The Evolution of a Cognitive Psychologist: A Journey from Simple Behaviors to Complex Mental Acts

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Abstract

The author summarizes his evolving interests from conditioning studies within a behaviorist orientation, thence to human memory, knowledge representation, and narrative understanding and memory. Arguing that the study of skilled reading provides a microcosm for revealing cognitive processes, he illustrates this by reviewing his research on the use of spatial priming to investigate readers' on-line updating of their situational models of texts. Conceptual entities close to the reader's focus of attention within the model are readily retrieved. Retrieval speed from memory declines with the probed object's distance from the current focus and decays with time elapsed in the narrative since the item was last in focus. The focus effect varies with the character's perspective, his status in the story, his active goals, and other factors. The results are accommodated within an associative network model distinguishing just-read sentences in short-term memory from activated portions of long-term memory structures to which they refer.

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INTRODUCTION

Authors of prefatory chapters for earlier *Annual Review of Psychology* volumes wrote scholarly reviews setting forth their contributions to a single major line of research. I am opting instead for an autobiographic approach that touches on the major research topics that I have pursued over successive phases of my career. Each topic could be elaborated to chapter lengths, but page limits constrain that impulse and rescue undaunted readers. Accordingly, this narrative briefly tracks my progression from simple animal conditioning experiments within the behaviorist tradition to cognitive approaches to human learning and memory, and, then, to human knowledge representation and utilization. The arc reaches its culmination, and longest description, in the research on narrative comprehension and memory that I carried out with several collaborators. I view my path as a conceptual progression from the simple to the complex, and as reflecting the expanding horizons and theoretical ambitions of cognitive science.

Early College Years

Influenced by a high school teacher, I acquired an early interest in Freudian psychoanalysis, reading the psychoanalytic canon extensively—Freud, Adler, Jung, Horney, Fenichel, Sullivan, Rank, and Melanie Klein—during late high school and early college at Western (now Case Western) Reserve University in Cleveland, Ohio. As an aspiring psychiatrist, I waded through two years of premed courses. After my freshman year, I worked as a summer ward attendant at the Cleveland State mental hospital; later, during my sophomore year, I was a part-time research assistant to the psychology staff there. Those sobering experiences convinced me of the somewhat primitive state of psychiatric knowledge and discouraged me from a career in psychiatry. At the same time, I became engrossed in an experimental psychology class taught by a young ex-Yalie, Charles R. Porter, who introduced me to learning theory, especially touting the quantitative approach of Clark Hull (1952). That interest put me on a path that led to Yale graduate school and study with Neal Miller. At the time, Miller was a premier learning theorist whose sympathies for psychoanalytic theory were evident throughout the book *Personality and Psychotherapy* that he coauthored with John Dollard (Dollard & Miller 1950).

Yale Graduate School and Early Stanford Years

I arrived at Yale in September 1955, just as Miller was shifting his research focus to identifying the areas of the mammalian brain that control reward, punishment, and biological drives. My early work tested cats and rats to plumb the motivational effects of brain stimulation. My first publication with Miller reported a dual reward-punishment effect from stimulating spots in the rat's limbic system (Bower & Miller 1958). My rats would press a lever to turn on the brain stimulation at these spots, but it quickly became aversive so they would rotate a wheel in the cage to turn it off. The animals would repeat this on-off behavior until both rodents and their observers grew weary of it. Although I took courses in physiological psychology and learned techniques of precise electrode implantation, recording, preparation, and histological examination of brain tissue, I preferred the more "behavioral" side of learning theory. While continuing work with Miller, I concentrated my behavioral research increasingly with Yale's Frank Logan (1956, 1960). When I received my PhD in 1959, I was a committed Hullian theorist with a strong "animal learning" orientation.

I set up an animal-learning lab when I started my first job at Stanford University's Psychology Department in fall, 1959. The lab was located in a Quonset hut leftover from World War II. I built my rat runways, shuttle boxes, and operant conditioning chambers there, using electrical components cannibalized from junked pinball machines. With this hardware, I investigated such diverse conditioning topics as transfer of training between Pavlovian and instrumental conditioning, schedules for developing avoidance and escape learning, reward contrast effects among reinforcement conditions, frustration from reward-reductions, "observing responses" in rats and pigeons, and errorless discrimination learning. I was happily and productively occupied, doing the kinds of research I was trained to do. But seeds of doubt about my animal-learning approach germinated as the allure of mathematical psychology increasingly attracted my attention.

Mathematical Models and Human Learning

Although I had started with an interest in quantitative learning theory, this was not Yale's strength. Fortunately, I got a crash course in mathematical learning theory after my second year in graduate school by attending a 1957 summer institute on mathematical psychology sponsored by the Social Science

Research Council. There I met many leaders, or soon-to-be leaders, of the emerging mathematical psychology movement that was a prominent stream within learning theory in the 1955 to 1975 era. That summer I formed a close intellectual bond with the leader of that movement, Bill Estes, who became my mentor. By the early 1960s, Estes, Dick Atkinson, and I had been hired to join Patrick Suppes at Stanford to fill out the mathematical learning theory segment of its department. In those heady years, we attracted some of the brightest graduate students who would help lead the next generation, including (alphabetically) John Anderson, Bobby Klatzky, Steve Kosslyn, Douglas Hintzman, David Rumelhart, and Richard Shiffrin.

MOVING INTO COGNITIVE PSYCHOLOGY

We tested most of our mathematical models on data collected from college students learning such experimental tasks as paired associates, free recall, serial learning, or simple category (classification) learning. Since massive amounts of data are easier to harvest from college students than from rats, my animal research was gradually displaced by my studies of human learning.

So two years after I received my Yale degree, I was deeply engaged in studying human "verbal learning" (as it was then called) despite having had no graduate training in this field. To get up to speed, I read widely and prepared a lengthy review of human learning research in 1962, although the entire book was not published until five years later (Bower 1967). At Yale, we had regarded Hullian behavior theory and animal learning, specifically studies of motivation and reinforcement, as royal roads to enlightenment, and we viewed studies of human learning as dull dead-ends. The apparent dullness of this field seemed to be captured in its major text at that time, *The Psychology of Human Learning*, by McGeogh & Irion (1952). Yet, human memory was one of the first barricades of tradition stormed and breached by the forays of the revolutionary cognitive psychologists. The sudden contrast and jolt of this intellectual shift taught me to stay nimble and be ready to move with the winds of change in academic psychology.

Major Influences Toward Cognitive Psychology

The information-processing viewpoint. The mid-1960s was a time of conceptual turmoil in experimental psychology. I was swept up in several of its waves. The most powerful of these was the "information-processing" approach, which viewed perception and memory as the taking in, transforming, storing, and retrieving of packets of information. Leading proponents of this approach were George Miller, Jerome Bruner, and Ulric Neisser. The movement's seminal works were *Plans and the Structure of Behavior* by George Miller et al. (1960) and *Cognition* by Neisser (1967). Both treatises upset the worldview of traditional behaviorists. Donald Broadbent (1957, 1958), the influential British leader of the information-processing approach, played a key role in directing the field into studies of selective attention and immediate memory. Broadbent and Arthur Melton (1963) spearheaded the popularity of research studies of short-term memory. Several of us at Stanford developed mathematical models using an information-processing metaphor for short-term memory and its transfer to long-term memory (Bower 1967). The dual-storage model of Atkinson & Shiffrin (1968) became the leading theory of that era.

Computer simulation modeling. Related revolutionary influences were computer simulation models of psychological processes as exemplified in the work of Allen Newell and Herbert Simon (1961, 1963). Their models of psychological processes were arguably even better specified than our mathematical models, and their simulations could be run under differing experimental circumstances to gauge whether the models predicted the behavior of real subjects. My first exposure to computer-simulation modeling was in a 1963 summer workshop at RAND Corporation with Simon, Newell, and several of their students, including Ed Feigenbaum. The first viable simulation project I was associated with was the "Stimulus and Association Learner" (SAL) model of my student, Douglas Hintzman (1968). Doug and I showed how many standard results in human verbal learning could be simulated by an elementary information-processing model. Specifically, SAL incrementally learned a discrimination net of features to distinguish among and respond to the stimuli of a paired associate list. These experiences instilled in me an abiding appreciation for the artificial-intelligence approach to knowledge acquisition and utilization.

