellectual excitement which led to an explosion of interest in how children learn language.

### 1.2.3. Experimental psycholinguistics

Chomsky's transformational theory of grammar shaped the first decade of research in experimental psycholinguistics. The theory of grammar presented in Chomsky 1957, in particular the notion of a transformationally related family of sentences built around a kernel sentence, generated a number of hypotheses that were experimentally tested in early studies of sentence perception and memory (e.g. Miller 1962; Clifton, Kurcz & Odom 1965). His

'standard theory' (Chomsky 1965) formed the basis for much of the psycholinguistic research done in the 1960s and early 1970s. The standard theory grammar contained three components: a phonological component, a syntactic component, and an interpretive semantic component. It also emphasized the distinction between surface structure and deep structure. Chomsky's ideas had the impact that they did in large part because of the influence of George Miller, one of the founders of modern cognitive psychology and cognitive science. We now turn to a brief history of language comprehension, beginning with Miller's early work.

## 1.3. Language comprehension

### 1.3.1. Psychological studies of grammar

In the early 1960s Miller began to explore the hypothesis that the language comprehension system directly incorporates a transformational grammar. One line of investigation was based on earlier studies by Miller and colleagues (e.g. Miller, Heise & Lichten 1951) that examined the recall of different linguistic units (e.g. phonemes, words, strings of words) presented in a noise background in order to determine the unit(s) of language processing. The central finding was that higher level (larger) units were better recalled than lower level units when presented against the same intensity noise background. Miller and Isard (1963) used the same technique with three types of stimuli: (1) random strings of words; (2) well-formed sentences; and (3) syntactically well-formed but semantically anomalous sentences. The best recall obtained in the normal sentence condition, but words from the syntactically well-formed but anomalous sentences were recalled better than words from the random strings, demonstrating that syntactic structure was being used during language comprehension.

Miller and his students also explored a specific proposal about how language structure was used in language processing that was later dubbed the 'derivational theory of complexity' (DTC) because it assumed that sentences with a more complex derivational history should be more difficult to process. The basic idea was that listeners first compute the surface structure of a sentence and then use transformations to map the surface structure on to the deep structure. The representation in memory was the kernel sentence plus its transformational tags. Although the DTC was supported by an initial series of experiments, it was quickly abandoned. Many of the results that supported the theory became difficult to interpret as transformational grammar changed. More importantly, the empirical predictions generated by the DTC were clearly disconfirmed by pairs of sentences in which the transforma-

tionally more complex member of the pair was easier to process (Fodor & Garrett 1966; Bever 1970).[3]

Other lines of research seemed to find evidence that listeners were recovering linguistic structure during comprehension. Fodor, Bever, and Garrett (in various combinations) conducted a well-known series of studies that demonstrated that brief clicks or tones embedded in sentences were perceived as occurring at linguistically defined boundary points. Other studies converged on the clause as a major boundary point in sentence processing. Syntactic variables became the focus of a growing number of studies using a variety of experimental paradigms. (Experimental paradigms such as phoneme monitoring, sentence–picture verification, lexical decision, and probe verification were all introduced during the middle 1960s.)

The studies of sentence memory conducted by Miller and his students had examined memory for syntactic structure (e.g. Mehler 1963). An important study by Sachs (1967) demonstrated that listeners rapidly forget the syntactic form but not the meaning of a sentence. This result was interpreted within the framework of Chomsky's (1965) theory as evidence that people remember the deep structure of a sentence. Studies by Blumenthal (1967) and Wanner (1974) provided the strongest experimental evidence that the deep structure of a sentence was stored in memory. For instance, Wanner had subjects memorize a set of complex sentences. Subjects were then presented with a probe word taken from the sentence as a cue to be used for recall. The effectiveness of the probe word as a recall cue was a function of the number of times that the word appeared in the deep-structure tree of the sentence.

