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Verbal and spatial processing in transitive inference: Effects of problem complexity and ambiguity

Huffman, Charles Jacob, Ph.D.

The University of North Carolina at Greensboro, 1994

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VERBAL AND SPATIAL PROCESSING IN TRANSITIVE INFERENCE: EFFECTS OF PROBLEM COMPLEXITY AND AMBIGUITY

by

Charles J. Huffman

A Dissertation Submitted to the Faculty
of the Graduate School at
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Recent theorizing concerning factors that affect cognitive processing during problem solving activity has postulated that simple or unambiguous versions of a problem task evoke more verbal than spatial processing, but as the task becomes more complex or ambiguous, spatial processing is used more than verbal processing. This project tested these assumptions by employing a problem task that is potentially solvable using either verbal or spatial processing: transitive inference, or the three-term series task (e.g., John is taller than Fred, Bill is taller than John; is Bill taller than Fred?). Problem complexity and ambiguity were manipulated in separate experiments, and the use of verbal and spatial processing was detected by interfering with each process selectively during the problem solving task. The project also examined the interaction of these manipulations with gender and individual differences.

The findings indicated that making problems more complex resulted in a greater amount of spatial relative to verbal processing, as indexed by the amount of time taken to solve the problems. Solution accuracy was not similarly affected by this manipulation, however. Manipulating problem ambiguity did not produce a reliable pattern of effects on the relative use of verbal and spatial

processing. Individual differences in preference for verbal or spatial thinking did not affect results, and the influence of gender differences on the results was inconsistent. Previous theoretical assumptions in this area were partially supported, but more work is needed to clarify our understanding of the various influences on cognitive processes during problem solving.

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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CHAPTER I

INTRODUCTION

During problem solving activity, people often report talking to themselves, going over the elements of the problem "in their heads." For example, faced with the perennial problem of quickly assembling a child's toy late on Christmas Eve, a parent might covertly verbalize and manipulate the information given in the instructions ("corners A and D both will fit into slot C so I can do that first, and then..."). Another strategy often reported is that of spatially arranging the elements of the problem "in their mind's eye." The would-be Santa thus might form a mental image of corners A and D fitting into slot C before making a decision about which parts to assemble first in order to finish the job quickly.

Although other cognitive processes, such as long-term memory, are certainly used in problem solving, these two strategies or "modes" of cognitive processing concern "on-line" working memory functioning (Baddeley, 1986, 1992). Working memory is conceptualized as being comprised of two "slave" systems: a verbal, language-based system, and a nonverbal, imaginal or spatial system, which are coordinated by a central executive component. Although it is possible that neither of the two slave systems is actually "responsible" for the decision regarding solution during the problem solving process (see Logie & Marchetti, 1991, for an explanation of the central executive's role in decision making), it is reasonable to assume that the two systems provide input for problem solution in most situations. These two processing modes are potentially of vital importance to problem solving tasks that involve consciously manipulating and maintaining information temporarily in order to facilitate reaching a solution (Frandsen & Holder, 1969).

In trying to understand problem solving, the question arises of why people report using one processing mode more than the other in certain situations. What influences when one mode or the other is predominant? The focus of this inquiry is on what factors affect the relative amount of input the two systems provide for problem solution. Relatively little is known concerning the identification of these variables. Determining what variables affect the use of verbal or imaginal solution strategies will increase our understanding of working memory systems in problem solving, a research endeavor which has only recently begun (Gilhooly, Logie, Wetherick, & Wynn, 1993). In addition, research on these variables has the potential to increase our overall understanding of the conscious, ongoing operation of the human mind.

Many variables have the potential to affect the relative use (and usefulness) of verbal and imaginal processing strategies in solving problems. The most obvious is the type of problem itself. Some problems, such as deciphering a code in which one word stands for another, lend themselves more to a verbal strategy. Other problems, such as determining mentally if all of your luggage will fit into the trunk of the car, lend themselves more to imaginal/spatial strategies. Most problems probably fall in between these two extremes, however, and draw on a mixture of verbal and imaginal processing. Clearly, the type of problem has the potential to affect the relative use of verbal and imaginal solution strategies. The effects of other aspects of the problem situation, such as how complicated or unclear the problem is to the solver, or how often the solver has encountered that type of problem, are theoretically more interesting.

Elucidation of the variables affecting the mode of cognitive processing used in problem solving is still in the early stages. Recently, these variables have begun to be explored in a model postulated by Geir Kaufmann (1980, 1984, 1985, 1988, 1990). Kaufmann's model assumes that imaginal/spatial processes are used "more" when a problem solving task has a low <u>degree of programming</u>, whereas verbal/linguistic processes are used more when a problem is more highly programmed. Degree of programming refers to how well-structured the problem is, or the extent to which the solver has a definite procedure to follow for the solution (Simon, 1977). When the problem has a high degree of programming, it is well structured and there is a definite, algorithmic procedure to solve it. When the problem has a low degree of programming, it cannot easily be solved with a definite, predetermined procedure and so requires a more flexible approach. According to Kaufmann's model, this degree of programming is affected by the complexity, ambiguity, and familiarity of the problem. Highly programmed problems tend to be relatively simple, unambiguous, or familiar to the solver, whereas problems with lesser degrees of programming are likely to be relatively complex, ambiguous, or unfamiliar to the solver.

The rationale for Kaufmann's assumption that imaginal processing (imagery) is used more than verbal processing (language) for problems with a low degree of programming, whereas verbal processing plays a larger role than imaginal processing for highly programmed problems, is based on functional differences between the two processing modes. Visual mental imagery is perceptual, specific to the visual modality, and holistic in nature (Finke, 1980, 1989). It is thus well suited for simultaneously representing multiple elements of information pertinent to the problem task (Paivio, 1971, 1986). Language is more abstract and less perceptual than imagery in its form of symbolic representation, usually linked to the auditory modality, and sequential/temporal in nature (Kaufmann, 1990; Paivio, 1986). It is thus well suited for describing explicit, precise relationships between elements of the problem in an orderly sequence (Kaufmann, 1990).

Imagery may be particularly useful for some problem situations by providing a holistic mental representation of the desired "goal state" of the problem, as well as the initial state. This analog representation could then facilitate the discovery of a solution that will lead from the initial state to that anticipated goal state. This way of mentally representing the problem might prove to be useful and even necessary in a situation in which the problem is complex, ambiguous, or unfamiliar (i.e., low degree of programming). On the other hand, language is sequential, abstract, and precise at describing the problem situation, and thus might be more efficient with problems that are familiar, simple, or unambiguous to the solver (i.e., high degree of programming).

For example, if the would-be Santa had never tried putting toys together before, or if the task seemed very complex or the instructions vague and unclear, then forming a mental image of the completed toy might reveal a way to derive a solution, perhaps by working backwards from the imaged goal state. However, if the would-be Santa had performed this particular task many times before, or if it was very simple or unambiguous, then it is more likely that the steps in the solution process could easily be converted into precise, orderly verbal descriptions of relationships that could be processed quickly and efficiently, and the use of mental imagery would not be necessary. Although imagery is holistic and language is sequential, it is probable, according to Kaufmann (1980), that using imagery to solve a problem is slower than using language, because of the need to scan the image or generate multiple images searching for a clue to the solution. Therefore, when the degree of programming is high, verbal processing is quicker and more efficient than imaginal processing. When the degree of programming is low, however, imaginal processing is needed to solve the problem.

Kaufmann's model has not been fleshed out or tested rigorously, and leaves some important parameters undefined. For example, the model states that particular cognitive processes are used more under certain conditions, but it is not clear whether "more" means more prevalent or more efficient use of that process, or both. Furthermore, the two types of processing, verbal and imaginal, have not been systematically compared while manipulating all of the three variables (complexity, ambiguity, and familiarity) postulated to affect the degree of problem programming.

It is also not explicit in the model whether these variables have an effect <u>between</u> problem tasks or <u>within</u> the task. For example, it appears that the model's predictions would be weakened in a comparison of the two tasks described above, which involve the two extremes of verbal and imaginal processing. Just because an individual is highly familiar with the luggage arrangement task does not mean that more verbal processing will be used for it than will be used for a code deciphering task with which the individual is unfamiliar. It is assumed in this study that the predictions of Kaufmann's model refer to <u>within-task</u> comparisons, such that varying the complexity, ambiguity, or familiarity of a particular problem task, which can be solved with either verbal or imaginal/spatial processing strategies, affects the determination of which strategy to employ.

One class of problems that has the potential to be solved using either processing mode is <u>transitive inference</u>, also known as linear syllogisms. The form of transitive inference that has gained the most attention by researchers is the three-term series task. In this task a subject is given two statements (premises) of the kind: "Joe is taller than Ralph. Ralph is taller than George." Then the subject is asked: "Is Joe taller than George?" There is considerable controversy concerning which mode of processing is used during the solution of these problems. (see Johnson-Laird, 1972; Kaufmann, 1984 for reviews).

According to one explanation, people form images that order the items spatially and then they use these images to deduce the answers (Huttenlocher, 1968). Although commonly called an imagery or imaginal strategy, this type of process is more specifically spatial, in that the items can be arranged in a "mental array" without actually visualizing any details of the items themselves. The position of the items on this array or "cognitive map" is all that is necessary for use as a solution strategy (Desoto, London, & Handel, 1965). This distinction between visual and spatial imagery has been made in working memory (Logie & Marchetti, 1991) and other domains as well (e.g., Kosslyn, Brunn, Cave, & Wallach, 1984). For the purposes of this project, the term "spatial" will be used instead of "imaginal" when referring to this cognitive process.

Another explanation for transitive inference solution is that people solve these problems verbally or linguistically, without imagery, by "marking" comparatives and encoding the lexical attributes of them (Clark, 1969). In this way, subjects might deduce the answer to the question by verbally working through the alternatives and eliminating impossible solutions. This strategy might also involve verbal rehearsal to assist in remembering the order of the items while deducing the answer.

Several attempts have been made to reconcile the two opposing views. For example, Williams (1979) proposed that the verbal model might be more applicable for the sentence processing aspects of the problem, while the spatial model might be more applicable for the actual solution of the problem. In defense of this idea he presented evidence which showed that response latency data supported the verbal model, whereas solution accuracy data supported the spatial model. For example, Williams' results supported the verbal model's prediction that syllogisms with the comparative "taller than" will be solved faster than those with the comparative "shorter than." Williams' results also supported the spatial model's prediction that syllogisms in which the first premise constitutes the upper end of the mental array (proceed downwards) will be solved more accurately than syllogisms in which the first premise constitutes the lower end (proceed upwards).

Wood, Shotter, and Godden (1974) showed that both the verbal and spatial models might be correct, depending on how familiar the subject is with the task. They found that subjects were likely to use a spatial strategy initially and switch to a verbal strategy as an heuristic after becoming familiar with the task (see also Johnson-Laird, 1972). Other studies, however, have produced discrepant results, with some authors (e.g., Potts & Scholz, 1975) concluding that a spatial strategy is used, some authors (e.g., Richardson, 1987) concluding that spatial imagery plays no role in solutions, and some authors (e.g., Newsome, 1986;

Sternberg, 1980) concluding that a mixed verbal/spatial strategy is used in solving transitive inference problems. Except for the Wood et al. (1974) study on familiarity, however, these studies have not manipulated variables affecting the relative utility and effectiveness of verbal and spatial strategies. Due to the controversy over which processing mode is primary in transitive inference, and the possibility that one is predominant in one task condition and the other predominant in another condition, transitive inference problems provide a very useful task for manipulating variables beyond familiarity postulated by Kaufmann (1980, 1984, 1985, 1988, 1990) to influence selection of processing mode.

The influence of problem complexity and ambiguity on which processing mode is predominant has not yet been incorporated into current models of how people solve transitive inference problems. For example, Johnson-Laird and colleagues (Johnson-Laird, 1983; Johnson-Laird, 1994; Johnson-Laird & Bara, 1984) propose that people construct "mental models" of the problem elements when solving three term series problems and other forms of transitive inference. A mental model is conceptualized by Johnson-Laird as a mental representation of the information presented in the premises that serves as a guiding framework for problem solution. This mental representation is different from a purely propositional (verbal) representation in that it depicts relationships between elements in an analog fashion. A mental model can be in the form of an image in some situations, but also can contain more abstract, propositional information that is not imageable (such as negation). Johnson-Laird points out that very difficult (e.g., complex and/or ambiguous) problems are likely to provoke the use of more than one mental model during solution activity. The influence of problem difficulty on the use of mental models, with regard to the relative prevalence of verbal and imaginal/spatial processing involved, is not explicitly addressed by his theorizing, however. That is, factors such as problem complexity and ambiguity, that have the potential to determine whether a mental model is a mental image, or a more abstract representation containing verbal information, have not clearly been identified in Johnson-Laird's approach.

Although problem complexity has not yet been systematically manipulated in problem solving tasks such as transitive inference, problem ambiguity has received some attention by Johnson-Laird's laboratory. Evidence for spatial processing being important for ambiguous problem situations was found by Bauer and Johnson-Laird (cited in Johnson-Laird, 1994). They found that subjects who were presented with diagrams depicting disjunctive syllogisms (i.e., describing several alternative situations) solved them better than subjects who were presented with the same syllogisms in verbal form. Presumably, the "diagram" subjects were able to generate and manipulate images of the diagrams that enabled them to test alternative possibilities, thus facilitating solution.

Other evidence for spatial processing playing a role in ambiguous problem situations was reported by Clement and Falmagne (1986), who presented subjects with "if p then q" type syllogisms varying in imageability and solution determinacy (i.e., whether a statement about q can logically be inferred from a statement about p). For indeterminate syllogisms, performance was better for material rated high in imageability than for low imageability material. The authors concluded that indeterminate reasoning provokes the use of imagery as a way of elaborating on the representation of the problem.

Overall, however, the scant body of evidence on this issue is as yet unconvincing. Systematic research employing more powerful methods is needed to clarify the effects of complexity and ambiguity on problem solving performance.

Overview of Methodology

Previous research on the use of imaginal/spatial processing in problem solving has frequently employed a method that may be of limited value. Some experiments (e.g., Clement & Falmagne, 1986) have indexed the use of imagery by ratings of stimulus imageability, which may provide only a weak measure of the use of spatial processing (even items low in imageability still can be mentally ordered in a spatial array). For example, Richardson (1987) found no significant correlation between stimulus imageability and scores on a spatial ability test in a study involving transitive inference. It is not clear that manipulations of stimulus imageability provide an adequate method of detecting spatial processing. Further, the extent of spatial processing relative to verbal processing cannot be determined with this method.