Chomsky and psycholinguistics. Another major influence in cognitive psychology was the Chomskian revolution in linguistics (Chomsky 1957, 1965). I had met Noam Chomsky at that 1957 Social Science Research Council summer institute, when he was assisting George Miller with a workshop on the psychology of language. Yet, I did not grasp the significance of Chomsky's approach until I read his devastating critique (Chomsky 1959) of Fred Skinner's book, *Verbal Behavior* (1957). In his critique, Chomsky ripped the veil from our eyes, revealing that, regarding the complexities of linguistic performance, our behaviorist emperor had no clothes. Chomsky persuasively argued that the stimulus-response approach was too impoverished to explain the complexities of verbal behavior, suggesting that the behaviorist analysis would be useless for understanding the learning and use of language. This unmasking came as a shock to those of us raised on psychologists' "internal stimuli and response hierarchies," which was the behaviorists' main tool in attempting to understand what language could do (Dollard & Miller 1950, Osgood 1953, Staats 1968). Chomsky countered that psychologists should develop more complex information-processing models of language, a challenge that gave birth to psycholinguistics. Leading the first halting steps of this incipient field were George Miller and his colleagues at the Harvard Cognitive Sciences Center. Chomsky and Miller were largely responsible for promoting language learning and language use as hot topics in cognitive psychology.

Organizational Factors in Memory

Having worked on mathematical descriptions of transfers of information from short-term to long-term memory, I wanted to know more about what caused these transfers to succeed. So my students and I studied the cognitive maneuvers that people use to learn and remember things (Bobrow & Bower 1969, Bower & Winzenz 1970). Many of us found that sheer repetition and rote rehearsal of an item in short-term memory was woefully insufficient for recording a more long-lasting memory. So what would accomplish this?

Chunking in memory. I found clues in the literature describing the role that organization plays in memorizing. My studies of organizational aids to memory were greatly influenced by the ideas of George Katona (1940) on how subjects' "understanding" of materials promotes memory, of George Miller (1956) on chunking, and of Endel Tulving (1962) and George Mandler (1967) on participants' subjective organization in free recall. Tulving and Mandler studied how people learned to free-recall lists of "unrelated" words studied repeatedly. They found that adult subjects spontaneously look for meaningful relations among the items, grouping them into "chunks," and perhaps even organizing the chunks into larger memory chunks. That prompted my research into the processes that created or disrupted chunks in memory (Bower 1970a, 1972).

Perceptual chunking and memory. In this work, I was influenced by Solomon Asch's thesis that memory was an incidental byproduct of the person organizing the materials into a perceptual or conceptual unity or whole (Asch 1969, Asch et al. 1960). By one or another means, people come to view disparate elements as inseparable parts of a single unit. This hypothesis guided my studies on the learning of "unrelated" pieces of information that we experimenters perceptually unitized (or not) for our subjects (Bower et al. 1969, Bower & Winzenz 1969). Asch's thesis also extended to the process of conceptual unitization and drew upon insights from mnemonic devices and mental imagery. As one consequence, I began studies of mnemonic devices (Bower & Clark 1969, Bower 1970b).

Mnemonics and Mental Imagery

Magicians and stage performers have long used mnemonic devices to enhance their memorization for disparate information, be it shopping lists, lecture topics, associating faces with names, their phone numbers, occupations, spouses, hometowns, and so on. I published studies on the mnemonic coding (translation) of "meaningless nonsense" into "meaningful sense" and on how people use language and imagery to form conceptual units. We found that in learning to associate pairs of unrelated words, memory was greatly improved by instructing subjects to search out and form meaningful relationships between the items, such as might be expressed in a sentence—no matter how bizarre. Similarly, asking subjects to construct a visual image of some interaction between the referents of a pair of nouns greatly facilitated their recall of the pair (Bower 1972b). At this time, Allan Paivio and his group at Western Ontario University were leading the research on mental imagery in learning (Paivio 1971). These studies of associative learning via conceptual or imagery combinations became a popular trend of the times, and were in sympathy with the contemporaneous "depth of processing" metaphor of Gus Craik and Bob Lockhart (1972, Craik & Tulving 1975).

During this period, the style and content of experimentation were markedly different from our previous learning research. Earlier mathematical models had attempted to describe trial-by-trial performance of subjects who were studying a collection of items repeated over many trials. The newer memory experiments typically involved single exposures to the information to be remembered. Also, those later experiments often involved unintentional learning created by instructing subjects to carry out some specified "processing" of the material (e.g., categorizing or imaging it) with no mention of its being memorized. These topics and experimental methods were increasingly far removed from the former mathematical models of learning on which I had been working.

Human Associative Memory

While depth of processing is an arresting metaphor, it was not entirely satisfying for me (cf. Ross 1981). I wanted to understand what created "meaningful combinations" of materials that caused them to be learned so quickly. The easiest approach was to study the meaningfulness of conceptual combinations generated through language. This belief led my student, John Anderson, and me to propose a theory of how people use conceptual knowledge to encode and remember new combinations of concepts, especially descriptions of events and factual assertions. That theory was set forth in several articles and our book, *Human Associative Memory*, affectionately known as *HAM* (Anderson & Bower 1973).

Anderson and I began with the ideas about semantic memory and question answering that Ross Quillian (1968) and Allan Collins (1969) had popularized (Collins & Quillian 1969, 1972). That approach (Minsky 1968) represents knowledge as a huge associative network. Within this network, a concept was represented by a structured set of labeled associations among its related properties and among other concepts. The meaning of a concept is the collection of other concepts as well as referent sensory shapes and features to which it is related. Memory retrieval was conceived as the cues in the question sending activation into corresponding regions of the associative network, searching for a matching structure. Although mildly adequate for representing static knowledge, this approach did not address the learning of any new facts or concepts. Anderson and I wanted to encompass new learning using an augmented association theory. We believed that people learn such new information by interassociating instances of familiar concepts, thereby creating novel configurations that describe the information.

Tests of HAM. We tested our theory by providing college students with many interrelated facts about people in a small town. They would read, for example, that "The town mayor owns a local restaurant" and "The town sheriff drives a white Chevy." The HAM theory was written as a computer simulation model. Anderson programmed a language parser that would take such typed sentences into its short-term memory and set up simple associative structures. As each fact was read, we supposed that subjects (as did the computer program) performed three tasks: (*a*) established a new unit in memory for the configuration of underlying propositions describing the fact or episode; (*b*) composed these propositions by creating new instances, or tokens, of pre-existing concepts that already had been stored in the person's (and computer's) memory; and (*c*) linked them together in a pattern of subject-predicate structures. These labeled associations enabled the simulated system to answer questions about who was doing what to whom, when, and where. Because the system used familiar concepts (Chevy, sheriff), the new fact could be combined with pre-existing knowledge that enabled the simulation to draw simple inferences, such as inferring that the person who enforces the law in town drives a white car.

The Zeitgeist surrounding HAM. Our efforts were part of the contemporary Zeitgeist. Psychologists and artificial intelligence (AI) researchers were then building computer models of knowledge representation and language understanding (Kintsch 1974; Rumelhart et al. 1972; Schank 1975a,b; Winograd 1972). What set our work apart was that Anderson and I explicitly sought to relate our computer simulation model to the systematic laws and generalizations found in the human memory and learning tradition. Relying on simple assumptions, for example, that associations are strengthened by repetition and weakened by time decay and interference, our model explained findings from our experiments on fact learning and retrieval. Significantly, our model was extendable so it could encompass many traditional findings of the experimental literature on human learning.

