Interaction and Analogy in the Comprehension and Appreciation of Metaphors

Robert J. Sternberg and Georgia Nigro

Department of Psychology
Yale University
New Haven, Connecticut 06520

Technical Report No. 26
October, 1980

Approved for public release; distribution unlimited. Reproduction in whole or in part is permitted for any purpose of the United States Government.

This research was sponsored by the Personnel and Training Research Programs, Psychological Sciences Division, Office of Naval Research, under Contract No. N0001478C0025, Contract Authority Identification Number NR 150-412.
Two experiments tested a theory of information processing in metaphor comprehension and appreciation. According to this theory, certain kinds of metaphors are based upon underlying analogies, and the processing components used to interpret these metaphors are highly similar to those used in the interpretation of analogies. A critical difference in the two kinds of information processing, however, is in the interaction of tenor and vehicle in the interpretation of a metaphor; a comparable interaction does not occur.
in the interpretation of the domain (first half) and range (second half) of an analogy. In the first experiment, modeling of latencies for comprehending analogies and corresponding metaphors showed that information processing was similar, but not identical, in the two tasks. In the second experiment, comparisons between different metaphoric forms showed that the proposed theory could account for ratings of the aptness and comprehensibility of various metaphors, and that making more clear the identities of the terms of the analogy underlying a metaphor and the nature of the interaction between tenor and vehicle increases both aptness and comprehensibility of a metaphor.
Interaction and Analogy in the Comprehension and Appreciation of Metaphors

Robert J. Sternberg and Georgia Nigro

Yale University

Running head: Metaphor

Send proofs to Robert J. Sternberg
Department of Psychology
Yale University
Box 11A Yale Station
New Haven, Connecticut 06520
Two experiments tested a theory of information processing in metaphoric comprehension and appreciation. According to this theory, certain kinds of metaphors are based upon underlying analogies, and the processing components used to interpret these metaphors are highly similar to those used in the interpretation of analogies. A critical difference in the two kinds of information processing, however, is in the interaction of tenor and vehicle in the interpretation of a metaphor; a comparable interaction does not occur in the interpretation of the domain (first half) and range (second half) of an analogy. In the first experiment, modeling of latencies for comprehending analogies and corresponding metaphors showed that information processing was similar, but not identical, in the two tasks. In the second experiment, comparisons between different metaphoric forms showed that the proposed theory could account for ratings of the aptness and comprehensibility of various metaphors, and that making more clear the identities of the terms of the analogy underlying a metaphor and the nature of the interaction between tenor and vehicle increases both the aptness and the comprehensibility of a metaphor.
Interaction and Analogy in the Comprehension and Appreciation of Metaphors

In comprehending and appreciating a metaphor, we conceive of something new in terms of something old. In the metaphor "Man is a wolf," for example, the new term, or tenor of the metaphor, man, is seen in terms of the old term, or vehicle of the metaphor, wolf. The basis for the comparison between man and wolf, or ground of the metaphor, is left implicit. Indeed, the extent to which one will comprehend and appreciate the metaphor will depend in large part upon the extent to which one can ascertain what the ground or grounds are that relate(s) the two terms of the metaphor. In this and other metaphors, "newness" and "oldness" refer to ways of seeing things, rather than to the things themselves. For example, almost everyone will have been familiar with many of the properties of men and wolves prior to seeing the metaphor for the first time; but at least some of these people will not have thought about the properties of men in terms of the properties of wolves.

Because the conception of something new in terms of something old forms the basis for analogical thinking as well as for metaphorical thinking, and because analogical thinking has generally been thought to comprise a broader range of mental phenomena than has metaphorical thinking, some students of metaphor have been inclined to view metaphorical understanding as a form of analogical thinking (e.g., Aristotle, 1927; Billow, 1975; Centner, 1977; Miller, 1979; Sapir, 1977; Sternberg, Tourangeau, & Nigro, 1979). On this view, the metaphor "man is a wolf" can be viewed as an implicit analogy in which the properties of a man are seen as relating to a man in a way analogous to that in which the properties of a wolf are seen as relating to a wolf. There are a number of specific viewpoints that are consistent with the general framework in which metaphors are seen as based in some way upon underlying analogies. Two specific viewpoints of particular contemporary interest are the comparison
Metaphor

and interaction ones (cf. Tourangeau & Sternberg, Note 1).