In order to examine the effects of complexity and ambiguity on the relative use of verbal and spatial processing during transitive inference, a method is needed that teases apart which processing mode is predominant when each variable is manipulated. Selectively interfering with verbal or spatial processes during the problem solving task, while manipulating the complexity or ambiguity of the problem, would provide such a method. Problem solving performance during selective interference should be impaired if the mode of cognitive processing being used to arrive at a solution is the same as that needed to perform the selective interference task, because of the competition between the tasks (Brooks, 1967, 1968). In other words, it is more difficult to do two tasks that require the same processing mode than it is to do two tasks that require different processing modes. Selective interference has proven useful in a variety of paradigms involving problem solving (Gilhooly, et al., 1993; Pezaris & Casey, 1991; Saariluoma, 1992), working memory (Baddeley, 1986; Farmer, Berman, & Fletcher, 1986; Logie, Zucco, & Baddeley, 1990; Quinn & Ralston, 1986), and categorization tasks (Hampson & Duffy, 1984).

The choice of interference tasks for this project was made based on the special requirements of the method of presenting the problems, as well as the effectiveness of these tasks in previous research. Verbal interference consisted of requiring subjects to continuously repeat, out-loud, a four-syllable word at their normal rate of speech, while solving each problem. Various forms of this articulatory suppression procedure have been used with success by many researchers (see Baddeley, 1986, for a review). Some of these researchers have used a digit counting task in which subjects count aloud from one to four (e.g., Farmer, Berman, & Fletcher, 1986; Longoni, Richardson, & Aiello, 1993). Interfering with articulation by using a digit counting task was deemed not desirable for this project because the task required subjects to press numbered keys on a keyboard, and digit counting might interfere with that process. Other researchers have used a sound (e.g., "blah") or word (e.g., "the") repetition task for suppressing articulation, where the words could range from one syllable (Murray, 1968) to four syllables (Slowiaczek & Clifton, 1980). A four syllable word was used in this study in order to reduce the possibility of the task becoming too automatic and therefore less interfering. Subjects were instructed to repeat the word at a normal rate of speech (approximately once per second) because going faster would place too much load on the attentional system (Besner, Davies, & Daniels, 1981), and going slower would allow subjects to solve the problems verbally in between utterances of the suppression word. Allowing subjects to rehearse at their normal rate of speech should maximize the effect of the articulatory suppression.

The spatial interference task chosen for this project was the same as that used by Gilhooly et al. (1993). This task required subjects to move their left hand in a clockwise direction (without looking at their hand), touching each of four knobs situated six inches apart and located in a square pattern on a panel to the left of the keyboard. Subjects did this continuously during the solution of each problem at a rate of approximately one second per knob. Like articulatory suppression, various forms of this task have been employed successfully in previous research to suppress spatial processing (e.g., Farmer et al., 1986; Gilhooly et al., 1993; Quinn & Ralston, 1986).

Although visual presentation of the problem by itself may constitute some visuospatial interference (Brooks, 1967), previous research on transitive inference has shown it to be too slight to be powerful at detecting spatial processing (Newstead, Manktelow, & Evans, 1982). Also, due to the complexity of some of the problems, auditory presentation of the problems using this procedure would create too much of a load on working memory (Johnson-Laird, 1983). Therefore, manipulating mode of presentation as selective interference was neither feasible nor desirable.

Some spatial suppression tasks have involved subjects tracking a moving object with their eyes (e.g., a pursuit rotor task; see Baddeley, 1986 for a review). For example, Baddeley and Lieberman (1980) used the task originated by Brooks (1967) that required subjects to listen to and recall spatial sequences of material (e.g., "in the middle square of a matrix place a one, in the square to the left place a two, in the square above place a three," etc.) and nonsense sequences (e.g., "in the square to the quick place a two," etc.). Pursuit rotor tracking during the presentation of these sequences interfered with the recall of spatial but not nonsense material. This evidence indicates that eye movements involved in visually tracking an object interfere with spatial processing. For this project, however, a type of spatial interference was needed that did not require visual tracking, because of the need for subjects to have their attention on, and eyes focussed on, the problems which were presented visually. Fortunately, Quinn and Ralston (1986) have demonstrated that it is movement per se, and not eye movement nor the attention to the movement, that disrupts spatial activity. They employed the Brooks spatial sequence task described above and found that hand movement (as long as it was not in the same pattern as the sequence of numbers on a matrix) disrupted recall of the sequences. Indeed, recall was impaired even when the experimenter moved the subject's hand instead of the subject performing (and thus attending to) the movement.

This project employed selective interference as a "double dissociation" method that more clearly detected whether verbal or spatial processing is prevalent, as well as defined the conditions that determine when each processing mode is prevalent. The method accomplished this by comparing accuracy scores and response latencies under verbal and spatial interference while systematically manipulating problem complexity (Experiment 1) or ambiguity (Experiment 2). Subjects were presented with problems that varied in complexity or ambiguity while simultaneously performing either verbal or spatial interference tasks. If relatively more verbal than spatial processing is used in a particular condition, then accuracy should be worse (and response latencies longer) under verbal than under spatial interference, because verbal processing is disrupted more by repeating a word than by the hand movement task. The opposite result, that performance should be worse under spatial than under verbal interference, should be obtained if relatively more spatial than verbal processing is used in that condition, because spatial processing is disrupted more by the hand movement task than by the word repetition task.

Additional Comparisons

Gender comparisons were made in this study because considerable evidence exists for a difference between males and females in verbal and spatial processing on a variety of cognitive tasks (e.g., Burnett, Lane, & Dratt, 1979; Goldstein, Haldane, & Mitchell, 1990; Pezaris & Casey, 1991). In general, males have performed better on spatial tasks (e.g., mental rotation) and females have performed better on tasks of verbal fluency (for a review see Halpern, 1986).

Controversy currently exists, however, regarding the extent of these differences and the possibility of certain factors affecting these differences (Hyde & Linn, 1988). Recently, some researchers have concluded that gender differences have been exaggerated by past studies, and/or the extent of these differences is diminishing (e.g., Feingold, 1988). In addition, in spite of observed gender differences in verbal and spatial tasks, no reliable gender differences have been found in most verbal or nonverbal reasoning tasks (Feingold, 1998; Linn & Petersen, 1986).

There is some evidence, however, to suggest that differences between males and females exist on transitive inference tasks. Wood et al. (1974) found that males solved complex problems (with five premises) more accurately than females. Simpler problems were not used in that study, however, and it is not clear if those results would be replicated when problem complexity and ambiguity are systematically manipulated along with selective interference. Due to the controversy over the exact nature of gender differences in cognitive tasks in general, and the lack of clear evidence of those differences existing in specific problem solving or reasoning tasks such as transitive inference, this project included comparisons of males and females in the analyses.

The influence of individual differences was examined by this project in order to ensure that effects of the factors under study, problem complexity and ambiguity, were not obscured or otherwise affected by these differences. Available evidence indicates that there is a wide range of individual differences in the relative use of verbal and spatial thinking (e.g., Haenggi & Steiner, 1989; MacLeod, Hunt, & Mathews, 1978; Richardson, 1977). Therefore, a further aim of this project was to determine whether the effects of problem complexity or ambiguity differ as a function of individual differences in preferences for particular cognitive processing, or "cognitive style" (Richardson, 1977).

The Individual Differences Questionnaire (IDQ), developed by Paivio (Ernest & Paivio, 1971; Paivio, 1971; Paivio & Ernest, 1971), provided insight into this issue. This 87-item questionnaire measures individual differences in the extent to which subjects prefer to use verbal or spatial processing in all facets of thinking. It has been validated and has good ($\underline{r}$ = .91) test-retest reliability (White, Sheehan, & Ashton, 1977). Following Richardson (1977), who developed the 15-item VVQ (Visualizer-Verbalizer Questionnaire) from items in the larger IDQ that pertain to cognitive style, a 12-item subset of the IDQ that is more relevant to problem solving was administered in this project. Not all items in this subset mentioned problem solving explicitly, but some did (e.g., "I often use mental pictures to solve problems"). Correlations were obtained between scores on this subset of the IDQ and all accuracy and response latency measures.

CHAPTER II

EXPERIMENT 1: COMPLEXITY

One variable postulated to affect the relative use of verbal and spatial processing in transitive inference is the complexity of the problem. In Experiment 1, complexity was manipulated by varying the number of premises presented. Although changes in complexity might involve changes in other aspects of the problem, it is reasonable to assume that this manipulation affects the complexity of the problem if other aspects are controlled. Some authors (e.g., Kaufmann, 1988) have suggested that a difference might exist in mode of processing as a function of the number of premises. Previous research employing transitive inference problems with more than two premises (e.g., Wood et al., 1974), however, has not compared them with problems having a smaller number of premises, such as the conventional three term series (two premises) problems.

Method

Subjects. As one alternative in a course research requirement, 32 introductory psychology students at the University of North Carolina at Greensboro volunteered to participate in the study. Half of the subjects were males and half females. None had any prior training in logic or experience with transitive inference.

<u>Materials</u>. Transitive inference problems were presented by an IBM computer using the Micro Experimental Laboratories, or MEL (Schneider, 1988), software package. All problems employed one syllable male names and the adjectives taller and/or shorter. "Simple" problems consisted of two premises and a question (three term series). "Complex" problems consisted of three premises and a question (four term series). All problems had determinate solutions such that the question could be answered correctly from the information contained in the premises. Examples of problems used are:

Simple (3 term): Jack is taller than Fred.
Fred is taller than Joe.
Is Jack shorter than Joe? (yes or no)

Complex (4 term): Dick is taller than Steve.
Steve is taller than Pete.
Bill is taller than Dick.
Is Bill taller than Pete? (yes or no)

Previous research has found that the way in which these problems are worded influences how fast they are solved (Clark, 1969). For example, if the two adjectives that represent "opposite sides of the same coin," like taller and shorter, are used, shorter conveys more information than taller. To say that one person is shorter than another implies that both are short, but to say that one person is taller than another does not imply that both are tall. In this way the adjective, shorter, carries more meaning and is said to be "marked" according to Clark. Clark found that marked adjectives slowed solution time of three term series problems compared to unmarked (e.g., taller) ones. Other aspects of wording, such as the congruence of the adjectives in the premises with the one in the question, and whether the first premise contains an item at one end of the linear set (end-anchoring), have also been found to affect solution time (Newsome, 1986). In order to minimize these effects and maximize the effects of the experimental manipulation, the problems presented to each subject were chosen randomly (without replacement) from a larger pool of problems which included equal numbers of marked and unmarked adjectives, congruent and incongruent wording, and premises that were end-anchored as well as premises not end-anchored. In this way the results were not affected by the particular wording of a few problems.

Design and Procedure. A two (problem complexity) by three (interference type) by two (gender) factorial design was employed with problem complexity (simple and complex) and interference type (none, verbal, and spatial) both manipulated within-subjects. Subjects were tested individually. Instructions were presented by the computer before the problems were presented, with the experimenter available to answer questions (see Appendix A). As part of the preparation for this rather complicated task, the experimenter also elaborated on the instructions and gave examples. Subjects were told that accuracy and speed were equally important, and not to sacrifice accuracy in order to go "real fast," nor to take an inordinate amount of time in order to try to get every one correct. Subjects also were told that how long they spent on both the premises and question was recorded by the computer, in addition to their accuracy. Instructions also stressed that performance on both tasks (problem solution and interference) was equally important, and that the interference tasks should be performed continuously and simultaneously with the problem task (i.e, not switching back and forth). Subjects were monitored by the experimenter during the task to make sure rate of responding to the interference tasks (approximately one second per word for verbal interference and approximately one second per knob for spatial interference) was kept consistent across trials. All subjects maintained consistent responding on the interference tasks throughout the experiment.

The experimenter stressed that the subject's task was to determine who is the tallest of the people presented in the premises, who is the shortest, and who is in-between. This rank-ordering process and what conditions affect whether it proceeds verbally or spatially are of primary interest here. The rank-ordering process is assumed to be of critical importance to solving the problem (Trabasso, Riley, & Wilson, 1975). The problem task confronting subjects, therefore, was to mentally arrange the items (names) in order according to their comparative relationships (height). The question then posed to the subject served as a sort of "partial report" method of determining the accuracy of that arrangement.

After instructions and presentation of sample problems to orient them to the task, subjects were presented with 24 problems, 12 simple and 12 complex, in blocks according to level of complexity. Blocked presentation of levels of complexity was used in order to maximize the power of the method at detecting a difference in processing mode as a function of complexity level. Random presentation of problem complexity would not be as likely to be sensitive to the detection of a shift in processing mode according to a change in complexity.

The order of presentation of blocks was counterbalanced across subjects and gender; half of each gender received simple problems before complex problems, and half received the other order. There was no break between blocks (i.e., the first problem of the second block appeared immediately after the last problem of the first block). Subjects were not told that the problems were divided into two types or that the two types were presented in blocks. For each block, one third of the problems was presented with no interference, one third with verbal interference, and one third with spatial interference. The order of presentation of the problems within each block was random; there was no predictable pattern of presentation of interference type.

The problems were presented one at a time with each problem consisting of three parts: 1) a statement indicating the type of interference for that problem, 2) the premises, and 3) the question. Each part of the problem was presented on separate screens. For the first part, a short two word statement appeared for a duration of three seconds to inform the subject which interference task to perform, if any, for that problem. The statements, "respond only," "repeat imitation" (or some other four syllable word), and "move clockwise," were used to indicate no interference, verbal interference, and spatial interference, respectively. If "respond only" appeared, subjects solved the problem without an interference task. If "repeat (some word)" appeared then subjects said the indicated word (out loud) over and over from the time they saw this instruction, while they viewed the premises, and until they answered the question. If "move clockwise" appeared then subjects moved, without looking, their left hand in a clockwise direction, touching each of four knobs on a panel. A cardboard partition between the panel and the keyboard prevented the subjects from seeing the panel. As with the verbal interference task, subjects performed this spatial interference task continuously from the time they saw the instruction to do so until they answered the question. In this way, interference was presented during the presentation of the question as well as the premises (i.e., for the entire problem).

For the second part of the problem, after the interference instruction went off the screen, either two (simple) or three (complex) premises were presented for an unlimited duration; subjects controlled how long they viewed the premises. All of the premises for each problem were presented together on one screen. Subjects were told to press a particular key when they had decided that they could answer a question regarding the height relationships described in the premises. Pressing the key terminated the presentation of the premises.

The third part of the problem consisted of the presentation of a question immediately after the premises disappeared. The question asked if one person mentioned in the premises was taller than (or shorter than) another person. Subjects were instructed to respond to this question, as quickly and as accurately as possible, by pressing one key for "yes" or another key for "no." Response to the question was followed by a screen that provided feedback as to whether the question was answered correctly or not. The next problem immediately followed this feedback screen. After the problems were presented, subjects were given a shortened version (pertinent to problem solving) of the IDQ (Ernest & Paivio, 1971; Paivio, 1971; Paivio & Ernest, 1971), and then debriefed.