Part of our goal was to recast the laboratory findings from memory research to relate them to novel ideas about knowledge representation coming out of AI. These AI topics included perceptual pattern recognition, propositional analysis of knowledge, semantic memory, labeled associative networks, retrieval by fitting a question to a content-addressable structure stored in memory, and answering questions by using a collection of specific strategies. Importantly, we demonstrated how to move laboratory research on memory away from its traditional lists of nonsense syllables and unrelated words toward more realistic materials, including coherent text.

Anderson later developed HAM into a far more powerful theory and simulation system. He introduced, for example, the important idea of "productions": the learned routines that move the cognitive system from one subtask to another as it works on a larger problem. Refinements of this production system, along with the labeled associative network and improvements in the perceptual front end of the system, enabled Anderson and his associates to develop cognitive psychology's most powerful and successful theoretical system (Anderson & Lebiere 1998). It is a major achievement. I am proud to have contributed to its origins in the early 1970s.

MOVING UP TO COHERENT TEXT

Anderson and I had addressed such prototypic "memory experiment" materials as single experiences (unrelated word lists) and single sentences (and their underlying propositions). Yet we understood that cognitive psychology had a long way to go before it could model the understanding of, and memory for, such coherent prose as a simple story or history lesson. Prose has properties that greatly transcend collections of unrelated or scrambled sentences. In meaningful prose, successive sentences are connected by a variety of coherence principles. For example, successive sentences should carry forward somewhat the same topic (concepts) and introduce new facts about it in a multilayered, interwoven way (Fletcher et al. 1996). Impressed by the pioneering theories of Walter Kintsch (1974), Roger Schank (1975b), and David Rumelhart (1975), my students and I began investigations of narrative comprehension and memory. Despite my primary interest in memory, I knew text comprehension had to be studied as well, because it is a major determinant of what people remember from a text.

Why Study Narrative Understanding and Memory?

Although there are many types of prose, psychologists began to focus on the study of narratives and story understanding in the 1980s. Several reasons led to this common interest. First, understanding of any text depends critically on the reader's expertise regarding the topic under discussion. Most adults already possess the requisite common knowledge of human affairs required to understand simple stories and folktales. For example, most adults understand basic human motives, goals, causes of purposive actions, and simple rules of social reciprocity. This homogeneity of subjects' knowledge eliminates what would otherwise be a major source of variability in experimental data. Second, reading, remembering, and summarizing narratives are familiar cognitive tasks for most literate people. Moreover, researchers using simple narratives as experimental materials can carefully construct variations in texts to create controlled comparisons and to isolate specific components of the comprehension process. In short, narrative understanding offers an excellent experimental test tube within which to study general aspects of people's understanding and memory.

Story Grammars

Our early efforts, as with many research ventures, followed other work in the area. After a few minor studies of text memory (Bower 1974, 1978), my student, Perry Thorndyke, and I became attracted to the story-grammar approach to understanding (Bower 1976, Thorndyke 1977). Simple stories and folktales contain such recurring components as a setting, characters, a theme (main goal), a plot, episodes, and a resolution. Colby (1973) and Rumelhart (1975) even conjectured that there might be something like a context-free story grammar. That is, some rewrite rules would specify how large narrative components would be expressed in terms of smaller constituents or terminal elements. For example, a narrative consists of a setting, a theme, episodes, and an outcome. The setting in turn can be rewritten as a list of characters and places. The theme is one or more goals, and an episode is made up of characters' actions in a setting that yields outcomes. Those outcomes, in turn, may establish new narrative subgoals. Rumelhart proposed that readers use this framework to interpret, understand, and recall simple problem-solving stories.

Our early research showed that adults not only prefer stories that follow the canonical grammar but also recall them far better than they do randomly scrambled sentences (Bower 1976, Thorndyke 1977). A crucial element for recall is the overall goal of the protagonist. If no overall goal is expressed or strongly implied, comprehension and recall plummet. Comprehension also suffers if subgoals, actions, and outcomes are spread out and misaligned over different episodes of the story. Furthermore, when summarizing a story, people typically recite the "higher" units of the grammatical hierarchy by naming the main characters, main setting, main goal, and main outcome. In other words, as the grammar expected, people recall the essential gist of the story, while letting go of lesser details. Kintsch (1974) similarly found that people recall the main points (generalizations) rather than finer details of expository text. This and other research (e.g., Mandler & Johnson 1977, Stein 1988) established that people in our culture acquire and use a schema that allows them to identify the principal elements of a well-formed narrative and how these elements are structured. This schema also guides their later recall of the narrative.

But story grammars had their shortcomings. A first shortcoming is that story grammars only specified abstract components (e.g., settings, goals) but said nothing about what kinds of content would fill those components. Yet, it is the content that makes any story concrete and interesting. A second shortcoming, in violation of proposed context-free story grammar rules, is the many constraints and relations among the elements that fill the constituents of a typical narrative. For example, the main goal must be that of the main character. His or her actions must be plausible within the context of the story and relevant to those goals. And the final outcome must be related to the initial goal. A third shortcoming is that the early story grammars ignored the critical role that the readers' inferences play in understanding—the grammar applies only to the surface sentences of the text. Yet, many important elements of a text are implied rather than stated explicitly. The inferences that people draw from events in a story (or in real life) reflect their pre-existent knowledge and beliefs. These shortcomings of the story grammar approach led researchers to the study of the conceptual meaning of narrative events, which provides a far richer lode to be mined.

Consensus View of Event Understanding

Dating from van Dijk & Kintsch (1983), researchers have developed the consensus that as people read or hear a story about events, a cascade of different cognitive processes go on in parallel, building multilevel representations of the information. First, readers take in the surface structure of the printed (or spoken) sentences and hold it in their working memory for several seconds. From this surface structure, they extract a propositional text base containing the logical relations between the concepts and the predicates stated in the text. Finally, a referential representation of what the text is about is constructed. This situation model or a mental model (Bower 1989, Johnson-Laird 1983, Zwaan & Radvansky 1998) is not the text itself but rather is what the text refers to. In some respects, the situation model is like a mental image of the story's settings and actions that the reader constructs and modifies based on clues in the text. In other respects, however, the model differs from an image. It contains, for example, hidden information that would not be visible in an image, such as characters' motives, thoughts, and hidden weapons.

The situational model includes mental tokens corresponding to the characters mentioned in the text, the approximate locations and arrays of objects in the scenes, the goal and actions taken by the characters, events, and so on. A situation model is constructed by connecting the concepts that are in the text to the real world or some imaginary world referents. Situation models draw upon the schematic knowledge the reader already has about the general situation that the text describes. This dependence acknowledges the role of expertise in understanding particular topics.

Theorists of situation models (as articulated by Zwaan et al. 1995) have hypothesized that the more significant attributes or dimensions of story situations include variations in story time, space, the current actor, his goals, emotions, and important causal relationships between events. What makes a text coherent is a high degree of overlap or constancy of these attributes from one clause to the next. Major changes in any of these attributes usually cause readers to update their current model. Research has shown that the greater the number of these attributes that are changed from one sentence to the next, the greater the updating that must occur, and the more time readers take to read and process those changes.

Causal Analyses of Motives, Actions, and Outcomes

A major clue about a situational change is a change in the characters' goals—their achievement, frustration, or failure. Therefore, I moved my research increasingly from full-blown stories to concentrate on how people recognize and understand characters' motives, plans, and actions (Black & Bower 1980; Bower 1978, 1983; Foss & Bower 1986). The causal linkages among these elements heavily influence a reader's representation of the meaning of the narrative. Tracking a reader's understanding of characters' plans and goals has been the focus of research on causal analysis of narratives (Black & Bower 1980, Schank & Abelson 1977, Trabasso & Sperry 1985).

Most simple stories introduce a main character who has a complicated problem to solve. The story describes the character's actions to overcome obstacles to achieve the solution. Readers assume that the character's actions can be explained by his goals as played out within the constraints of the situation. While frustration of a goal may prompt the character to abandon it, more often he responds by establishing subgoals that, once conquered, pave the way to achieving the principal goal. Readers use everyday psychology to try to explain the character's motives and actions. In this way, readers connect new narrative events to earlier goals or actions in the text. Readers build a network of causal connections among the events of the story—going from some initiating event (for example, the sheriff learns that rustlers have stolen cattle) through the various goals, subgoals, and actions of the main character (the sheriff chases them), overcoming obstacles (they hide and ambush him), and arriving at some final resolution (he captures the rustlers and retrieves the cattle).