The combination of evidence that listeners recover the deep structures of sentences and evidence that they do not use transformations posed a puzzle for theories of language comprehension, namely how do listeners map linguistic input on to deep structures without using transformations? Fodor & Garrett (1966) and Bever (1970) suggested that listeners use heuristic parsing strategies that Bever termed 'perceptual strategies.' Among the most compelling evidence for these strategies were examples of grammatical sentences that were difficult, if not impossible, to parse, because the strategies assigned the wrong structure to the sentence. The most famous example is Bever's sentence *The horse raced past the barn fell*, a grammatical sentence with a reduced relative clause (*The horse (which was) raced past the barn*) that is misparsed because the past participle is misanalyzed as a simple past tense of a main verb. Fodor, Bever & Garrett (1974) integrated perceptual strategies into a clausal model of sentence processing that incorporated three principles: (1) the clause is the primary unit of analysis; (2) within the clause

[3] The contrasts that provide evidence against the DTC are between sentences that are no longer transformationally related in current grammars. Thus it can be argued that rejection of the DTC needs to be reconsidered (e.g. Berwick & Weinberg 1983). See Garnham 1983 and note 6 for a discussion of some of the reasons why psycholinguistics are currently not interested in reviving the DTC.

perceptual strategies relate the elements of the clause; and (3) after the clause ends, it is recoded, freeing memory for further processing.

### 1.3.2. The end of the transformational era

The most detailed presentation of the strategies approach is in Fodor, Bever & Garrett (1974). Fodor *et al.* concluded that the structures assigned by transformational grammar are psychologically real (used during processing) but the rules (transformations) used to generate those structures are not, a position that Wanner (1977) has characterized as the 'weak theory of the psychological reality of transformational grammar.' This theory provided an integrated framework for psycholinguistics around a position that briefly represented a consensus and that has served as a reference point for subsequent work. By the time that the book was published, however, the consensus had already broken down. The next sections detail some of the reasons why.

#### 1.3.2.1. The constructive nature of sentence memory

The hypothesis that the memory representation for a sentence includes its deep structure did not survive the early 1970s. Bransford and Franks and colleagues conducted an influential series of studies that demonstrated that (1) stored representations do not respect sentence boundaries and (2) memory representations of a sentence combine information provided by the propositional content of the sentence with information drawn from inferences based on real-world knowledge. For example, after hearing a sentence such as (2):

(2) Three turtles rested on a log and a fish swam beneath them

subjects believed that they had heard (3) as often as (4),

(3) The fish swam beneath the log
(4) The fish swam beneath the turtles

even though the meaning of (3) is not in any sense represented in the deep structure of (2). Rather, it is inferred from the meaning of (2) by the use of knowledge of spatial relations in the real world. This study and others of the same period highlighted the ways in which context conditioned the interpretation of words, sentences, and larger texts. Although all of the experimental studies examined memory representations, the results were interpreted as providing evidence about the nature of the comprehension process as well. Studies of sentence-level mechanisms and representations were considered sterile and unexciting, given the constructive nature of comprehension.

### 1.3.2.2. Online processing

In the early 1970s, Marslen-Wilson conducted a series of influential experiments that highlighted the rapid real-time nature of language comprehension. For instance, Marslen-Wilson (1973) and Marslen-Wilson & Welsh (1978) demonstrated that lexical, syntactic, and nonlinguistic contextual information all determine the likelihood that people who are listening and repeating back a message at a lag of about one syllable (close shadowers) will fluently restore a distorted word in shadowing a running text. A series of studies with Tyler demonstrated that listeners rapidly use pragmatic information in resolving structural ambiguities and in interpreting both explicit and implicit anaphors (e.g. Tyler & Marslen-Wilson 1977). Thus listeners have rapid access to syntactic, semantic, and pragmatic knowledge, which they use to develop an integrated representation of an incoming sentence as each word is heard. Marslen-Wilson (1975b) argued that the weak theory of psychological reality was impeding progress in understanding language comprehension. Transformational grammar assumes simultaneous access to all aspects of a derivation. As a result, psycholinguists were led to explore processing models in which the input was more or less passively accumulated until it could be mapped on to a complete linguistic sequence. Marslen-Wilson and Tyler's work focussed attention on the temporal characteristics of language comprehension and on the interaction of different sources of information during online comprehension. They also identified the lexicon as the source of many of these processing interactions.