Predictions

Kaufmann's model assumes that verbal processing is more prevalent than spatial processing during the solution of simple versions of a transitive inference problem, but that spatial processing is more prevalent than verbal processing for more complex versions of these problems. For simple (three term) problems, this model therefore predicts that accuracy will be reliably worse (i.e, fewer correct answers to questions), and response latencies reliably longer, under verbal interference than under spatial interference. For complex (four term) problems, the model predicts the opposite result: accuracy will be worse and response latencies longer under spatial interference than under verbal interference. Thus a statistical "crossover" interaction should be obtained between problem complexity and interference type for Kaufmann's model to be supported.

Results and Discussion

Solution Accuracy. Unless otherwise noted, for both experiments all results that are reported were reliable at the .05 alpha level. For each problem, solution accuracy (correct answer to the question), response latency to the premises, and response latency to the question were recorded. Tables and figures for both experiments are presented in Appendix B. See Table 1 for the mean proportion of correct answers as a function of problem complexity, interference type, and gender. Correct answers to questions were analyzed with a 2 X 3 X 2 factorial ANOVA to detect differences between the levels of problem complexity, interference type, and gender. As expected, this analysis revealed a main effect of complexity, $F(1,30) = 4.02$, MSe = .04, with simple problems (mean proportion correct = .71) solved correctly more often than complex ones (.65). There were no other reliable main effects or interactions. However, there was a marginally reliable main effect of interference, $F(2,60) = 2.40$, MSe = .05, $p < .10$, with none, verbal, and spatial interference resulting in means of .73, .65, and .67, respectively.

The lack of a reliable main effect of interference was surprising, revealing that neither selective interference condition substantially impaired accuracy performance compared to the control condition (no interference). To check if this result could be due to the possibility that subjects were engaging in a speed-accuracy tradeoff (taking more time for selective interference conditions than for the no interference condition in order to increase accuracy under interference), correlations were obtained between accuracy and response latencies overall and in all conditions. There were no reliable correlations, indicating that response latencies did not increase as accuracy improved. It is concluded that no speed-accuracy tradeoff occurred, and that the lack of a strong effect of interference on accuracy could be due to this dependent measure not being as sensitive to the interference manipulation as response latency. The range of possible scores for accuracy is much more restricted (limited, in fact) than the range of possible values for response latency (which is unlimited). The effect of interference on accuracy was marginally reliable and in the right direction (scores in the no interference condition were higher than in both selective interference conditions), so perhaps more problems and/or more subjects would produce a reliable effect.

There also was a marginally reliable interaction between interference and gender, $F(2,60) = 2.48$, $p < .10$, with females appearing to have suffered more disruption from verbal interference than did males. Accuracy means for males for none, verbal, and spatial interference were .72, .70, and .64, respectively. For females, means were .74,

.59, and .70, respectively. The biggest difference between the genders was with verbal interference, although this difference was not reliable at the .05 alpha level by a Tukey multiple comparison test.

The influence of individual differences on the results was examined by scoring responses to a twelve item subset of the IDQ or Individual Differences Questionnaire (Ernest & Paivio, 1971; Paivio, 1971; Paivio & Ernest, 1971) that pertained to problem solving. Six of the twelve true/false items reflected a preference for verbal thinking if answered true, and six reflected a preference for visual/spatial thinking if answered true. The number of true responses to the verbal items minus the number of true responses to visual/spatial items constituted the subject's IDQ score. A constant was then added to eliminate negative numbers. This scoring procedure was used to place subjects along a continuum according to relatively greater preference for one type of process, verbal or visual/spatial, over the other. Thus a high score indicated that the subject was more of a verbalizer than a visualizer (greater preference for verbal than visual/spatial thinking), and a low score indicated that the subject was more of a visualizer than a verbalizer (greater preference for visual/spatial than verbal thinking). Notice that a subject could be placed in the middle by correctly answering all of the items, both verbal and visual/spatial, or by incorrectly answering all of the items; both ways of answering indicate that the subject does not prefer one mode of thinking over the other.

Correlations between IDQ score and response accuracy (overall and for each condition) then were performed. There were no reliable correlations obtained with this analysis, indicating that subjects' preferences for one processing mode over the other did not correlate with how accurately they solved problems in any of the conditions. This is somewhat surprising, given that verbalizers would be expected to have more trouble than visualizers with problems presented under verbal interference, and visualizers would be expected to have more trouble than verbalizers with spatial interference problems. To provide a validation of the scoring procedure, which might not have separated visualizers and verbalizers completely, responses to the IDQ were scored again. This time, separate scores for visual and verbal thinking were obtained for each subject by simply tabulating the number of true responses recorded for each scale, without subtracting one from the other as done previously. As before, there were no reliable correlations obtained between any of these IDQ values and solution accuracy.

A final, post hoc analysis was performed to ensure that the order in which subjects received the blocks of simple and complex problems did not affect the results. Order of presentation of simple and complex blocks of problems was counterbalanced across subjects, with equal numbers of males and females receiving each order. Order was not included in the design because there was no a priori reason to expect an order effect with the variables under study. However, it is worthwhile to examine the effect of order because findings in other areas of research reveal order effects when variables are manipulated within-subjects and materials are presented in blocks (e.g., Marschark, Cornoldi, Huffman, Pe, & Garzari, 1994; Richman, 1992). Order, with two levels: simple problems first and complex problems first, was entered into a 2 X 3 X 2 X 2 ANOVA as an independent variable (between-subjects) along with complexity, interference, and gender.

There was no reliable difference in solution accuracy between those who received simple problems before complex problems and those who received the opposite order, $F(1,29) < 1$, and no interactions between order and any of the other independent variables, all Fs < 1. This result was corroborated by the lack of a reliable correlation between order and solution accuracy. It is therefore concluded that the order in which subjects received the levels of complexity did not affect any results for this dependent variable.

Response latency. As mentioned earlier, perhaps a more sensitive measure of the effects of interference lies in the amount of time it takes subjects to solve each problem.

Response latency has the potential to be affected more than solution accuracy because of its greater range of possible values. Response latencies to the premises and to the question were recorded for each problem. Before analyzing those separately, however, it is informative to analyze the effects of the experimental manipulations on the total amount of time spent on each problem. The total response latency for each problem was calculated for each subject by adding that problem's premise response latency and question response latency. See Table 2 for the mean total response latencies as a function of problem complexity, interference type, and gender. Total response latencies were analyzed with a 2 X 3 X 2 ANOVA corresponding to the design. As with solution accuracy, this analysis revealed a main effect of complexity, $F(1,30) = 51.74$, MSe = 14734765 milliseconds (ms), with simple problems (mean = 12.67 seconds) solved reliably faster than complex ones (16.66).

There also was a main effect of interference for this dependent measure, $F(2,60) = 17.01$, MSe = 7687764 ms. Tukey multiple comparison tests revealed that spatial interference problems (mean = 16.25 seconds) took reliably more time than verbal interference problems (14.29) and no interference problems (13.46). Surprisingly, although verbal interference response latencies were greater than no interference, the difference was not reliable.

These main effects are qualified by a reliable interaction between complexity and interference, $\underline{F}(2,60) = 3.64$, MSe = 3472261 ms; Figure 1 shows the mean total response latencies as a function of complexity and interference (collapsed across gender). Tukey tests showed that for simple problems, verbal (mean = 12.80 seconds) and spatial (13.93) interference total response latencies were not reliably different from each other, and both were reliably greater than no interference (11.29). A different pattern emerged from this analysis for complex problems, however. Latency under spatial interference (mean = 18.57 seconds) was reliably greater than under verbal interference (15.78), which was not reliably greater than no interference (15.63).

The nature of this interaction is evident in Figure 2, which depicts the amount of verbal and spatial interference adjusted for the no interference (baseline) condition for each level of complexity. This adjustment was accomplished by subtracting the mean latency under the no interference condition from the mean latency under each selective interference condition, for each level of complexity. Thus a large remainder, or difference score, indicates that there is a large decrement in performance compared to no interference (i.e., a large effect of that type of interference). This, in turn, indicates that the particular processing mode interfered with was used to a large extent for that type of problem. The larger this difference score, the greater the extent of the use of that processing mode. A larger verbal than spatial difference score, for example, indicates that more verbal than spatial processing was used for that particular type of problem (simple or complex).

Figure 2 shows that, for both simple and complex problems, the difference score for spatial interference was greater than the difference score for verbal interference. More importantly, perhaps, Figure 2 also shows that the verbal difference score for simple problems was greater than for complex ones. This suggests that simple problems evoke more verbal processing than complex problems, relative to their respective control conditions. There was no similar decline in spatial processing from simple to complex problems. In fact, there was a slight incline, as revealed by the slightly greater spatial difference score for complex problems than for simple ones.

The above results are qualified perhaps by a marginally reliable three way interaction between complexity, interference, and gender, $F(2,60) = 3.08$, MSe = 3472261 ms, $p < .10$ (refer again to Table 2). For males, the difference scores for both types of interference were greater for simple than for complex problems (see Figure 3). Moreover, although spatial difference scores were greater than verbal difference scores for both simple and complex problems, there was approximately the same amount of difference between the two types of interference for both types of problems. For females, a different pattern emerged (see Figure 4). As with the two way interaction, there was a greater difference between the two interference conditions for complex problems than there was for simple problems. Like the males, the females displayed a greater verbal difference score for the simple problems than for the complex problems, suggesting a decrease in the amount of verbal processing from simple to complex problems. Unlike the males, however, their spatial difference score was smaller for the simple than for the complex problems, suggesting an increase in the amount of spatial processing from simple to complex problems. A possible reason for this difference between the genders will be discussed later. Finally, as with response accuracy, there were no main effects of gender or of order. Also, there was no correlation between IDQ and total response latency (in any of the conditions).

In order to pinpoint the locus of the effects described above for total response latency, and to further delineate the parts of the problem that are affected by the manipulations, response latencies to the premises and to the question were analyzed separately. The reason for partitioning response latency in this way is because the solution to the problem may well be arrived at before the question is presented, due to the nature of the task and the instructions. The question was presented after the premises disappeared from view, so that subjects could not read the question first and then work backwards (or otherwise take a "shortcut") to arrive at the answer without mentally ordering all of the items presented in the premises. How they go about ordering the items, verbally or spatially, and what factors affect that ordering process, is the topic of study. The question then serves as a "partial report" method of detecting the accuracy of that ordering.

In order to answer the question without the premises in view, subjects probably start (and finish) the ordering process while viewing the premises. Therefore, measures of response latency to the premises are likely to be sensitive to the selective interference method of detecting whether verbal or spatial processes are used more in solving the problem. Response latency to the question is less likely to show that sensitivity because the ordering of items has probably already been completed. Question response latency is therefore more likely to be sensitive to factors that affect maintenance of that order, rather than to the ordering process itself.

See Table 3 for the mean response latency to the premises as a function of problem complexity, interference type, and gender. Premise response latencies were analyzed with a 2 X 3 X 2 ANOVA corresponding to the design. As with total response latency, this analysis revealed a main effect of complexity, $F(1,30) = 74.56$, MSe = 8857691 ms, with simple problems (mean = 9.26 seconds) solved reliably faster than complex ones (12.96). Also like total response latency, there was a main effect of interference, $F(2,60) = 15.53$, MSe = 7081287 ms. Tukey multiple comparison tests revealed that spatial interference problems (mean = 12.23 seconds) did not differ reliably from verbal interference problems (11.44), both of which took reliably more time than the no interference condition (9.67).

These main effects are qualified by an interaction between complexity and interference, $F(2,60) = 3.72$, MSe = 2526891 ms. See Figure 5 for the mean response latencies to the premises as a function of problem complexity and interference type (collapsed across gender). Tukey tests revealed that for simple problems, verbal (mean = 9.98 seconds) and spatial (10.00) interference conditions were not reliably different, with both reliably greater than none (7.78). For complex problems, spatial (14.45) was reliably greater than verbal (12.89), which was reliably greater than none (11.56).

As with total response latency, the locus of this interaction can be illustrated by a graph (see Figure 6) of the means adjusted for the appropriate baseline (no interference) condition (i.e., a difference score). Figure 6 shows that for simple problems, verbal and spatial difference scores were almost identical, but the spatial difference score was greater than the verbal difference score for complex problems. This reveals that there was a decrease in the effect of verbal interference from simple to complex problems, but an increase in the effect of spatial interference when problems got more complex. In other words, verbal interference was more disruptive for simple than for complex problems, but spatial interference was more disruptive for complex than for simple problems. As with total response latency, this suggests that simple problems evoke more verbal processing than complex ones, as evidenced by the simple problems showing a greater verbal difference score than the complex problems. Complex problems, on the other hand, evoke more spatial processing than simple ones, as evidenced by the complex problems showing a greater spatial difference score than the simple problems.

Also obtained with this dependent measure was a marginally reliable interaction between interference, complexity, and gender, $F(2,60) = 2.61$, $p < .10$. For total response latency this interaction also was marginally reliable, and the same pattern was obtained here. Females displayed a greater verbal difference score, but a smaller spatial difference score, for simple than complex problems, suggesting an increase in spatial processing and a decrease in verbal processing from simple to complex problems (see Figure 7). For males there was no similar difference between the interference conditions from simple to complex problems (see Figure 8). As with total response latency, there was no main effect of gender, $F(1,30) < 1$, and there was no reliable correlation between IDQ and response latency to the premises.

The final dependent measure, response latency to the question, also was analyzed with a 2 X 3 X 2 ANOVA. See Table 4 for the mean question response latencies as a function of problem complexity, interference type, and gender. The results of this ANOVA were quite different from those of previous analyses. In addition to the previously observed lack of a main effect of gender, $F(1,30) < 1$, there also was no effect of complexity, $F(1,30) = 1.87$. The lack of a reliable difference between simple and complex problems in the time taken to answer the question could simply be due to the problem being solved during the viewing of the premises, as discussed earlier.

A main effect of interference, $F(2,60) = 21.96$, MSe = 1114678 ms, was obtained as expected. However, Tukey tests indicated that response latencies under verbal interference (mean = 2.61 seconds), were reliably faster than both spatial interference (3.82), and no interference, (3.66), the latter two means not differing reliably. The finding that verbal interference resulted in faster responses to the question than no interference is surprising, and could be due to the way in which the two parts of the problem, premises and question, differ in their demands on the solver. This will be discussed in more detail in the general discussion. There were no reliable interactions.

In summary, the results of Experiment 1 revealed that for response latency to the premises, verbal and spatial interference did not differ in the magnitude of their effect on simple problems. For complex problems, however, spatial interference was more disruptive than verbal interference. Response latency to the premises appeared to be more sensitive to the manipulations than solution accuracy or response latency to the question. For example, although simple problems were solved correctly more often than complex ones, the effect of interference on this dependent measure was only marginally reliable, and there were no reliable interactions. For response latency to the premises, however, complex problems were viewed longer than simple problems, and selective interference was disruptive compared to no interference. Further, response latency to the question revealed no complexity effect, and the effect of interference was not as expected.