Readers consider events along this main causal chain to be the most significant parts of a story (Schank 1975b, Schank & Abelson 1977). Tom Trabasso and his associates (Suh & Trabasso 1993, Trabasso & Sperry 1985, Trabasso & Suh 1993, Trabasso & van den Broek 1985) analyzed many simple narratives, asking whether each event (described in a story statement) was enabled or caused by earlier events or whether it enables or causes later events. In a coherent story, the enabling events and causes form a web of connections. The importance of a statement in a story turns out to be determined by its number of connections. This connectivity is what determines the likelihood that readers will recall a given statement (or the event that it describes) or will include it when summarizing the story. This causal analysis replaces the empty platitude that readers recall the gist of a story (Bartlett 1932)—a statement that is useless until we know what determines the gist. Causal connectivity, based simply on analysis of the text itself, is an excellent predictor of what readers consider the gist of a narrative.

Goal-Based Explanations

Because character goals are the most important causes of character actions, my associates and I investigated how readers search in memory for goals to explain actions. For example, plans and actions for achieving goals range from the well trod to the unexpected. We showed that when the number of subgoal inferences required to connect a character's action to his or her primary goal increases, it takes readers longer to comprehend the action in question (Foss & Bower 1986). Thus, we understand immediately why a hungry man eats a pizza. But it takes an extra step—and moment—to deduce why he might open the yellow pages of the phone book. We also know that in stories involving conflict, readers attribute competence and noble motives to characters with whom they identify, whereas they attribute negative traits to their adversaries. Moreover, their later recollections often contain distortions that justify these attributions (Bower 1978).

Readers establish a goal list in memory for each character and monitor how story events relate to those goals. Along the way, the character may add a goal, move closer to completing a goal, drop a completed goal, or abandon a frustrated (unachievable) goal. The more independent goals the character is juggling simultaneously, the longer it takes readers to understand the character's actions. We hypothesize that as each action occurs, the reader scans that actor's goal list, taking more time to find one that explains that action. The extra time readers take to sort through a character's multiple goals is shortened if the character's action satisfies several goals simultaneously (Sharkey & Bower 1984, 1987). Studies of goal monitoring and action explanation reveal much about how people comprehend actions in stories as well as in real life.

The Spatial Dimension

An important dimension of the situational model is the spatial location where significant story events take place. This spatial information may include a mental map of the story's places, landmarks, and objects as they are laid out in space, as well as the locations of the characters as they move about. Furthermore, to be coherent, the description of the spatial layout and of the characters' movements should be consistent. If a tower is said to be north of Bill's current location, then he cannot see it by looking to the south. O'Brien & Albrecht (1992) have used detection of such inconsistencies to measure the accessibility of spatial information. A major narrative change in spatial location often flags the start of a new episode, signaling readers that the current model must be updated to incorporate the change. For example, the sentence "Meanwhile, back at the ranch, the outlaws..." signals a location change and a likely change in the current actor(s).

Not every story requires a detailed spatial situation. A sketchy default location often suffices. For example, stories beginning "There was once an old king who lived in a beautiful castle..." rarely provide details about the castle or where in the world it is located because such details may be irrelevant to the character's pursuit of his goals. Readers pay little attention to, and do not encode, detailed setting information unless or until it becomes relevant to the actions of the story. Black & Bower (1982) showed that setting information is best remembered when it causally relates to, or enables, later significant plot actions. For example, an earlier description of a telephone in an office becomes relevant and memorable if the character later has to telephone to report a crime.

Similarly, changes in spatial attributes of the scene do not routinely cause situational shifts unless they are both large and relevant to ongoing actions (Zwaan & van Oostendorp 1993). When spatial location is relevant to ongoing actions, readers carefully track the locations of the main character and critical objects. This point was demonstrated by Sundermeier et al. (2005). They found that objects and spatial locations were kept accessible in a reader's model and were reactivated if the current action or outcome hinged upon that information.

FOCUS AND UPDATING WITHIN SITUATION MODELS

As readers take in successive clauses of a story, they update their current model, making some elements more active in memory even as they drop other entities that had been active previously. This updating process is controlled by what readers deem significant to a story's plot. A convenient way to study this updating of situational models is by observing how readers track the changing locations of the main character. This especially holds true when the location is relevant to the main character's goal and likely actions. The remainder of this chapter summarizes what colleagues and I have found about updating caused by changes in the character's location.

Readers focus on that part of their situational model where a significant change occurs, which implies that they typically focus on the main character, his goal, and movements. This moment-by-moment tracking defines the "here and now" point in the progress of the narrative. Linguists, who call this focal point the deictic center, refer to items in the focus as being foregrounded in the reader's consciousness. Psychologists think of focus as a particularly active portion of the current model in the reader's working memory. Language provides many ways to shift this focus to a new person, place, time, or topic. This is often done explicitly, as in "Later, inside the bank vault, Jack worked furiously to crack the safe." Once mentioned, this new person and place moves to the foreground until another shift is introduced.

In research I started with postdoctoral students Dan Morrow and Steve Greenspan and further advanced with Mike Rinck, we explored the psychological consequences of such shifts of focus. We hypothesized that memory-representations of focused objects are highly activated. If so, they would be readily accessible for answering questions about them. This increased accessibility reflects nonconscious activation of memory-representations of objects near the focus. As one implication, Morrow (1985) found that items near the current focus (i.e., the current actor in a story) are likely to be selected as the referent for ambiguous pronouns. Consider, for example, the sentence "John walked past the car and up to the house; its windows were dirty." Most people assume that the house, not the car, had dirty windows because the narrative locates John near the house now.

Paradigm for Studying Spatial Priming

To study the role of focus in updating, we familiarized our college student with a map or floor plan of the spatial layout of a building to which later experimental stories would refer (Morrow et al. 1987). The memorized map would serve as the long-term memory base for the later stories. Across different experiments, we varied the floor plan as well as the stories and test items to measure the influence of several variables on the accessibility of different objects in the situational model. **Figure 1** shows an example map used in some of our experiments.

Our standard experiments had college students memorize a map and then read 10 to 20 brief stories that were each about 20 lines long. Each story introduced a new character whose goal required him or her to move around the previously mapped building. These stories described the characters' thoughts, plans, and actions as they moved between rooms. For example, in one story a research lab manager, Wilbur, is assigned the goal of cleaning up lab rooms for an upcoming inspection by the Board of Directors. In another story, a security officer named Jack has to search throughout the building for a burglar who reportedly broke into the building. Participants read the stories at a computer terminal, presenting them line-by-line at their own pace, and their reading times per sentence were recorded.