### 1.3.2.3. The linguistic wars

One of the factors that had contributed to the influence of transformational grammar within psycholinguistics was that Chomsky's theories represented a consensus among linguists. As this consensus broke down, the debates between proponents of Chomsky's variations of standard theory and proponents of generative semantics made it difficult for psycholinguists to incorporate linguistic theory into their experimental work. At the same time that psycholinguistic studies were finding that syntactic structures played a minimal role in sentence memory, generative semanticists such as Ross, Lakoff, and McCawley were arguing that the underlying structures were semantic rather than syntactic in nature and that there was at best a fuzzy boundary between syntax and semantics. The generative semanticists' work highlighted aspects of language, such as indirect speech acts, that were not easily integrated into generative grammars. It also emphasized the fuzziness of grammatical categories and the ways in which conceptual structure influenced judgements about linguistic well-formedness. The boundary

between linguistic representations and conceptual representations seemed to be rapidly eroding, with some linguists beginning to appeal to cognitive psychologists for explanations for the cognitive foundations upon which language seemed to depend (see e.g. Ross 1974).

Despite its appeal to psychologists, generative semantics never had much of an influence within psycholinguistics.[4] Many of the phenomena that the generative semanticists explored were never plausibly incorporated into the transformational framework (e.g. speech acts). There was also a growing irritation on the part of psychologists with the prevailing attitude among linguists that performance data were irrelevant to the formulation of competence theories, especially after Chomsky had endorsed Miller's initial studies. But the primary reason was that psycholinguists no longer considered transformational grammars to be viable candidates for processing models.

### 1.3.3. Psycholinguistics without linguistics

By the middle 1970s there remained no unequivocal evidence that transformational grammar provided a model of either the rules or representations that listeners and speakers use during comprehension (Johnson-Laird 1974).[5] As a result, psycholinguistics largely severed its ties with linguistics and became absorbed into mainstream cognitive psychology. The field changed in a number of ways. During the 1960s psycholinguists had concentrated primarily on syntactic variables in sentence processing. During the 1970s, they focussed on higher level processes such as the comprehension and memory of discourse or text, and on lower level processes such as the recognition of lexical and sub-lexical units. The study of syntax was largely abandoned in favor of the study of meaning. In addition to studies of literal meaning, psycholinguists began to examine various aspects of nonliteral meaning such as indirect requests (e.g. Clark & Lucy 1975) and

[4] Among the few exceptions were studies by Kintsch (1974) and Fodor, Fodor & Garrett (1975) that tested the hypothesis that complex verbs such as causatives are more difficult to process than simple verbs. Generative semanticists decomposed causative verbs into underlying semantic primitives. For instance *kill* was analyzed as being derived from (CAUSE to (BECOME (NOT ALIVE))). No differences were found in these experiments.

[5] The reader might wonder about the Wanner (1974) study discussed earlier that seemed to provide evidence for deep-structure representations in sentence memory. As Wanner (1977) later pointed out, the results can be explained without recourse to deep structure because the number of times that a word is mentioned in the deep-structure tree of a sentence is correlated with the number of propositions in which it participates. With a few exceptions, the studies that examined the psychological reality of grammar did not investigate properties of linguistic structure that were uniquely attributable to transformational grammar. One study (Bever, Lackner & Kirk 1969) found that listeners mislocate clicks towards clause boundaries only when the surface clause is also a deep-structure sentence. However, linguistic analysis of the materials used and the interpretation of results obtained with the click location methodology have been extremely controversial. Bever and his students have continued to develop the clausal model, but one of the first moves was to abandon the assumption that the major processing unit could be defined linguistically (e.g. Tanenhaus & Carroll 1975; Carroll, Tanenhaus & Bever 1978; Townsend & Bever 1978).

idioms and metaphor (e.g. Ortony 1979). These studies were influenced by Grice's (1967) theory of conversational logic and by Searle's (1969) analysis of sentences as speech acts.