There were no main effects of gender in this experiment, but females appeared to show an increase in the effect of spatial interference (and a decrease in the effect of verbal interference) when problems were more complex. Males did not exhibit this pattern. The results of this experiment were not affected by variations in individual differences, and the order in which subjects received simple and complex problems did not affect any results.

Although Kaufmann's predictions were not fully supported by these results, it is noteworthy that the increase in premise response latency difference scores when problems were more complex was obtained under spatial, but not under verbal interference. This suggests that spatial processing is used more than verbal processing for complex problems, as predicted by the model. The model's other prediction: that verbal processing should be used more than spatial processing for simple problems, was not supported by the results, however.

CHAPTER III

EXPERIMENT 2: AMBIGUITY

According to Kaufmann's model, the ambiguity of the problem situation is one factor, in addition to problem complexity and familiarity, that affects which processing mode is predominant. Kaufmann's model predicts that clear, unambiguous versions of a problem lead to more verbal than spatial processing, because the problem elements and their relationships can be mentally represented in a precise, one-to-one way that lends itself easily to verbal descriptions. When the problem situation presents unclear, vague, ambiguous relationships between elements, however, spatial processing is assumed to be more prevalent than verbal processing. The reason for this assumption is that spatial processing in working memory provides an analog mental representation of the problem elements (perhaps multiple representations) that allows different possible relationships to be depicted and compared.

For transitive inference, ambiguity can be manipulated by making the premises of the problem describe an order of names that is ambiguous with regard to all of the comparisons. For example, the premises: "John is taller than Steve. Steve is shorter than Jim" present an ambiguous, non-linear ordering such that it is not known if

John is taller than Jim. If the question asks for this unknown information then the problem cannot be solved (indeterminate solution).

Method

Subjects. As one alternative in a course research requirement, 32 introductory psychology students at the University of North Carolina at Greensboro, who had not participated in the first experiment, volunteered to participate in the study. Half of the subjects were males and half females.

Materials, Design, and Procedure. Experiment 2 employed the same materials, design, and procedure as Experiment 1 with the following exceptions. All of the problems consisted of two premises (simple). However, half of the 24 problems presented to each subject were unambiguous and half ambiguous. Ambiguity thus was manipulated within-subjects in the same manner that complexity was in the first experiment. Unambiguous problems were identical to the simple problems used in Experiment 1. As with the first experiment, problems were randomly drawn from a larger pool in order to control for possible "wording" effects. All questions were followed by three response choices (yes/no/can't tell) instead of two choices. Subjects were instructed that some problems would not be answerable from the information given in the premises. An example of an ambiguous problem used is:

Bill is taller than Jake.
Jake is shorter than Sam.
Is Bill taller than Sam? (yes/no/can't tell)

As with Experiment 1, the way in which subjects manipulate the order of these items for problem solution, either verbally or spatially, is at issue. Therefore, the ambiguity of the presentation is what is being manipulated, not necessarily whether the solution can be determined. In the above example, if the question were: "Is Jake shorter than Bill?" then the solution would be determinate even though the presentation has ambiguous order with regard to _all_ of the items in the premises.

If all unambiguous problems have determinate solutions and all ambiguous problems have indeterminate solutions, then it is possible that subjects would learn to respond "can't tell" to all ambiguous problems, and never respond "can't tell" to unambiguous problems, without evaluating each question completely. In order to prevent this possible response bias, half of each of the unambiguous and ambiguous problems had determinate and half indeterminate solutions.

An example of an unambiguous problem with an indeterminate solution is:

Bill is taller than Jake.

Bill is shorter than Sam.

Is Bill taller than Ralph? (yes/no/can't tell)

The answer cannot be determined because Ralph was not mentioned in the premises.

Comparisons and Predictions

The same comparisons were made for this experiment that were made for Experiment 1, with ambiguity replacing complexity as a variable. Kaufmann's model predicts that for unambiguous problems, solution accuracy will be worse (and response latencies longer) under verbal interference than under spatial interference. For ambiguous problems, spatial interference will produce worse accuracy and longer response latencies than verbal interference.

Results and Discussion

Solution Accuracy. As with Experiment 1, for each problem, response accuracy (correct answer to the question), response latency to the premises, and response latency to the question were recorded. Correct answers to problem questions were analyzed with a 2 X 3 X 2 factorial ANOVA corresponding to the design. See Table 5 for the mean proportion of correct answers as a function of problem ambiguity, interference type, and gender. As expected, this analysis revealed a main effect of ambiguity, $\underline{F}(1,30) = 48.57$, MSe = .06569, with unambiguous problems (mean proportion correct = .82) solved correctly more often than ambiguous ones (.57). Unlike Experiment 1, there also was a main effect of gender, $\underline{F}(1,30) = 12.97$, MSe = .09338, with males (.77) solving reliably more problems than females (.62).

These two main effects perhaps are qualified by a marginally reliable interaction between ambiguity and gender, $\underline{F}(1,30) = 3.10$, $\underline{p} < .10$, however. Tukey multiple comparison tests revealed that for females the ambiguous problems (mean proportion correct = .45) were solved reliably less accurately than the unambiguous problems (.78), but for males there was no reliable difference between the ambiguous (.68) and unambiguous (.87) problems. This suggests that females had more trouble with ambiguous problems (in fact were near chance performance for both types of selective interference) than males.

The ANOVA also revealed a reliable main effect of interference, $\underline{F}(2,60) = 14.70$, MSe = .045. Tukey tests indicated that accuracy under verbal interference (mean proportion correct = .60) was reliably less than none (.79) and spatial (.70), the latter two not differing reliably.

Final analyses for this dependent measure included the following. As with Experiment 1, to see if response accuracy increased as response latencies became longer (i.e., a speed-accuracy tradeoff), correlations were performed between accuracy and all of the response latency measures. No speed-accuracy tradeoff was observed as evidenced by the lack of any reliable correlations with this analysis. Individual differences were analyzed for this experiment the same as in Experiment 1. There were no reliable correlations obtained between IDQ scores and response accuracy. Lastly, with order entered into an ANOVA there was no reliable effect, $\underline{F} < 1$, and no reliable correlations between order and any of the conditions, indicating that receiving ambiguous problems first did not differentially affect the results compared to receiving unambiguous ones first.

Response latency. As with Experiment 1, response latencies to the premises and to the question were recorded for each problem, and the first analysis was performed on those two measures combined. The total response latency was calculated by adding each problem's premise response latency and question response latency. See Table 6 for the mean total response latencies as a function of problem ambiguity, interference type, and gender. Total response latencies were analyzed with a 2 X 3 X 2 ANOVA corresponding to the design. As with response accuracy, this analysis revealed a main effect of ambiguity, *F*(1,30) = 25.34, MSe = 7877257, with unambiguous problems (mean = 14.60 seconds) solved reliably faster than ambiguous ones (12.56). The effect of gender was marginally reliable for this dependent measure, *F*(1,30) = 3.04, MSe = 110706292, $p < .10$, with males (14.90) taking longer than females (12.26).

There also was a main effect of interference for this dependent measure, *F*(2,60) = 3.32, MSe = 6416929, with spatial interference problems (mean = 14.22 seconds) taking reliably more time than no interference problems (mean = 13.10 seconds), by Tukey multiple comparison tests. Verbal interference problems (mean = 13.41 seconds) did not differ reliably from no interference.

These main effects are qualified, however, by a reliable interaction between ambiguity and interference, *F*(2,60) = 7.56, MSe = 4983915. Tukey tests revealed that for unambiguous problems, verbal (mean = 13.20 seconds) and spatial (13.12) interference conditions were not reliably different, and both were reliably different from no interference (11.37). For ambiguous problems a very different picture emerges, with the no interference condition (14.84) not differing reliably from either the verbal (13.62) or spatial (15.34) interference conditions. The only reliable difference for ambiguous problems was between the two selective interference conditions, with verbal taking less time than spatial (see Figure 9). Note that the verbal interference condition also produced faster response latencies than the control condition for ambiguous problems. This result is surprising and makes interpretation difficult. It is apparent that without interference, subjects took a lot of time for ambiguous problems. Verbal interference, however, actually sped up processing time compared to no interference, although this difference was not reliable. The influence of question response latency on this result will be discussed later. The reliable difference between spatial and verbal interference indicates that more spatial than verbal processing was used. Finally for this dependent measure, there was no order effect ($\underline{F} < 1$) and no reliable correlations with IDQ.

As with Experiment 1, response latencies to the premises and question were analyzed separately. See Table 7 for the mean premise response latencies as a function of problem ambiguity, interference type, and gender. Premise response latencies were analyzed with a 2 X 3 X 2 ANOVA corresponding to the design. As with total response latency, this analysis revealed a main effect of ambiguity, $\underline{F}(1,30) = 11.47$, MSe = 5624065, with premises of unambiguous problems (mean = 9.88 seconds) responded to reliably faster than premises of ambiguous problems (mean = 11.04 seconds). This analysis also revealed a main effect of gender, $\underline{F}(1,30) = 4.40$, MSe = 72457632, with males (11.75) taking reliably longer than females (9.17). There also was a main effect of interference, $F(2,60) = 4.37$, MSe = 5247997, with verbal (10.80) and spatial (10.81) interference problems not differing reliably, and both taking reliably more time than the control condition (9.77), by Tukey multiple comparison tests.

As with total response latency, there was a reliable interaction between ambiguity and interference, $F(2,60) = 4.37$, MSe = 4620673. As is illustrated by Figure 10, for unambiguous problems both verbal (mean = 10.81 seconds) and spatial (10.26) interference conditions were reliably greater than none (8.58), by a Tukey multiple comparison test. The two types of interference did not differ reliably from each other. For ambiguous problems, verbal interference (10.80) did not differ reliably from spatial interference (11.37), and neither differed reliably from the no interference condition (10.96). In other words, selective interference did not interfere with premise processing time for ambiguous problems. Verbal and spatial interference means for both types of problems were all approximately the same. The main difference between the two types of problems was in the no interference condition. The interaction appears to be due to the increase in processing time for the no interference condition from unambiguous to ambiguous problems (a reliable difference), not due to differences between the two types of interference. It is worth noting, however, that the interference means, although not reliably different, exhibited the pattern predicted by Kaufmann's model: verbal was greater than spatial for unambiguous problems and vice-versa for ambiguous problems. As with total response latency, there was no effect of order and no correlation between IDQ and response latency to the premises.

The final dependent measure, response latency to the question, also was analyzed with a 2 X 3 X 2 ANOVA. The results of this analysis were quite different from those of previous analyses for this experiment. See Table 8 for the mean trial response latencies to the question as a function of problem ambiguity, interference type, and gender. As with total and premise response latency, this analysis revealed a main effect of ambiguity, $\underline{F}(1,30) = 43.27$, MSe = 859263, with responses to unambiguous problem questions (mean = 2.68 seconds) taking reliably less time than those to ambiguous ones (3.56). Inconsistent with the other dependent measures, this analysis also revealed <u>no</u> main effect of gender, $\underline{F} < 1$. There also was a main effect of interference, $\underline{F}(2,60) = 12.72$, MSe = 971073, with no interference (mean = 3.33 seconds) and spatial interference conditions (3.41) not differing reliably, and both taking reliably more time than verbal interference (2.61), by Tukey multiple comparison tests. Notice that the fastest condition, verbal interference, was even faster than the control condition. This result also was obtained in the first experiment for this dependent measure, and a possible explanation will be discussed later.

There also was a reliable interaction between ambiguity and interference, $\underline{F}(2,60) = 3.72$, MSe = 660499 (see Figure 11). This result indicates that the tendency for verbal interference (mean = 2.83 seconds) to produce faster response latencies than spatial (3.97) or none (3.88) was found only for ambiguous problems. Although the same trend was observed for the unambiguous problems, verbal (2.40) was not reliably faster than spatial (2.84) or none (2.79). As with the previous measures, there was no effect of order for this dependent measure, and no correlations between IDQ and response latency to the question.

In summary, results of the second experiment revealed that for premise response latency, selective interference affected unambiguous problems compared to no interference, but the two types of interference did not differ reliably from each other. For ambiguous problems, however, performance in all three interference conditions did not differ reliably. For question response latency, performance was fastest in the verbal interference condition, especially for ambiguous problems.

There were some differences between the genders, but they were not substantial. Although males solved more problems correctly than females, they took longer to do so.

Females appeared to have more trouble solving ambiguous problems correctly than males, but this was only marginally reliable. Finally, individual differences, and the order in which the two types of problems were presented, did not affect results.

CHAPTER IV

GENERAL DISCUSSION

The primary aim of this project was to determine the extent to which the processing mode used during the solution of transitive inference problems is affected by the complexity and ambiguity of the problem. Determining if these factors affect the relative use of verbal and spatial processing has important theoretical and practical implications in both problem solving and working memory domains. The results yielded some suggestive evidence for the influence of the complexity manipulation on use of processing mode, but evidence for the influence of ambiguity on processing mode was not uncovered. That is, manipulating problem complexity by increasing the number of premises resulted in a greater amount of spatial relative to verbal processing, as indexed by the effect on the amount of time taken to solve the problems. Solution accuracy was not similarly affected by that manipulation, however. Manipulating problem ambiguity by making some problems describe a nonlinear ordering did not produce a consistent pattern of effects on processing mode. Individual differences in preference for verbal or spatial thinking did not affect the results, and the influence of gender differences on the results was inconsistent. Although some results differed among males and females, there was no overall trend for the manipulations to have different effects as a function of gender.

In the first experiment, the premise response latency results provided partial support for the hypothesis that more complex problems involve a greater amount of spatial than verbal processing. For simple problems, the effect on response latency was almost identical under both types of selective interference. For complex problems, however, response latencies were reliably longer under spatial than under verbal interference. This finding can be interpreted as suggesting that the simple problems in this experiment were solved with both verbal and spatial processing approximately equally, but that the complex problems evoked more spatial than verbal processing. Thus, for the complex problems, response latency was slowed under spatial interference compared to verbal interference. This was in spite of the complex problems having one more premise than the simple problems, which should have resulted in more time spent verbally processing the complex problems.

This result is not fully consistent with the predictions made from the model described by Kaufmann (1985, 1988, 1990). For Kaufmann's model to be strongly supported, the simple problems would have shown the opposite result from the complex (i.e., verbal interference resulting in longer latencies than spatial interference). Perhaps that result was not obtained because the "simple" problems used here were not simple enough, at least not for these university-level subjects. One could speculate that if subjects were given simpler, two term problems involving only one premise and a question, that these "problems" would be solved with more verbal than spatial processing. Perhaps three term problems involving only one comparative, e.g., taller, would also be simpler and result in more verbal than spatial activity. The three term series problems employed in this project as simple problems might fall in between simple and complex, therefore involving a mixture of verbal and spatial activity.