The focus hypothesis directs interest to the movement sentences, such as "Wilbur walked from the Reception Room into the Library." Following linguists' conventions, the place the character just left is called the Source room and the place he just entered is called the Goal (or Current Location) room. As characters moved about, we measured how quickly

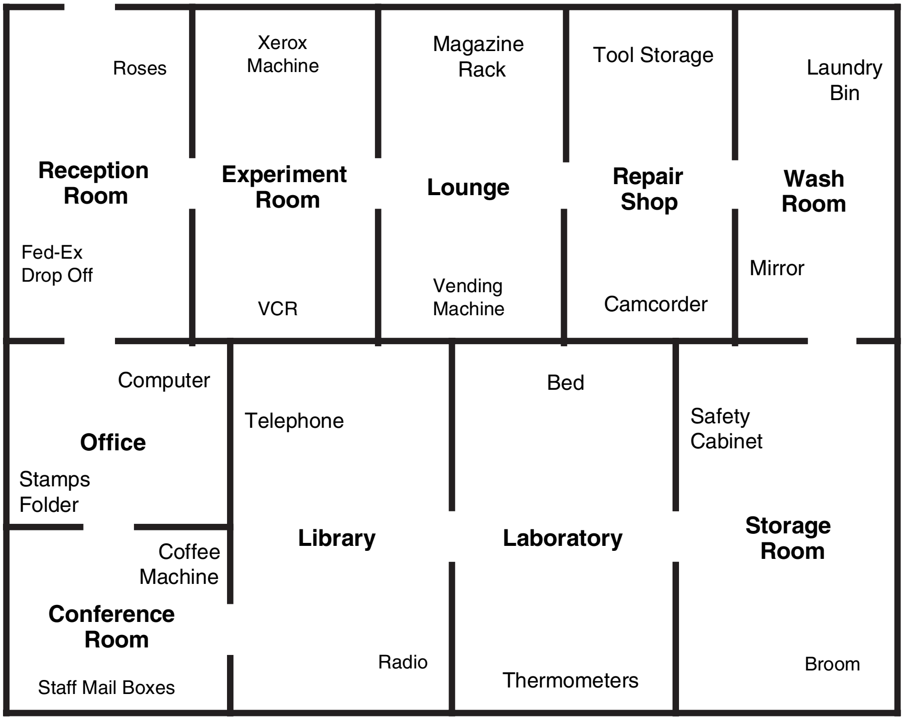

Figure 1

Example of a building layout studied by participants in our experiments. The number and location of objects as well as the room layouts were varied across different experiments.

subjects remembered from memory places and objects that were temporally or spatially near their focus of attention. To this end, after self-paced reading of a movement sentence, readers were occasionally interrupted and given a probe test. The probes required subjects to quickly answer either a yes/no question about the location of an object or whether or not two objects were located in the same room. The correct answer to a random half of the questions was "yes," while "no" was the correct answer to the rest. Our interest centered on the "yes" probes. To increase observation samples, each story contained three or four such interruptions. To ensure that readers consistently tracked the current location of the main character, occasional questions tested subjects' knowledge of his or her current location. After indicating their decision (with a yes or no key press), subjects continued reading the story until the next interruption or the end of the story. To encourage good comprehension, each story concluded with two or three yes/no questions about it. We rewarded subjects for accuracy; those who were too inaccurate on the questions were replaced.

The following sections summarize what we have learned by considering spatial priming as a window on readers' updating of their situation model (for other reviews, see Bower & Morrow 1990, Bower & Rinck 1999, Rinck & Bower 2003).

The Basic Distance-Effect

We hypothesized that memory activation would be greatest for objects in the location currently in focus (where the protagonist is now) with activation diminishing the further the object was from the focus. We found this distance-effect in our first experiments, in which subjects learned the floor plans of two buildings: a lab and a storage barn (Morrow et al. 1987, 1989). Probe tests given after a movement sentence clocked the fastest retrieval speeds for the current Location room, followed by the Source room, and then by more distant Other rooms in the building the current story was about. The slowest retrieval speeds involved probe tests about objects from the other building not mentioned in the current story. The Other room was presumably faster than objects from the other building because it had been activated by mention of the current building and sometimes by the character having been there earlier during his tour of the building. Objects in the room farther along the path in the direction just ahead of the character's current location had a level of activation (retrieval speed) that fell between that of the Source room and the Other room.

Our initial experiments also ruled out two extraneous factors: (*a*) The same distance effect arose regardless of whether the movement sentence mentioned the Source room before or after the Location room; and (*b*) an incidental mention of a room that the character does not enter or think about results in negligible activation. An example might be, "Wilbur went into his office to review the messages that had been sent over earlier from the reception room." Such a sentence activates objects in the office but not in the reception room.

Major Versus Minor Characters

If the main character recruits a minor character to help achieve his goal, readers continue to focus more attention on the major character. In tests for this effect, the narratives included several critical sentences that described the movements of the two characters. A story might relate that Wilbur (major character) went into room A, while John (minor) went into room B, or it might reverse the order of the two clauses. A test probe followed such sentences, naming the major or minor character plus an object from the building. Subjects had to decide whether the probed character was in the same room as the object. We found that questions about the major character were answered more quickly than were those about the minor character. This suggested that readers could split their attention between both characters, but the main character continued to command more of their attention.

Intermediate Locations

We found that intermediate landmarks along an implied path were activated somewhat by the character passing through their room. Critical motion sentences in this experiment took such forms as, "Wilbur walked from room A into room C." In this case, the memorized map made clear to the reader that Wilbur would have to pass through an intermediate room, B, when walking from room A to C. We found that retrieval speeds were fastest for items in the Goal room, C; next fastest for those in the intermediate (Path) room, B; next for objects in the Source room, A; and slowest for objects in some Other, more distant room that had not been activated by the sentence just read. We presume that this gradient arises because readers mentally simulate the character's imagined movement as he passed—and briefly activated—objects in the implied Path room. This Path room activation immediately begins to decay as soon as the character enters the Goal room. Significantly, the implied Path room caused greater activation than the explicitly mentioned Source room. I present a theory below that accounts for this intermediate-path effect.

Mental Location

We have also found that the most activated location is the place that the character is currently thinking about, which is not necessarily where he is currently located. After a movement sentence, the critical sentence described the character thinking about an activity in another room, e.g., remembering that he had to paint its walls or sand its floors. Test probes showed that readers accessed unmentioned objects in the thought-about room more quickly than those in the current location room. In fact, when the character's thoughts were elsewhere, subjects' access to objects in the Location room was only slightly faster than to objects from some distant Other room. Apparently, readers track the thoughts of the character more than his physical location.

This mental-location advantage would probably be reversed if readers know that the character's physical location at the moment is more important than his present thought-location, for example, if he is sitting on a ticking time bomb about to explode as he is thinking about another place. The underlying principle in such examples is that readers focus on places where they expect significant events to occur that will either advance or foil the protagonist's goals. Here again, fate of the character's goal is a major determinant of what readers identify as the crux of a story.

Objects Accompanying the Main Character

Consistent with these distance effects, Glenberg et al. (1987) showed that mentioned objects carried by the main character as he moves around are relatively accessible for as long as this character is in focus. Their vignettes introduced a character and mentioned an object that he either took with him on a walk or left behind. They found that after an intervening sentence or two, the object the character carried with him was more accessible for recognition memory and for pronoun resolution than was the object left behind.

Spatial Perspective Within the Situation

The situation model of readers mirrors the main character's perspective. Consequently, readers answer questions best from the character's vantage point. DeVega (1994) had subjects memorize locations of four buildings, such as around a town square. They then read vignettes about a main character walking through the square in a specific direction. The vignettes then introduce a second character who is walking in the same direction as the first character or in the opposite direction (that is, they are approaching one another). Probe questions then asked readers to quickly identify where a landmark was (ahead, behind, left, right) relative to one of the characters. Responses were slower for left-right rather than for ahead-behind judgments, slower for questions about the character not currently in focus, and much slower when the orientations of the two characters were opposite rather than congruent. This research indicated that readers construct and view their situation model from a particular perspective and orientation (see also Taylor & Tversky 1996).

Distance Effects in Anaphor Resolution

A criticism of the map-then-story procedure is that it overemphasizes spatial information (learning the map and then answering spatial questions), a process that might prompt subjects to read unnaturally. Perhaps readers do not normally pay so much attention to spatial information (Zwaan & van Oostendorp 1993). In response, Mike Rinck and I (Rinck & Bower 1995) conducted experiments that assessed focus effects without using any interrupting location probes. Instead, we simply measured the time subjects took to read a target sentence that contained an anaphor (such definite noun phrases as "the telephone") that referred to an object in one of the rooms of a building. Having just moved from a Source into a Goal room, the character thought about (or remembered, planned, envisioned, etc.) doing something with a critical object in another room, e.g., "Wilbur remembered that he should check the VCR in the experiment room." We found that the further the object (in this case, the VCR) was from the focus on the character's location, the longer it took subjects merely to read the anaphor sentence. Moreover, the reading time per syllable was quickened when the anaphor sentence specifically mentioned the room where the critical object was located (in the just-cited example, the target sentence reminds readers that the VCR is in the experiment room). The extra room cue presumably saves subjects the time that they otherwise would expend retrieving which room contains the object in question. This is a familiar result in memory retrieval: Two converging cues elicit a satisfactory answer more readily than either cue alone. The important result is that subjects reading "naturally" are showing the distance-from-focus effect even though they are not being interrupted to answer location questions.