Studies of word recognition were framed by two competing views about the nature of lexical access. On one view lexical access proceeds by parallel activation of a set of candidate 'logogens' (Morton 1969) and on the other by rapid serial search through a file (Forster 1976). At the sub-lexical level, researchers began to ask what codes and units of representation are computed during recognition, as well as how these units interact during processing. The role of morphological structure in word recognition emerged as an empirical issue (Taft & Forster 1975), as did the role of phonological representations in reading. The dual-route model of reading (Coltheart 1978), in which access to the lexicon can proceed either through a visually based whole word recognition process or through the application of spelling-to-sound rules, helped provide a framework for understanding normal visual word recognition (and later certain characteristics of acquired dyslexia: Coltheart, Patterson & Marshall 1980). Studies of auditory word recognition concentrated on the role of phonemes and syllables in lexical access and on the processing of ambiguous words (see Cutler & Norris 1979 for review). The structure of 'semantic memory' and the representation of concepts became the focus of extensive research. Seminal studies by Rosch and colleagues (e.g. Rosch 1975) challenged the classical view that concepts are represented in terms of defining and necessary features, arguing instead for prototype or instance-based representations.

The comprehension of stories and texts emerged as an important research topic in the middle 1970s. A number of propositional models for the representation of sentences and texts were developed (e.g. Norman & Rumelhart 1972; Anderson & Bower 1973; Kintsch 1974; Fredricksen 1975). The most influential of these models were the Anderson and Bower model, the subsequent model proposed by Anderson (1976), and the Kintsch and van Dijk (1977) model of text processing, which built upon the earlier Kintsch model. As cognitive psychologists became more interested in discourse and text, the interpretation of anaphora and inferential processing emerged as central research topics.

Studies of anaphora focussed primarily on how anaphoric expressions are associated with their antecedents. A number of factors were found to influence how easily an anaphor could be interpreted, including the number of potential antecedents for the anaphor, the distance of the antecedent from the anaphor, whether or not the antecedent was in focus and the 'implicit causality of verbs' (see Garnham in press for a review). Many of these studies were influenced by the work of Halliday & Hassan (1976) and other functionalist linguists.

More recent studies of anaphora have been influenced by the 'mental models' framework developed by Johnson-Laird and colleagues (e.g. Johnson-Laird 1983) in which the mental representation of a text is described in terms of discourse entities and their relationships rather than a set of propositions derived from the text. The mental models approach is closely related to recent work on discourse representation in linguistics (e.g. Kamp 1981; Heim 1982) and artificial intelligence (Webber 1981).

Studies of inferencing have focussed on when comprehenders draw various types of plausible or invited inferences. Haviland & Clark (1974) demonstrated that readers make 'bridging inferences' when they do not have a mental antecedent for a definite noun phrase. Other studies demonstrated that readers generally don't make forward (predictive) inferences. One question that received particular attention was whether or not comprehenders infer the plausible instrument for a verb such as *pound* (e.g. *hammer*) when an instrument is not mentioned. Experiments incorporating appropriate controls have concluded that instrument inferences are generally not made during comprehension (e.g. Corbett & Dosher 1978; McKoon & Ratcliff 1981). Work on inference was also influenced by proposals from artificial intelligence, especially Schank & Abelson's (1977) notion of a 'script' (a temporally organized memory structure that lists the sequence for stereotypical activities such as going to a restaurant). A number of studies (e.g. Bower, Black & Turner 1978) found that in recalling a story, readers tend to fill in from scripts information that was not explicitly mentioned in the text.

### 1.3.4. The influence of artificial intelligence

At the same time that Chomsky was beginning his work on syntactic theory within the framework of automata theory, Newell, Simon and Shaw were developing their thesis that symbol manipulation lies at the heart of intelligent behavior (e.g. Simon 1962). Digital computers, they argued, manipulate symbols and therefore provide both a theoretical and a methodological model for understanding intelligent behavior. The symbol manipulation idea merged with the view that the cognitive system is an information-processing system to form a new information-processing approach that quickly became synonymous with cognitive psychology. The earliest influence was seen in 'stage' models of memory in which information flow through the cognitive system was described in terms of transformations as it passed through different storage systems or buffers. The development of the additive factors logic for reaction time by Sternberg (1966) provided experimental psychologists with a powerful methodology for evaluating these models.