In addition, what constitutes problem simplicity or complexity might depend on how familiar the subject is with the problem task. Subjects in these experiments were novices at transitive inference; none had any pre-experiment training or experience at any form of syllogistic reasoning. With familiarity, the three term series problems in this project might become "simpler" to the subject and require less spatial activity. An effect of familiarity resulting in more verbal and less spatial processing was found by Wood et al. (1974). Future studies could manipulate more than two levels of complexity to examine the pattern of influence on processing mode, as well as the interaction of complexity with familiarity.

An alternative explanation for the greater effect of spatial than verbal interference on premise response latencies is simply that the spatial task was in some way more difficult or demanding than the verbal task. On the surface this explanation seems implausible because both tasks require little attention and effort by themselves. In addition, this explanation would not be tenable if there had been a "crossover" interaction obtained where spatial interference had produced a larger effect than verbal interference for one level of complexity or ambiguity, but vice versa for the other level. It would then be tenuous to argue that one interference task is more difficult for one condition, and the other more difficult for the other condition, without concluding that the complexity or ambiguity of the problem is responsible for this pattern.

In agreement with Saariluoma (1992), it is argued here that the difficulty of the interference task cannot be judged on any absolute dimension, nor can a task that interferes with one cognitive process be compared as to its ease or difficulty with a task that interferes with another cognitive process. If an interference task is difficult or demanding, it is <u>because</u> it is tapping into the same process being used for problem solution. The difficulty of the task is inseparable from its role as interference.

The lack of an interaction between ambiguity and interference as predicted by Kaufmann's model in Experiment

2 could have been due to the ambiguous problems simply being too difficult for these inexperienced subjects. As reported above, there was an interaction between ambiguity and interference for premise response latency. The interaction, however, appeared to have been caused by unambiguous problems showing a predictable pattern of both interference conditions taking longer than no interference, while ambiguous problems were approximately equal in all three interference conditions. It appears that although subjects solved the unambiguous problems better than the ambiguous ones, and took longer over all interference conditions for ambiguous problems, receiving interference with ambiguous problems made no reliable difference, compared to not receiving interference, in response latency to the premises. There was a trend in the data in the direction predicted by Kaufmann's model, however. Verbal interference was more disruptive than spatial interference for unambiguous problems, but the reverse was found for ambiguous problems, although the differences in the means were not reliable. Again, it is possible to speculate that more training and experience for subjects would produce a reliable pattern of results.

As mentioned earlier, premise response latency is arguably the best index of the sensitivity of the manipulations because of the task requirement of determining the order of names according to height before the question is presented. There was less effect of the manipulations on solution accuracy (e.g., no reliable effect of interference in Experiment 1, no reliable interactions between complexity or ambiguity and interference), perhaps because of the restricted range of scores (zero to four for a subject in each condition). The range of values possible for response latency was potentially unlimited. There also was less of an impact of the manipulations on question response latency than on premise response latency (e.g., no reliable effect of complexity in Experiment 1). This was due presumably to the problem having been solved (the names ordered according to height) during viewing of the premises, with the question being answered without any further ordering necessary.

The question arises concerning question response latency, however, of why verbal interference resulted in faster times than no interference (which was not reliably different from spatial interference)? This pattern of results occurred in both experiments. A possible interpretation of this result is that the ordering of names, whether via verbal or spatial processing, has been reached before the question is presented. Answering the question then requires maintenance of this order for a brief interval (question response latencies were much shorter than premise response latencies) until the question can be read and the correct key pressed. It is possible that although the ordering of names might proceed with either a verbal or spatial strategy, the <u>maintenance</u> of that order might be performed verbally. The articulatory loop system of working memory appears well suited for this task (Baddeley, 1986). Repeating a word might induce subjects to respond quickly before this verbal interference causes forgetting of the order. With this explanation, under no interference or spatial interference (which did not differ reliably from each other in both experiments) there was not as much urgency to respond, because there was little or no interference with maintenance of the order and thus less chance of forgetting.

A final note should be made concerning response latency as a dependent measure. In this study, latency to both correct and incorrect responses was recorded and analyzed, not just latency to correct responses. The reason for this procedure was to maximize the sensitivity of the interference conditions at detecting use of processing mode (an interference task can slow performance by interfering with the cognitive process used to attempt problem solution, even when the subject makes an incorrect choice). It is possible, however, that guessing by subjects introduced some extra variability into the response latency data that might have reduced the sensitivity of the measure. Analyzing only the latency to correct responses has the drawback of producing less usable data, however, which also reduces sensitivity. This is a particular problem when the subject has only two or three solution choices, as in this study. There are advantages and disadvantages to each method, and previous studies have analyzed latency to all responses (e.g., Newstead, et al., 1982; Richardson, 1987), as well as latency to correct responses only (e.g., Clark, 1969; Huttenlocher, 1968; Williams, 1979).

Gender differences were examined in order to see if the well known superiority of males in spatial tasks, and superiority of females in verbal tasks (Halpern, 1986), would interact with this project's manipulations of complexity and ambiguity to affect use of processing mode. In Experiment 1 there were no main effects of gender. There were two marginally reliable interactions in that experiment worth noting, however. One was the finding that females suffered more from verbal interference than did males, as reflected in solution accuracy. This finding is in accord with previous research that found females superior to males in verbal tasks (Halpern, 1986). The other marginally reliable interaction was the finding that females showed an increase in premise response latency under spatial interference, but a decrease in premise response latency under verbal interference, from simple to complex problems. Males did not exhibit this increase in the effect of spatial interference as problems got more complex. That result suggested that females used more spatial processing for complex than simple problems, but more verbal processing for simple than complex problems.

Interpretation of this result is also consistent with previous research on gender differences showing that females perform better on verbal tasks than males (Halpern, 1986). With regard to this dependent measure, females showed an increase in spatial processing when the problems got more complex, but males did not. Assuming that females perform better than males on verbal tasks because of a greater tendency to use verbal than spatial processing, perhaps females need to engage more spatial, relative to verbal, processing for the complex problems than for the simple ones, because the increased difficulty of the complex problems forces them to resort to it. The males, on the other hand, are more used to spatial thinking and so do not need to use it to a greater degree when the problems get more complex.

In Experiment 2, males solved ambiguous problems more accurately than females, but took longer on premise response latency. This apparently reflects a trade-off by which males were more concerned than females with getting correct solutions, even if it took longer. In this experiment there also was a marginally reliable interaction between ambiguity and gender in solution accuracy, where females had somewhat more trouble with ambiguous problems than males. Although this project did not provide evidence in support of a connection between ambiguous problems and spatial processing, if there is such a connection, then females, with their greater use of verbal processing, would be expected to have more trouble with ambiguous problems than males.

The only difference between the genders reported by previous research using a transitive inference task was observed by Wood et al. (1974). They found that males solved complex problems (with five premises) more accurately than females. In contrast, this project did not observe a difference in solution accuracy with complexity manipulated. In general, this study did not find a strong, consistent pattern of substantial differences between the genders on all measures, supporting Feingold's (1988) conclusion that males and females are closing the gap in cognitive differences. Similar lack of a difference in reasoning tasks was observed by Linn & Petersen (1986).

Individual differences in preferences for verbal or spatial processing appeared to have had no influence on the results of this study. Consistent with previous research (e.g., Haenggi & Steiner, 1989), this project observed a wide range of individual differences in the reported use of verbal and spatial thinking, as measured by widely variable scores on the IDQ. There were no reliable correlations observed between IDQ scores and any of the conditions created by manipulating gender, complexity or ambiguity, and interference, however. Although the IDQ is effective at measuring how people prefer to think (verbally or spatially/imaginally) in a variety of situations, this project's task was probably equally verbal and spatial. Verbalizers and visualizers were therefore both able to perform equally well, and the variables manipulated, complexity and ambiguity, did not influence verbalizers more than visualizers, or vice versa. In other words, being a verbalizer might mean that one prefers to think verbally in most situations, but is still able to think spatially when the situation calls for it. The same situation might hold for visualizers and thinking verbally.

However, the result that IDQ scores did not correlate with any of the interference conditions, for any of the dependent measures, is still puzzling. For example, even if verbalizers can use spatial processing when needed, one would expect them to have more trouble in general with verbal interference than with spatial interference. As mentioned earlier, a subset of the IDQ that pertains to problem solving was administered in this project. Although some of the IDQ items used pertained to problem solving, not all did. Perhaps future research could include a more extensive questionnaire with all of the items designed so as to be more sensitive to detecting which cognitive processes are preferred for problem solving specifically. In addition to the questionnaire, a battery of problem solving tests could be used to provide additional power for detecting differences between individuals in preference for use of processing mode during problem solving.

This project helped to delineate two factors, problem complexity and ambiguity, that have the potential to affect the relative use of verbal and spatial processing in the solution of transitive inference problems. Previous theoretical assumptions in this area were partially supported, but more work is needed to clarify our understanding of the various factors affecting processing mode during problem solving. Although the generalizability of the results is limited to the problem task employed here, the foundation has been laid for future studies to explore the effects of these variables on other tasks. A systematic categorization of factors, and classes of problems that are affected by those factors, can then be undertaken that will increase our theoretical knowledge of verbal and spatial thought processes in problem solving. This will enhance our overall understanding of the roles language and imagery play in cognition.

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Appendix A

Experiment 1: Instructions to Subjects

Welcome to the experiment, which is about solving logical problems. Don't worry, you don't have to be good at solving these type problems to do this task. Shortly you will see on the screen statements of the kind: John is taller than Bill; Bill is taller than Joe. Your task is to figure out the order of names according to height. When you have done that, press the "1" key and the statements will disappear and a question such as "Is John taller than Joe?" will appear. To answer the question press "1" for yes and "2" for no. Try to respond to the statements and answer the question as fast as possible without making errors. Speed and accuracy are both important.

For each problem, before the statements appear you will see one of three instructions. If "respond only" appears on the screen, just respond to the statements and answer the question as explained above. If "repeat imitation" (or some other word) appears, then repeat that word out loud (at your normal rate of speech, about once per second) until you've answered the question. If "move clockwise" appears, then touch (without looking) each of the four knobs to the left of the keyboard in a clockwise direction until you've answered the question. Do this with your left hand and move at about one second per knob.

Start doing this word repetition or hand movement task as soon as you see the instruction to do it, and continue doing it until you've answered the question (don't stop when the question comes up!). Remember, doing these tasks is just as important as solving the problems accurately and quickly. Any questions before doing some practice problems?

Appendix B

Tables and Figures

Table 1

Experiment 1: Mean Proportion of Correct Answers to Problem Questions as a Function of Problem Complexity, Interference Type, and Gender. (Standard deviations are in parentheses. Also note that means with an asterisk are not reliably different from chance performance, as measured by a t-test in comparison with a data set having a mean of .50 and comparable variability.)

	Males		Females	
	Simple	Complex	Simple	Complex
None	.70	.73	.78	.70
	(.21)	(.25)	(.24)	(.25)
Verbal	.69	.72	.69	.50*
	(.30)	(.22)	(.27)	(.29)
Spatial	.69	.59*	.72	.67
	(.25)	(.24)	(.22)	(.20)

Table 2

Experiment 1: Mean Total Response Latencies (in Seconds) as a Function of Problem Complexity, Interference Type, and Gender. (Standard deviations are in parentheses.)

	Males		Females	
	Simple	Complex	Simple	Complex
None	11.35	16.20	11.24	15.06
	(3.71)	(5.43)	(3.27)	(4.77)
Verbal	12.64	15.56	12.96	16.00
	(4.63)	(6.60)	(4.31)	(6.97)
Spatial	14.14	17.68	13.71	19.45
	(5.96)	(6.26)	(3.96)	(5.71)

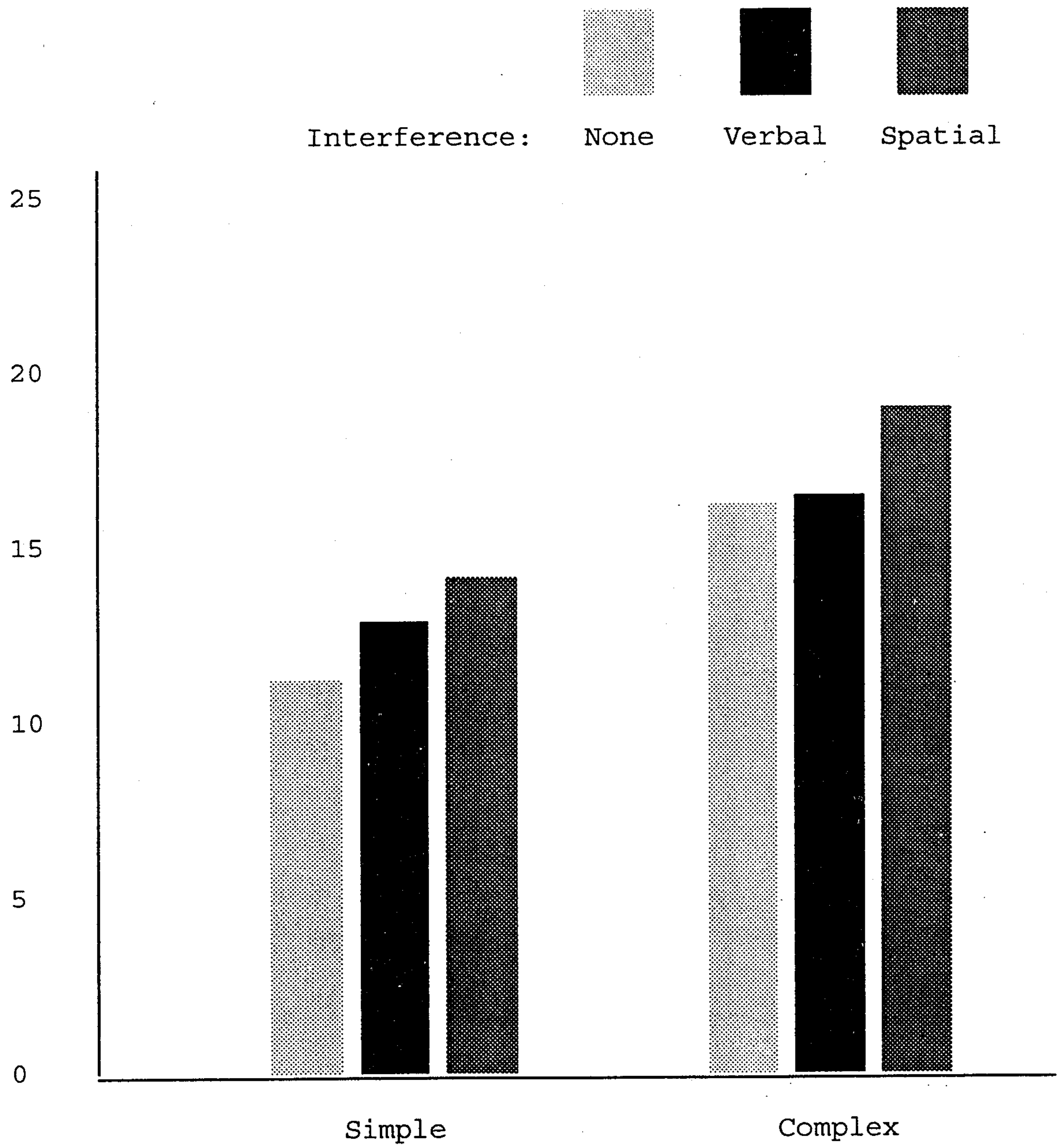

Figure 1

Experiment 1: Mean Total Response Latencies (in Seconds) as a Function of Problem Complexity and Interference Type.