Interference in Resolving Ambiguous Anaphors

If anaphor resolution involves memory retrieval, then it should be slowed by associative interference. If, for example, "the table" could refer to any one of several tables scattered throughout several rooms in the building, readers should read it faster if they are told the room-location of the mentioned table. Otherwise, readers are left in limbo, awaiting information that is more specific. In our experiment, subjects memorized a map that contained one, three, or five different example objects such as tables, chairs, and computers, distributed throughout different rooms in a building (Bower & Rinck 2001). Next, they read stories that moved the character into a specific room (e.g., the Reception room), and then they read critical sentences such as "Sally remembers having had her lecture notes while she was standing *at the table in the library*." The alternate rendering reversed the final noun phrases, e.g., while she was standing "in the library at the table." Precise measurements of the time subjects took to read the critical anaphor (i.e., the table) were obtained by having subjects press the space bar to read each successive word on the computer screen. This method, known as "rapid serial visual presentation," is often used in reading research.

As predicted, subjects took more time to read the ambiguous anaphor (the table) when it preceded (rather than followed) the specific room name in the sentence. Subjects also took longer to read the anaphor when there were more examples of the mentioned category (e.g., tables) in different rooms. The time they took to read the room name reflected the usual distance-from-focus effect. In contrast, the increased reading time associated with increasing the number of instances of the object anaphor (from one to three to five tables) was considerably offset when the room name preceded the anaphor. In these cases, the room name clearly flags which table is being discussed, thereby reducing competing claims on memory retrieval. These results confirm the earlier finding that "natural" readers who are not interrupted by location questions nonetheless show the distance-from-focus effect. They also show how interference slows anaphor resolution. In addition, the results support the "immediacy" assumption (Just & Carpenter 1992), which posits that readers immediately attempt to identify the referent for each anaphor as they encounter it in a sentence.

What's the Distance Metric?

We wondered if the distance-from-focus effect should be measured by a Euclidean metric (in a straight line as the crow flies) or by route distance: the number of rooms or spatial segments separating the focus from the mentioned object. In experiments by Rinck et al. (1997), these two types of distance were varied independently. The memorized maps allowed the stories and test-probes to put either a long or a short metric distance between the current focus and the referent object. Additionally, this distance either was divided into two rooms or was left as an undivided room. Following a movement across this distance, the character thought about an object along the path. This object was either metrically near or far from the focus room, and that distance either was divided into two rooms or was not. The dependent variables were the time subjects took to read the movement sentence itself and the "think about" object-anaphor sentence.

The experiment produced several clear results. Overall, the primary determinant of reading time was the route (room) distance, and not the Euclidean metric distance. Subjects took longer to read the movement sentence when its path traversed two rooms rather than one, whereas room length had no effect on reading time. Also, the reading time for the anaphor in the thought-about object sentence increased dramatically when the path was divided into two rooms compared to one. Here again, the metric length of this room (or rooms) was immaterial. Readers' references to an object on the other side of a shared wall (a minimal metric distance), for example, required no more reading time than references to an object on the other side of the building (a long metric distance). Although room segments had a major impact on reading, metric distances had no measurable impact.

What is odd about this finding is that we know that subjects had recorded metric information in memory. When asked to draw maps from memory of the rooms and their objects, they do a reasonably good job of reproducing relative locations and distances. Yet, in our reading task, they skipped from one landmark to another without regard for metric distances. Why? A plausible answer is that they do not need to keep metric information active while reading since they are never asked questions about it, so it remains inactive. I presumed that if subjects were required to pay attention to metric distances in order to answer relevant questions (i.e., "Is object A or B metrically closer to the character now?"), then their reaction times would show metric distance effects, e.g., two objects close to the focus would lead to faster decisions than two objects far from the focus. This leaves open the question of whether such metric influences would then appear in readers' anaphor look-up times.

Learning a Spatial Layout from a Verbal Description

Spatial distance effects do not depend upon learning layouts from a map. Similar distance effects occur when subjects learn spatial arrangements of rooms and objects from detailed verbal descriptions. Relying exclusively on verbal descriptions, our subjects memorized a rectangular preschool with five rooms (Rinck et al. 1996). Each room had two doors leading to adjacent rooms and a third door opening into a common inner courtyard. The rooms contained common school objects and each room was named for the teacher (e.g., Ms. Hill's room). The verbal descriptions also located the rooms relative to the outer shell of the building. Subjects were not allowed to physically draw maps of the building (although most undoubtedly constructed mental images of its presumed layout).

Compared to our earlier physical map learners, those relying just on verbal descriptions took far longer to memorize the spatial layout. They also later read the stories slightly slower. Nonetheless, during the standard story reading following map learning, the distance gradient for the retrieval of probed objects remained orderly and significant across both groups. Regardless of whether subjects had learned from physical maps or verbal descriptions, their retrieval speeds were fastest for objects in the Goal room, followed by those in the Path room, then those in the Source room, and finally were slowest for objects found in some Other room.

Whether or not memory for the spatial array is identical for map learners and verbal-description learners, we note that the distance effects in both cases appear to reflect the connectivity structures among rooms that both types of subjects memorized. Similarly, Taylor & Tversky (1992) found that subjects who studied maps and those receiving verbal descriptions of maps performed comparably on tests of spatial knowledge.

Using Prelearned Spatial Arrays

To insure homogeneity of spatial knowledge, subjects in the foregoing experiments memorized a map of a unique space in which the story events take place. Some evidence suggests that a distance effect occurs when the stories refer to a spatial layout that is already familiar to subjects before they show up to participate in the experiment. In pilot work, my student, Saskia Trail, found a small but significant distance effect for subjects who read many stories about characters driving long distances between major United States cities, pursuing a goal such as delivering furniture or selling encyclopedias to libraries. The critical sentences had the character drive from one city to another (e.g., San Diego to Miami). In the destination city, he would think about some activity (e.g., spending his bonus pay) in the current Location city (Miami), the Source city (San Diego), or a city along the just-completed driving Path (e.g., New Orleans).

Trail measured how quickly subjects, who were never shown a map, read those critical "thinking" sentences depending on which city the character was thinking about. These anaphor reading times showed the usual distance gradient, with reading time for Path cities being intermediate between the times for the shorter Goal city and the longer Source city. In an unforeseen complication to her experiment, Trail found that her college subjects' pre-existent map knowledge often was fuzzy and imprecise. Morrow et al. (2004) did a more substantial follow-up study that found that senior citizens showed a more robust "city-distance" effect in anaphor reading times than did young people. The authors suggested that the weaker effect for younger subjects might have resulted from their poorer knowledge of geographic locations of the cities in the stories.

Clearly, more research is needed regarding distance effects with familiar arrays. One logistical challenge is identifying highly familiar spatial arrays (such as floor plans, towns, or campuses) for a large sample of subjects and then writing stories about characters moving around in those spaces. Trail and I tried using our own university campus as the known spatial array. But we abandoned this approach after discovering surprisingly large variation in students' knowledge of different campus spots (such as dorms, lecture halls, and eateries).

Elapsed Story Time

Once a character leaves one place and enters another, distinct space, we hypothesize that activation on the initial place decays as its relevance to the character recedes into the past. This decay process turns out to be determined by the lapse of time spelled out in the story, not the real time that passes as subjects read intervening sentences before they hit an anaphor referring back to the original location.