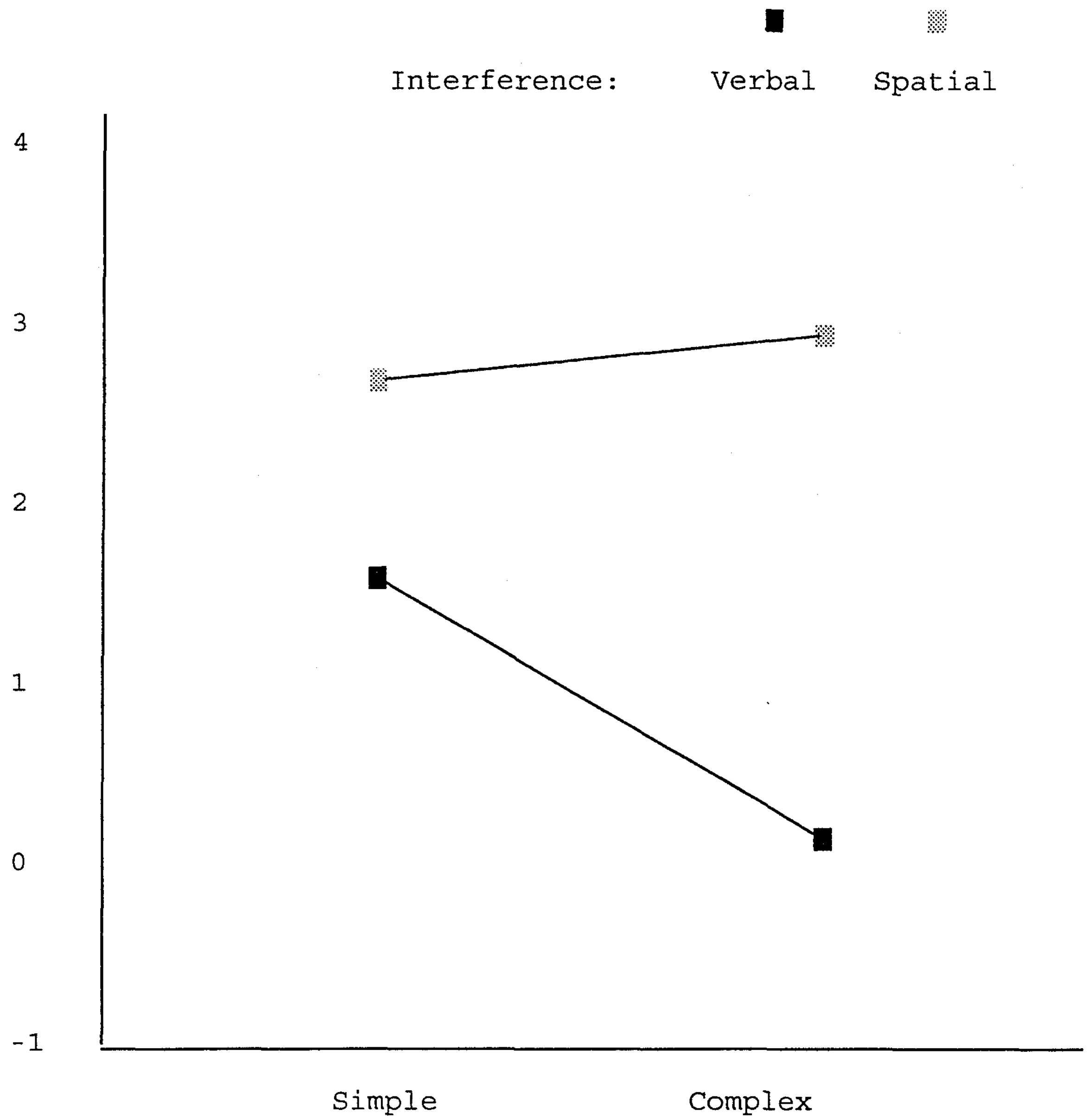

Figure 2

Experiment 1: Total Response Latency Difference Scores (in Seconds) as a Function of Problem Complexity and Interference Type.

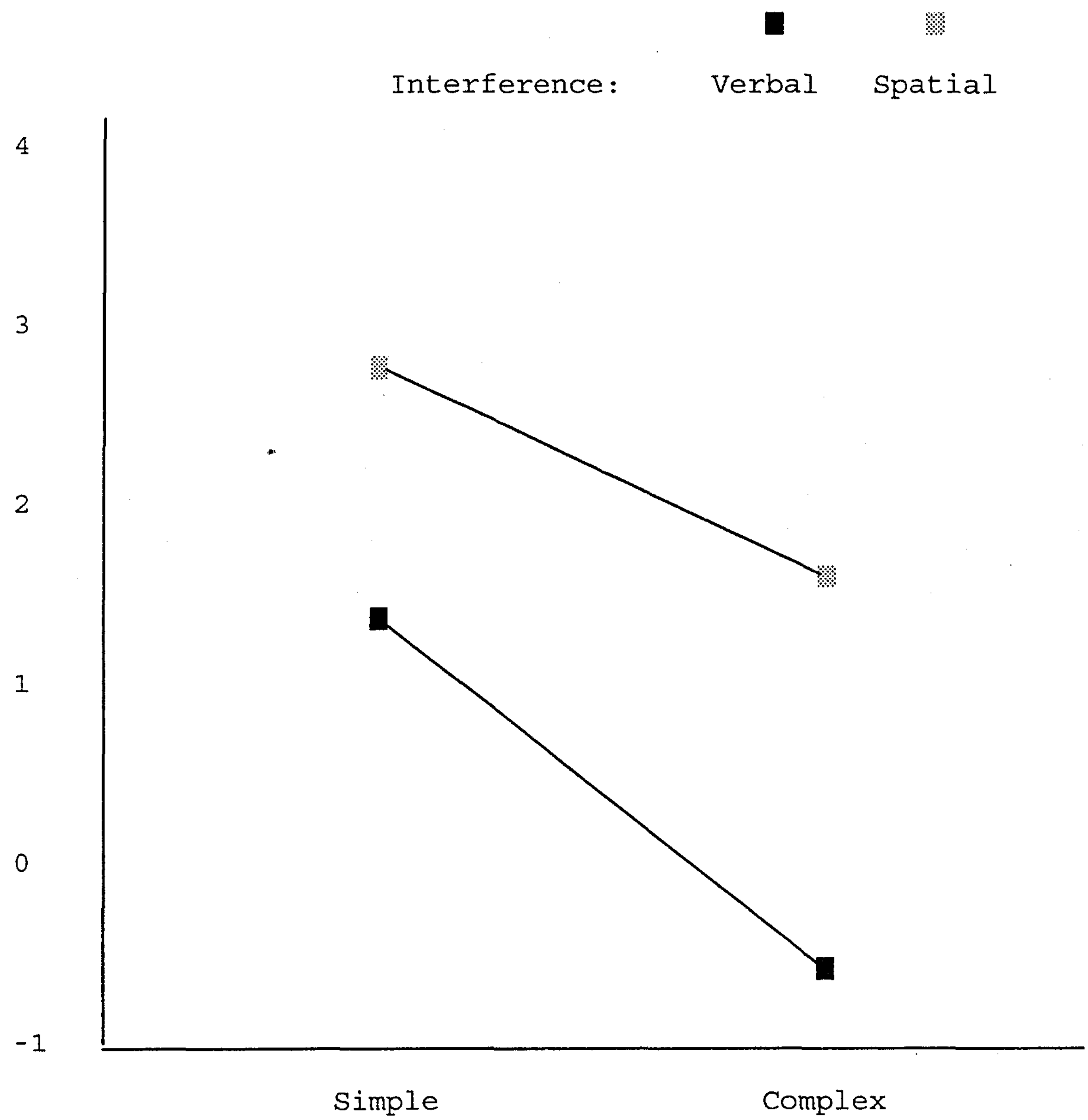

Figure 3

Experiment 1: Total Response Latency Difference Scores (in Seconds) as a Function of Problem Complexity and Interference Type. Males Only.

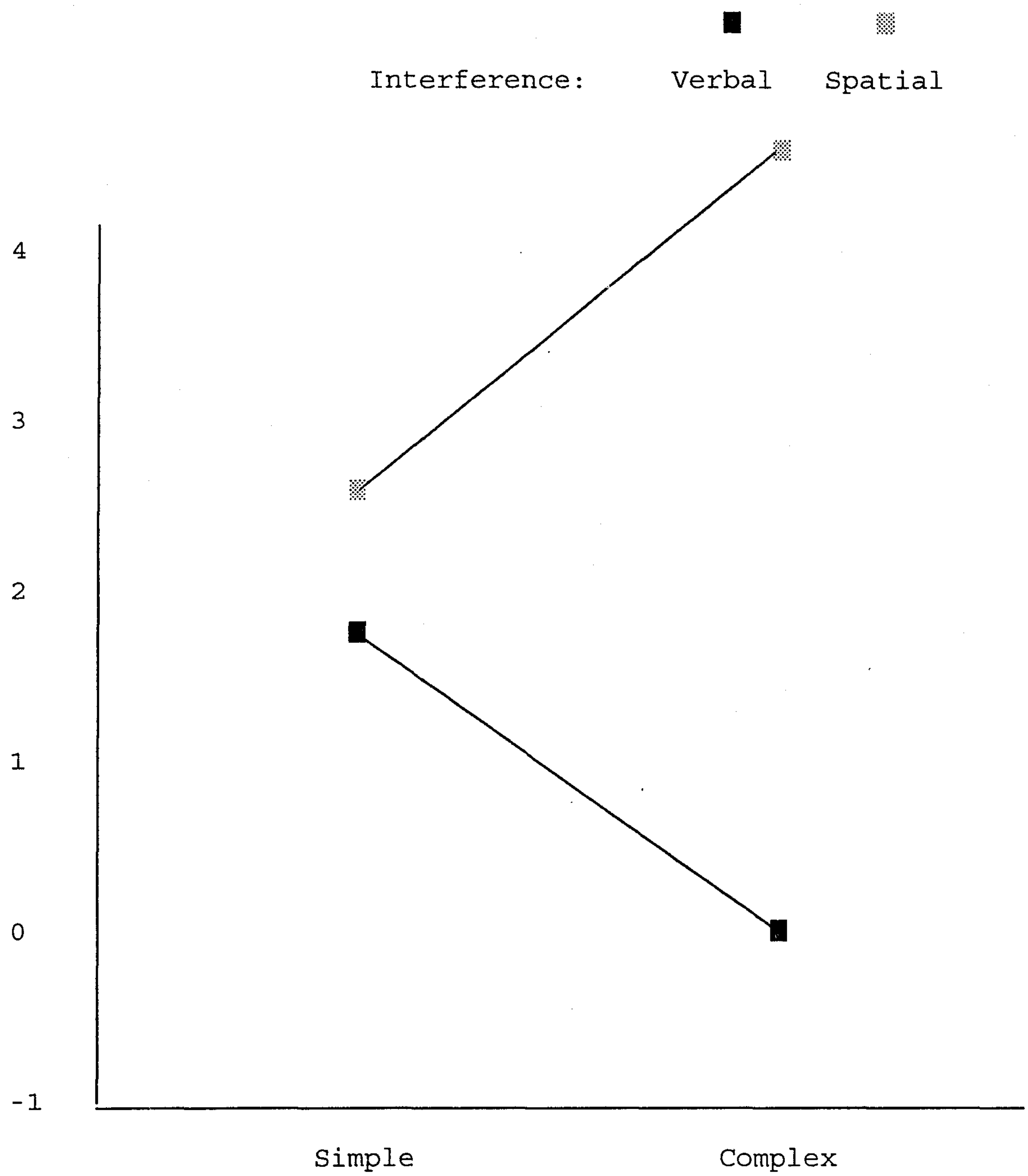

Figure 4

Experiment 1: Total Response Latency Difference Scores (in Seconds) as a Function of Problem Complexity and Interference Type. Females Only.

Table 3

Experiment 1: Mean Premise Response Latencies (in Seconds) as a Function of Problem Complexity, Interference Type, and Gender. (Standard deviations are in parentheses.)

	Males		Females	
	Simple	Complex	Simple	Complex
None	8.29	12.55	7.26	10.57
	(3.27)	(4.39)	(2.37)	(4.19)
Verbal	10.08	12.96	9.89	12.82
	(3.92)	(5.81)	(3.65)	(5.77)
Spatial	10.29	13.93	9.73	14.96
	(4.66)	(5.48)	(3.30)	(4.58)

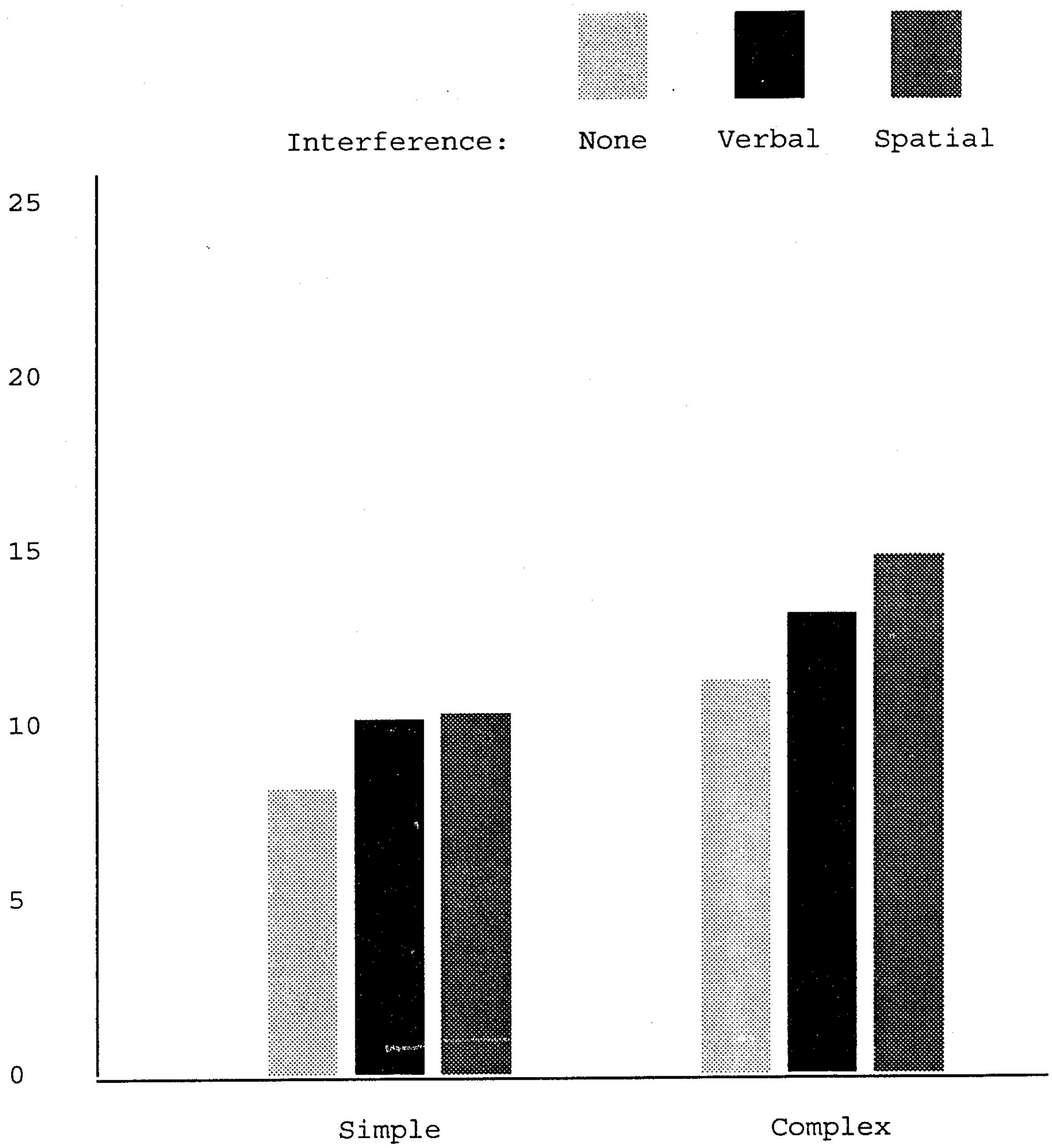

Figure 5

Experiment 1: Mean Premise Response Latencies (in Seconds) as a Function of Problem Complexity and Interference Type.

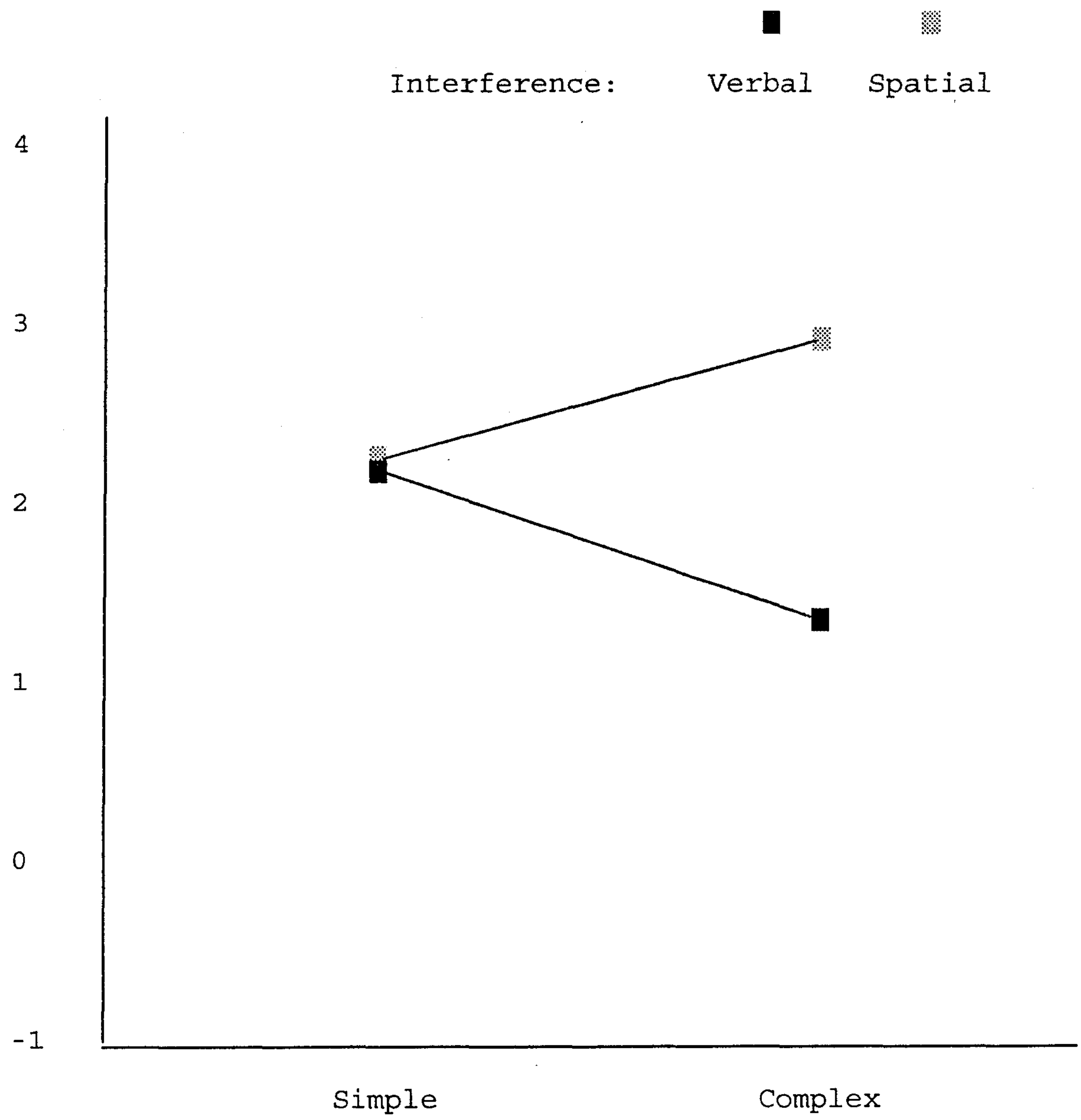

Figure 6

Experiment 1: Premise Response Latency Difference Scores (in Seconds) as a Function of Problem Complexity and Interference Type.

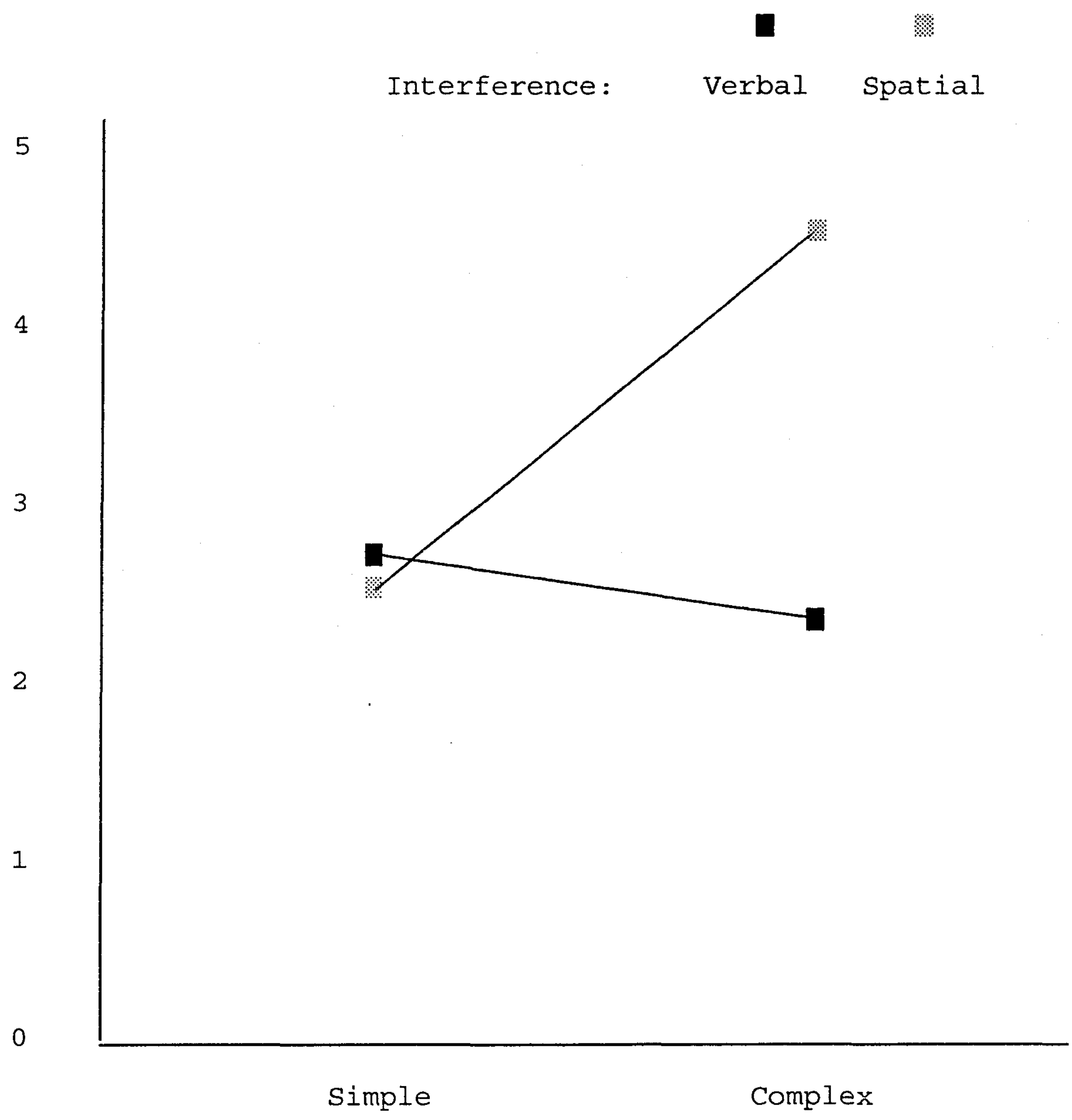

Figure 7

Experiment 1: Premise Response Latency Difference Scores (in Seconds) as a Function of Problem Complexity and Interference Type. Females only.

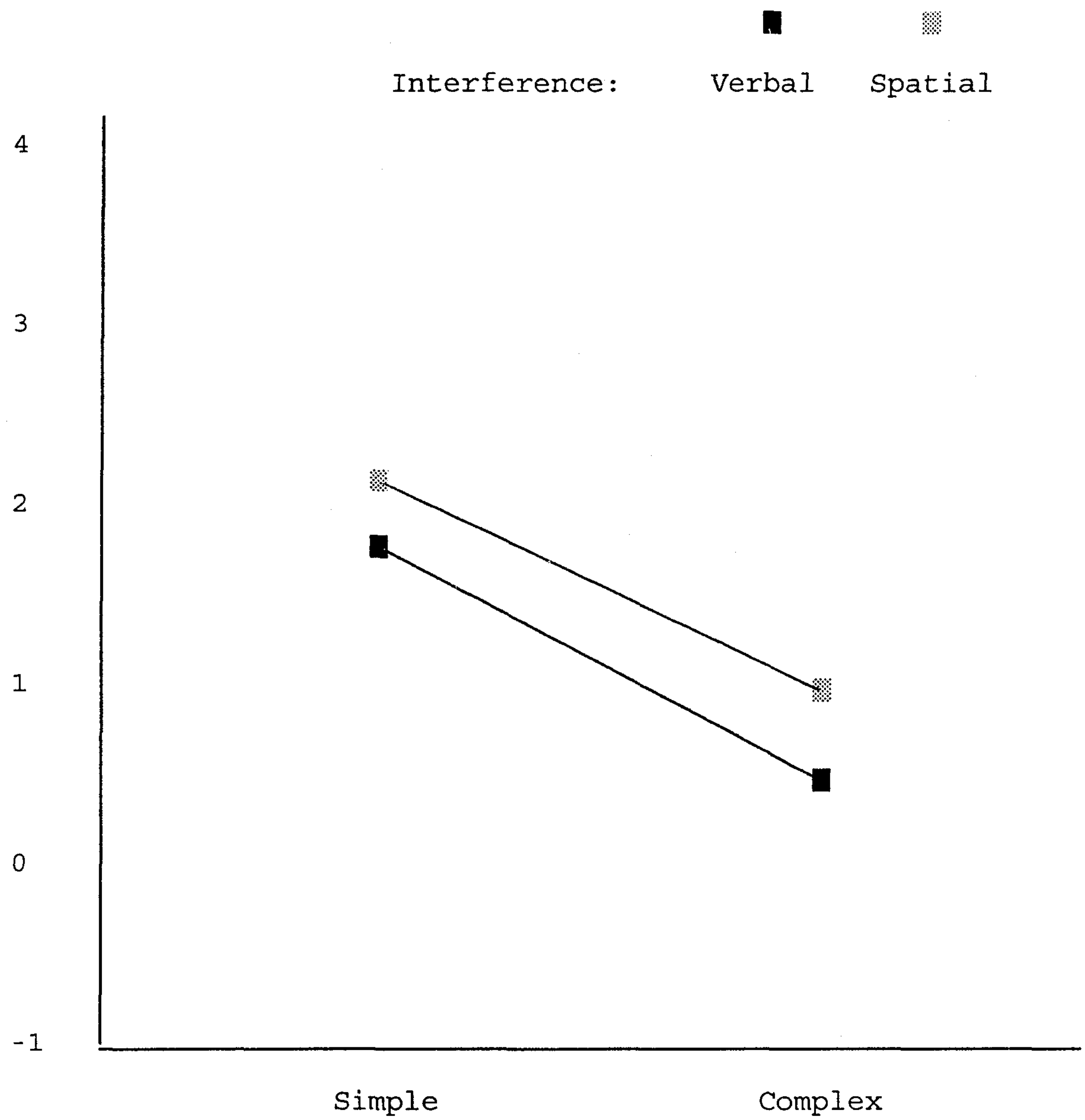

Figure 8

Experiment 1: Premise Response Latency Difference Scores (in Seconds) as a Function of Problem Complexity and Interference Type. Males only.

Table 4

Experiment 1: Mean Question Response Latencies (in Seconds) as a Function of Problem Complexity, Interference Type, and Gender. (Standard deviations are in parentheses.)