Rinck et al. (2000) investigated this question in experiments that built on the work of Rolf Zwann (1996). Our movement sentences moved the story character from a Source room through a Path room into a Goal room. Significantly, he carries out an activity in the Goal room that alternately is described as taking either a short time (e.g., two minutes) or a long time (e.g., two hours). In addition, we varied the number of intervening sentences separating the movement event from the elapsed story-time statement, following which we presented the probe test. The probe measured the accessibility of an object in the Path room. For example, Wilbur walks from room A (through room B) into room C, where he notices that room C needs to be cleaned up. This action was followed by zero or five sentences elaborating on the activity in room C before the critical time-lapse sentence stated that Wilbur took either two minutes or two hours to clean up room C. We probe-tested the subject, asking about an object in either Path room B or Goal room C. If elapsed story time is critical for deactivation of earlier entities, then objects in the Path room will have notably less activation after a stated two-hour cleanup than a cleanup said to take just two minutes.

The results in this experiment were striking: The elapsed story time caused a large and consistent slowing of object retrieval time, whereas actual elapsed reading time (determined by the zero versus five intervening sentences) had virtually no effect. Retrieval times for objects in the just-left room were markedly slower following elapsed hours than elapsed minutes. This occurred even though subjects took no longer to read the elapsed-hours statements than the elapsed-minutes statements. Apparently, readers of the longer (hours) verb-modifier deactivated Path-room objects significantly more than did readers of the shorter (minutes) verb modifier. This inhibition occurs very quickly given that the test probe immediately followed the subject's self-paced reading of the elapsed time sentence. Such rapid suppression of activation has been a premise of several language-processing theories (Gernsbacher 1990).

Although we found little effect resulting from our manipulation of the number of intervening sentences, the maximum number we tested was only five sentences. We would expect a larger effect if this cap was pumped up to hundreds of intervening sentences before the test probe. However, this would introduce logistical and conceptual problems. Namely, it is difficult to interject so many intervening sentences without introducing new topics, subgoals, and episodes. These changes would shift the situation away from the one that immediately follows the critical movement sentence. This shift, in and of itself, likely would deaden accessibility related to the prior Path room.

Priming by a Momentary Active Goal

Earlier we found that activation tracks the place that the character is thinking about as he plans to do something there. Readers can predict what is on a character's mind by knowing his active goal (wish, desire, plan). Thus, if they read that the character is hungry, then food items and their associated places in the building should be activated in the readers' mind.

In our goal-activation experiments (Rinck & Bower 1999, 2003), each story tested several goal-related probes by introducing a momentary, minor goal that temporarily interrupts the character's overarching main goal. For example, Wilbur's main goal in one story was to clean up all the rooms in the research building before tomorrow's inspection by the board of directors. During this lengthy chore, however, he has the apparently spontaneous thought that he also needs to make copies of a handout for his speech to the directors the next day. Once Wilbur addresses this momentary copying goal and we have probed the accessibility of some related object, the narrative returns Wilbur to his chief goal: cleaning up the building.

At each critical point in the text, we introduced either of two momentary goals (such as to make photocopies or to videotape his practice speech), followed by a probe referring to a goal-object probe that was either in the current Location room or in the prior Source room. We created four experimental conditions: The goal-object probe in the Location or Source room was either relevant to the temporary goal (for example, the Xerox machine is relevant to the copying goal) or it was irrelevant because the object probe did not relate to the temporary goal (for example, although Wilbur wanted to videotape, the probe tested the location of the Xerox machine).

This experiment revealed major effects of spatial distance and goal relevance on memory-retrieval times. As expected, Location-room probes always were answered more quickly than Source-room probes. Independently, probes of goal-relevant objects were always answered more quickly than probes of goal-irrelevant objects. Significantly, these two factors did not interact: The speed-up advantage of goal-relevant over goal-irrelevant probes was about the same for objects in the Location room as for those in the Source room.

Priming by Active, Completed, or Postponed Goals

The accessibility of goals and their relevant objects vary throughout a story, reflecting their evolving status with the protagonist. Earlier research has shown that a character's active, uncompleted goals remain more accessible than completed goals (Dopkins et al. 1993, Lutz & Radvansky 1997, Suh & Trabasso 1993). Presumably, a protagonist's uncompleted goals are kept active in the reader's working memory, as opposed to completed goals, which fall victim either to passive decay or by inhibition. Readers expect that completed goals will no longer motivate the character and, therefore, will no longer be needed to explain the character's later actions.

Our experiments compared active and completed goals to a third type of goal, namely, those that the character briefly considers, but then postpones or abandons. Our postponement-narratives had the character set aside the briefly considered goal due to his pressing need to finish the overarching goal. We tested whether a mentioned but then postponed goal retains any more activation than a completed goal. We modified the texts and test probes of previous "goal" experiments to include the postponed goal condition along with the active and completed goal conditions. After introducing a momentary interrupting goal, the narrative then described it as either active, completed, or postponed—that is, considered briefly but rejected. Immediately thereafter, the probe-object test was presented. All probe objects were goal relevant and located in either the current Location room or the preceding Source room.

The results showed strong main effects of goal status as well as spatial distance to the goal object. Specifically, subjects always retrieved objects relevant to the active goal fastest and always retrieved those related to the postponed goal the slowest. Retrieval time for the completed goal-object varied with its spatial location: Subjects retrieved a completed goal-object as quickly as an active goal-object when it was in the current Location room where the character had just used it. However, retrieval time for the completed goal-object slowed to that of an object related to a postponed goal when the completed goal was in the just-preceding Source room. To clarify this result, a second experiment varied the number of sentences (zero or three) between the goal-status sentence and presentation of the probe test. The intervening three sentences described the character's return to his overarching goal. In this experiment, we replicated the previous results for active and postponed goals; furthermore, we found that the completed-goal condition yielded fast retrieval when no sentences intervened before the test probe, but much slower retrieval after three intervening sentences.

The results suggest that readers may process postponed versus completed goals differently. The sudden drop in accessibility of postponed-goal objects suggests that readers actively inhibit postponed goals and related objects. In contrast, the decrease in accessibility of completed-goal objects probably reflects a gradual decay of activation (from zero to three intervening sentences).

A NETWORK EXPLANATION OF FINDINGS

Activating Associative Networks in Long-term Memory

I will invoke a familiar conceptual framework to summarize our findings. First, consider the long-term memory structure that our subjects might use to represent the maps of the experimental buildings. Following longstanding conventions in AI (Anderson 1978, Kosslyn 1980, Pylyshyn 1973), the memorized map may be represented as a hierarchical tree structure containing units or nodes (denoting objects, rooms, buildings) with labeled links or associations (containment of objects in rooms, paths between rooms, geometric relationships, etc.). The upper part of **Figure 2**, labeled "Long-Term Memory,"

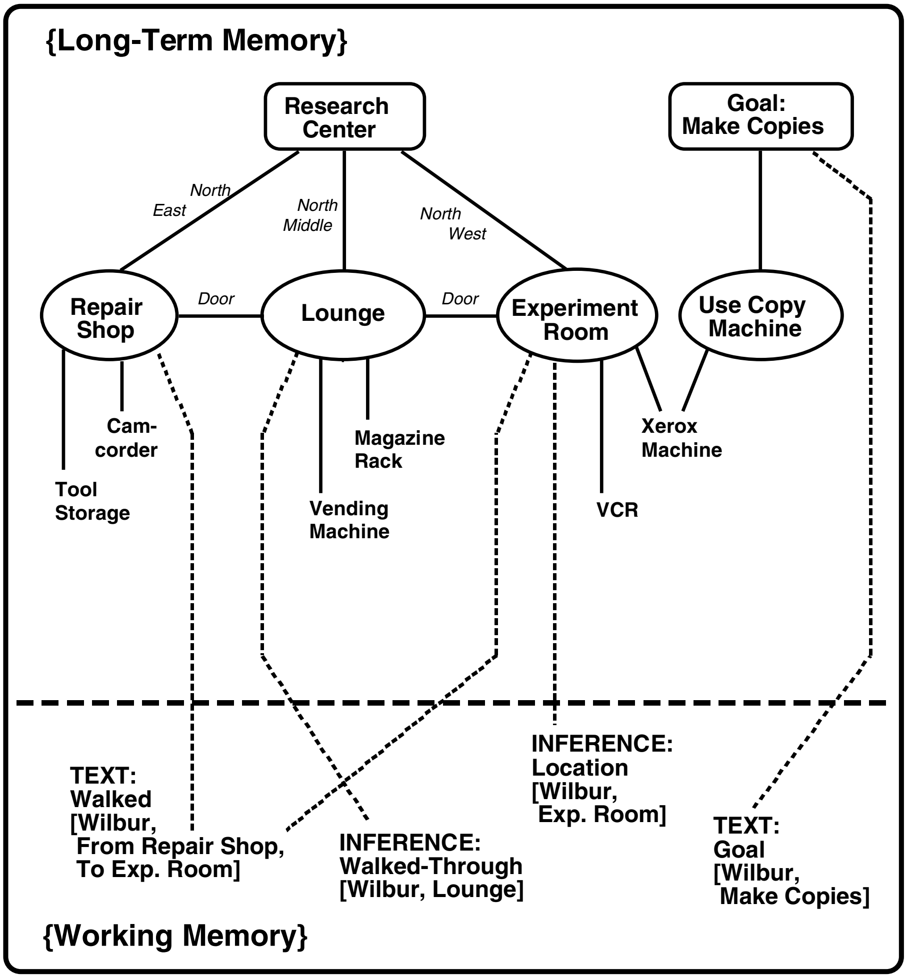

Figure 2

An associative network in long-term memory encoding knowledge of the building's spatial layout. Conceptual units (nodes) denote rooms and objects, and links denote spatial relationships and connections. Working memory (lower part) contains the "Here-Now" focus on the current location, the currently active sentence, and a spatial inference from it. The unit representing the goal of making photocopies is also shown in the right side of the figure. Reproduced with permission from Rinck & Bower 2003, Figure 8.

depicts part of such a hypothetical spatial encoding of several rooms, with each room containing several objects. The rooms also have various access relations and locations relative to one another (Bower & Rinck 1999). The bottom part of **Figure 2**, labeled "Working Memory," holds the most recent sentence the subject has read and parsed into basic propositions (such as "Wilbur walked from the Repair Shop into the Experiment Room"). The theory supposes that the concepts mentioned in this sentence are temporarily linked to their corresponding referents in long-term memory. This is depicted by dashed lines connecting the working-memory concepts to their corresponding units in the hierarchy. These linkages pass activation from working memory to the units in the long-term memory structure. An example would be to activate the proposition that the camcorder is in the repair shop. Below I discuss the goal-plan features on the right side of **Figure 2**.

In this scheme, the focus of attention (or foregrounded concepts) zeroes in on currently active concepts in working memory and their counterparts in long-term memory. It also is the narrative's here-and-now point. As the narrative flows, the concepts that are active evolve and change, as does the Here-and-Now pointer. In this network model, questions about object locations require the processor to activate and retrieve propositions from long-term memory, for example, "The Experiment Room contains the Xerox machine" (Collins & Loftus 1975). Because such concepts have received spreading activation from the preceding movement sentences, they have a head-start advantage relative to entities more distant in the network, so the network can more readily retrieve them and answer questions about them. The farther is the queried room from the focus in the network, the weaker the spread of activation and the slower the time to retrieve information to answer questions. This property yields the basic categorical ("room") distance gradient independently of the Euclidian metric distance.

These object-concepts now in the spotlight (speaking metaphorically) are more accessible for answering related questions than are objects lying outside the spotlight. The distance-from-focus gradient suggests two possible metaphors. One features a fuzzy spotlight that scatters light in a gradient around its center. The more peripheral an object is to the center, the dimmer is its lighting, so the more time required for checking and verifying an answer. An alternative metaphor invokes a sharply defined spotlight that must be swung from its current location to focus on a probed object. The time for the spotlight to traverse the path in the model would be presumed to reflect greater distances. Both metaphors correspond to plausible models of attention focus.

Explaining the Intermediate-Room Effect

To illustrate the workings of the spatial network model in **Figure 2**, consider how it explains two of our results. Consider first the intermediate-room result of an earlier experiment. We assume that the character's movement from room A (**Figure 2**, Repair Shop) to C (**Figure 2**, Experiment Room) invokes a conscious or unconscious inference (via the network linkages) that the character passed through room B (**Figure 2**, Lounge). This inference is reflected in the proposition "Wilbur walked through the Lounge," which **Figure 2** shows as now active in working memory. This inference activates the Lounge room concept in memory, so that questions about its objects are answered more readily than objects in other, more distant rooms. Likewise, once the story moves on to other rooms and topics, the activations of previously visited rooms decay back to the baseline, losing their temporary accessibility boost. As they read, subjects create a dynamic wave of activation spreading across their network memory structure. This wave's surge creates peaks and valleys of activation (and accessibility) that sweeps across the concept units that track the character's current location, thoughts, and goals (see also van Den Broek et al. 1998).

Explaining the Goal-Relevance Effect

As a second example, the effects of goal relevance on accessibility can be explained by the associative network outlined in **Figure 2**. We begin with the plausible assumption that readers track the character's active goals, retaining them in working memory. Each familiar goal is associated with plan structures in long-term memory that guide inferences about instrumental objects typically used in those plans. For instance, educated readers know that copy machines make photocopies, camcorders make videotapes, and so on. Likely goal-related links between the "Make photocopies" plan units are depicted in the upper right side of **Figure 2**.

When a goal is active in working memory, it presumably activates its corresponding goal-plan structure in long-term memory, which, in turn, activates associated instruments—such as the copy machine in the preceding example. The activation of the goal-relevant object enhances the activation coming from the room location unit that has also just been activated by its concept in working memory. We therefore expect reaction time to be further reduced by the combined relevance of the goal and location of focus. Moreover, activation caused by these goal-based instrumental inferences should be kept aroused as long as the current goal is active. Yet, this elevated activation on this goal should decay once this goal is completed and the character moves on to another goal and, perhaps, another location. On the other hand, if the goal is abandoned or postponed, then the goal activation is quickly and actively inhibited, much as Gernsbacher (1990) suggested.

In conclusion, this network model—combined with some auxiliary assumptions about automatic inferences, goal activation, and decay—readily accounts for the bulk of our experimental findings about memory access during narrative comprehension. More specifically, it appears to help explain focus effects in spatial priming within situation models.

SUMMARY AND CONCLUDING COMMENT

To summarize, I have argued that one goal of reading research should be an understanding of how people process narratives and construct situation models from them. A major factor in updating a situation model is how the text guides the reader's momentary focus of attention. The last part of this chapter has reviewed many results on how narrative focus changes or "primes" the accessibility of entities in the situation model. This priming was examined using both subjects' times to read an anaphor referring to an object and to answer explicit questions about its location.

The primary findings indicate that narrative focus enhances accessibility of nearby objects in the model. The effect during reading appears determined not by Euclidean distance but by route distance from the focus. Readers' focus follows the major character and tracks his location, goals, and thoughts. Readers' retrieval of an anaphoric reference to an object is slowed by their momentary uncertainty (e.g., which of several instances of a category is being referred to). The enhanced accessibility of the current place or goal fades as the character, and hence the focus, moves on to other places and topics. This fading is quickened when the text states that a long time has elapsed in the story.

Readers construct their situation models from a given perspective and orientation; questions about object locations are most readily answered from that perspective. The distance-from-focus effect arises when the spatial layout is learned from a verbal description as well as from a map. Some evidence suggests that distance effects also arise for narrative questions about familiar maps not studied in the experiment.

Explicit mention of a character's goal increases the accessibility of objects relevant to that goal. This accessibility is highest when a goal is being actively pursued, it fades soon after a goal is achieved, and is absent if a considered goal is abandoned. I proposed an associative network model with retrieval determined by spreading activation as a way of summarizing some of the major findings.

The research described in this review is a selected sample of topics my collaborators and I have investigated throughout my career. I have had a stellar collection of graduate and postgraduate students and colleagues who have contributed their ideas and experimental labors to this research. Many of them have gone on to illustrious research careers. I consider them my lasting legacy to cognitive psychology, outweighing by far the findings summarized here.

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Errata

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