	Males		Females	
	Simple	Complex	Simple	Complex
None	3.06	3.65	3.98	4.49
	(1.07)	(1.75)	(2.33)	(2.12)
Verbal	2.57	2.60	3.07	3.18
	(1.20)	(1.20)	(1.66)	(1.46)
Spatial	3.85	3.75	3.98	4.49
	(2.32)	(1.56)	(1.77)	(1.91)

Table 5

Experiment 2: Mean Proportion of Correct Answers to Problem Questions as a Function of Problem Ambiguity, Interference Type, and Gender. (Standard deviations are in parentheses. Also note that means with an asterisk are not reliably different from chance performance, as measured by a t-test in comparison with a data set having a mean of .33 and comparable variability.)

	Males		Females	
	Unambiguous	Ambiguous	Unambiguous	Ambiguous
None	.94	.81	.83	.59
	(.11)	(.27)	(.18)	(.29)
Verbal	.78	.53	.70	.34*
	(.26)	(.24)	(.19)	(.24)
Spatial	.89	.69	.80	.42*
	(.13)	(.30)	(.26)	(.31)

Table 6

Experiment 2: Mean Total Response Latencies (in Seconds) as a Function of Problem Ambiguity, Interference Type, and Gender. (Standard deviations are in parentheses.)

	Males		Females	
	Unambiguous	Ambiguous	Unambiguous	Ambiguous
None	12.71	15.90	10.02	13.78
	(5.49)	(5.38)	(3.07)	(3.72)
Verbal	15.13	14.74	11.28	12.50
	(6.54)	(5.73)	(2.97)	(4.36)
Spatial	14.15	16.78	12.06	13.88
	(6.06)	(5.16)	(3.02)	(4.94)

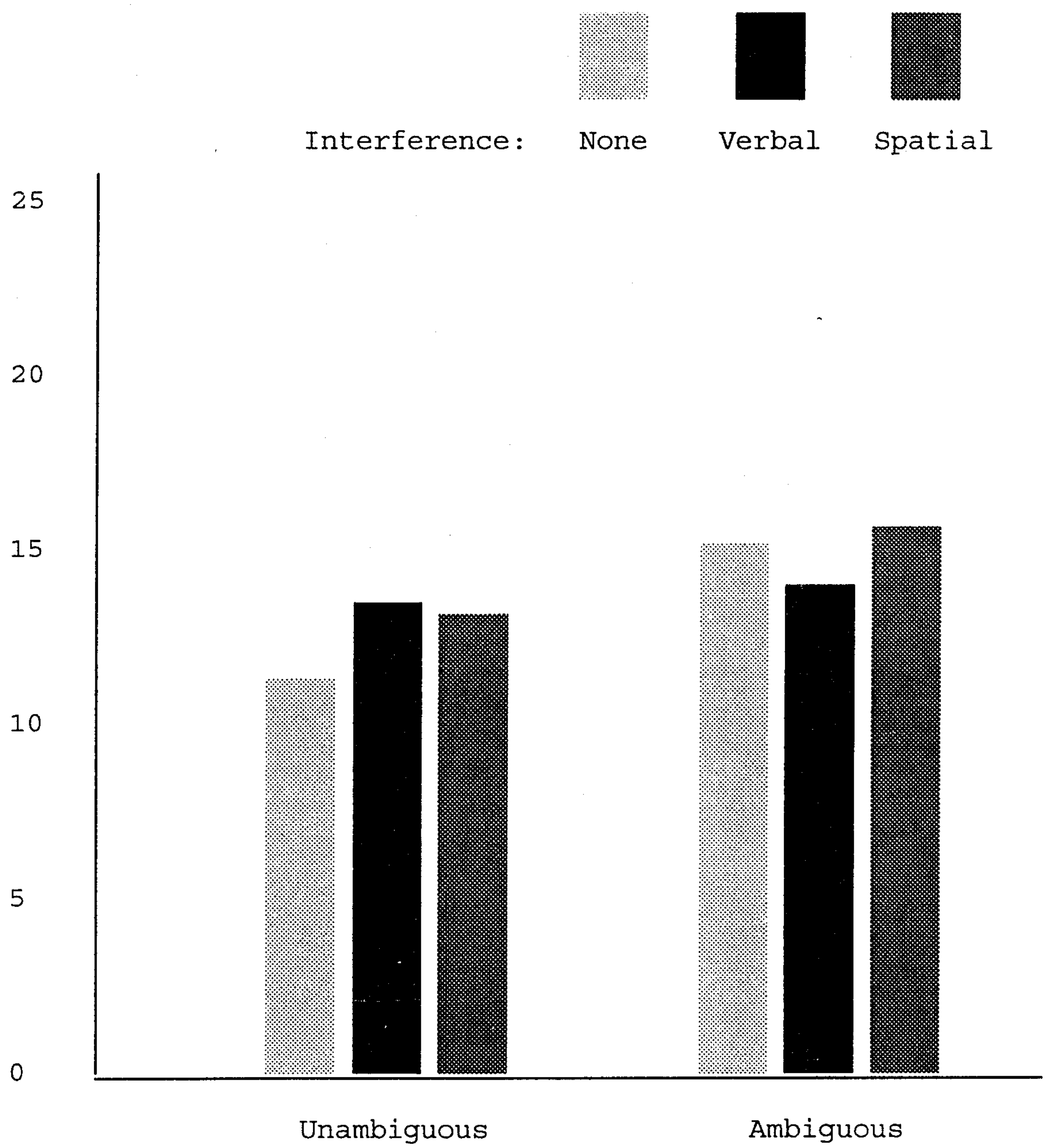

Figure 9

Experiment 2: Mean Total Response Latencies (in Seconds) as a Function of Problem Ambiguity and Interference Type.

Table 7

Experiment 2: Mean Premise Response Latencies (in Seconds) as a Function of Problem Ambiguity, Interference Type, and Gender. (Standard deviations are in parentheses.)

	Males		Females	
	Unambiguous	Ambiguous	Unambiguous	Ambiguous
None	9.74	12.22	7.42	9.70
	(4.39)	(4.24)	(2.70)	(2.96)
Verbal	12.52	11.73	9.09	9.86
	(5.74)	(5.13)	(2.40)	(3.92)
Spatial	11.32	12.96	9.20	9.77
	(5.23)	(4.31)	(2.66)	(2.99)

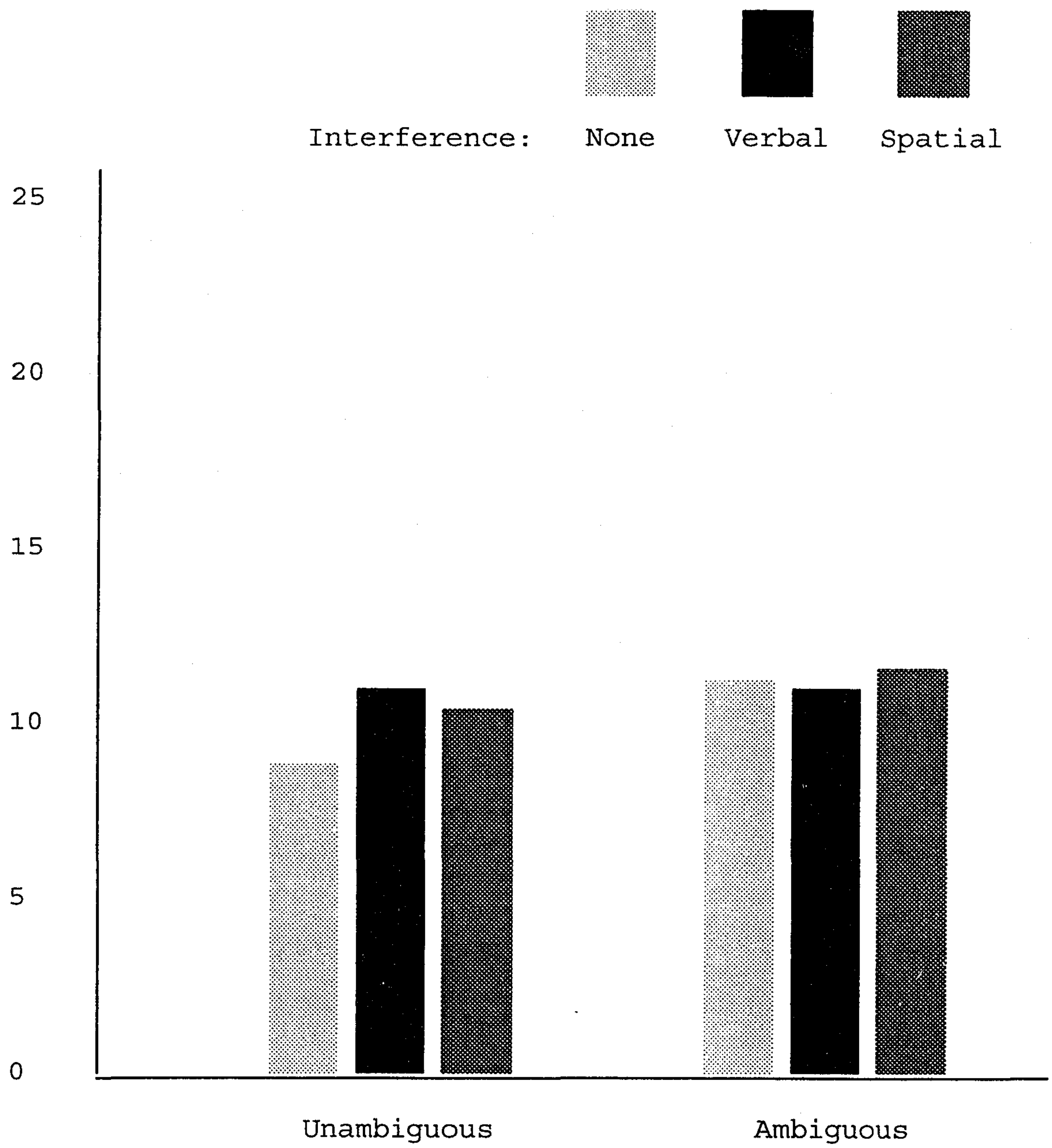

Figure 10

Experiment 2: Mean Premise Response Latencies (in Seconds) as a Function of Problem Ambiguity and Interference Type.

Table 8

Experiment 2: Mean Question Response Latencies (in Seconds) as a Function of Problem Ambiguity, Interference Type, and Gender. (Standard deviations are in parentheses.)

	Males		Females	
	Unambiguous	Ambiguous	Unambiguous	Ambiguous
None	2.97	3.68	2.61	4.08
	(1.33)	(1.53)	(0.94)	(1.36)
Verbal	2.61	3.01	2.19	2.64
	(1.12)	(1.06)	(0.80)	(0.95)
Spatial	2.83	3.82	2.86	4.11
	(1.14)	(1.25)	(1.32)	(2.39)

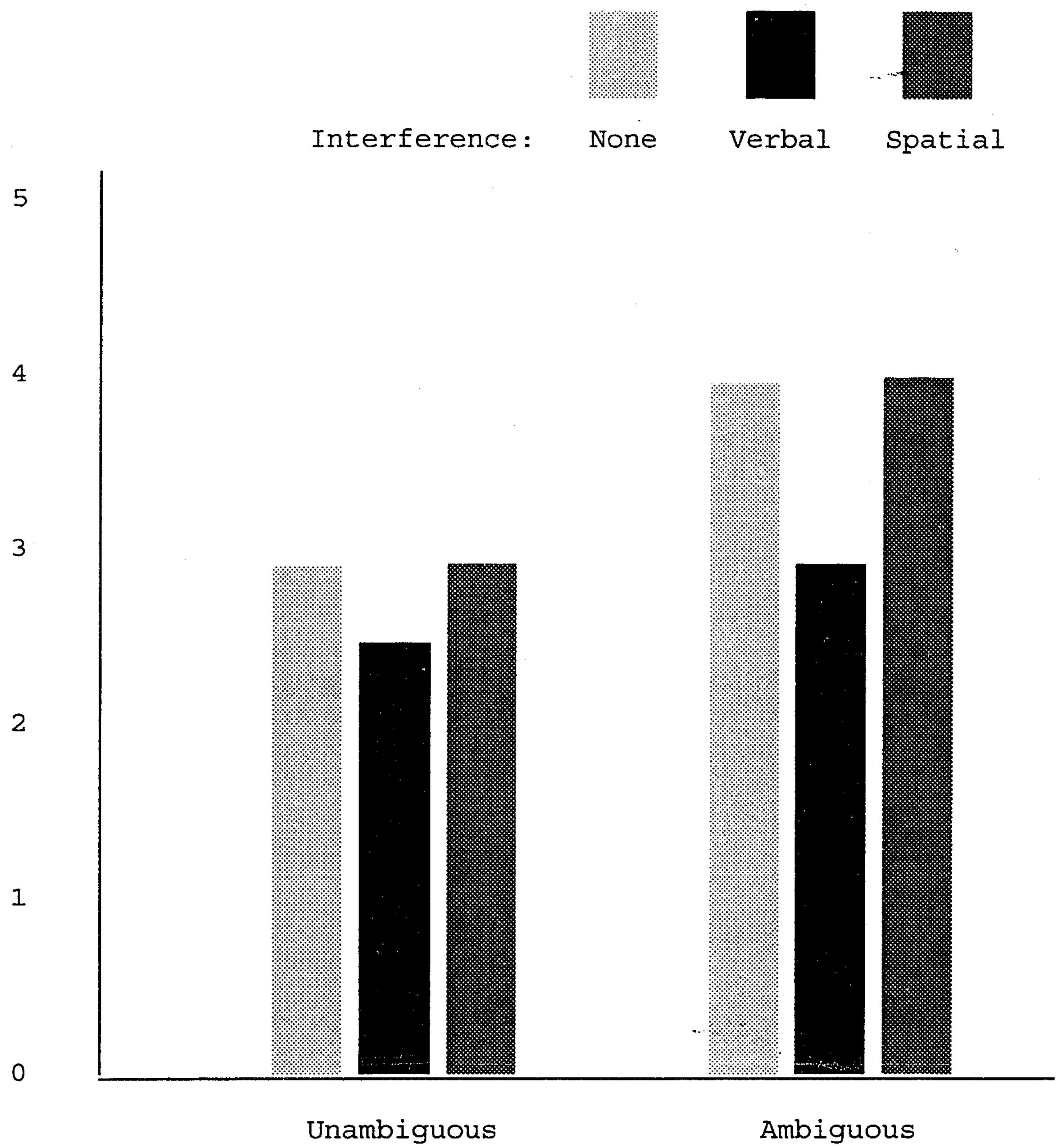

Figure 11

Experiment 2: Mean Question Response Latencies (in Seconds) as a Function of Problem Ambiguity and Interference Type.