Strict comparison theorists view metaphors as essentially analogies with missing terms, and nothing more. Miller's (1979) view of a metaphor "as a comparison statement with parts left out" (p. 226) comes close to this strict comparison view, as does his quotation of the definition of a metaphor in Webster's New International Dictionary (2nd ed.): "A metaphor may be regarded as a compressed simile" (cf. Miller, 1979, p. 226). Indeed, Miller sees as a major goal of his theorizing a response to Black's (1962) criticism that the comparison view of metaphor "suffers from a vagueness that borders on vacuity" (p. 37). Miller proposes that "the comparison view of metaphor can be made considerably less vague" (p. 227), and indeed, Miller does clarify the comparison point of view. For example, Miller suggests that underlying the metaphor, "The lion is the king of beasts," is the incomplete analogy, "lion : beasts :: king : ?." Other metaphors, such as "Britain was the ruler of the waves," "George Washington was the father of his country," and "André Weil is the Bobby Fischer of mathematics," can be understood in the same way, namely, as implicit and incomplete analogies. As one can make the transition from a metaphor to an analogy, so can one make the transition from an analogy to a metaphor. An analogy such as "toes : foot :: fingers : hand" can be re-formed into a metaphor, "The toes are the fingers of the foot," where the fourth term of the analogy, "hand," is left implicit. Miller provides a detailed formal analysis of these kinds of proportional metaphors that shows their proposed basic isomorphism to analogies.

Interaction theorists can view analogies as underlying metaphors, but they propose that to view metaphors as nothing more than analogies with missing implicit terms is to miss the essence of metaphor. Richards (1936), for example, has suggested that "when we use a metaphor we have two thoughts of different
things active together and supported by a single word, or phrase, whose meaning is a resultant of their interaction" (p. 93). Richards has further viewed metaphor as "fundamentally a borrowing between and intercourse of thoughts, a transaction between contexts" (p. 94), and as requiring two ideas "which co-operate in an inclusive meaning" (p. 119). On this view, then, metaphor is more than an analogy with missing parts. In Black's (1962) terms, "the new context...imposes extension of meaning upon the focal word" (p. 39).

One's interpretation of the tenor changes as a result of the tenor's interaction with the vehicle. Consider, for example, the metaphor "Man is a wolf." On the comparison view, a person might be seen as mapping properties of a wolf onto a man, and seeing the extent to which they fit. On the interaction view, a person might be seen as reorganizing his or her views about men in terms of wolf-like properties.

A suitable hearer will be led by the wolf-system of implications to construct a corresponding system of implications about the principal subject. But these implications will not be those comprised in the commonplaces normally implied by literal uses of "man." The new implications must be determined by the pattern of implications associated with literal uses of the word "wolf." Any human traits that can without undue strain be talked about in "wolf-language" will be rendered prominent, and any that cannot will be pushed into the background. The wolf-metaphor suppresses some details, emphasizes others—in short, organizes our view of man. (Black, 1962, p. 41)

Do people attempting to understand and appreciate metaphors actually treat some subset of them analogically, representing information and then processing it in ways similar to those used in the representation and processing of information in the solution of analogies? If so, is there an interaction between the tenor and vehicle of the metaphor? We shall consider each question in turn.

Several empirical investigations have suggested that analogies can underlie metaphorical statements.
Tourangeau and Sternberg (in press) tested a refined and augmented version of a theory of mental representation in metaphorical reasoning first explicated by Sternberg, Tourangeau, and Nigro (1979). The theory of representation is based upon that applied to analogical reasoning by Rumelhart and Abrahamson (1973) and extended to other forms of inductive reasoning by Sternberg (1979, 1980) and Sternberg and Gardner (Note 2). On this view, information can be represented by means of a multidimensional "semantic space" in which each dimension represents some graded characteristic of the set of concepts under consideration (Fillenbaum & Rapoport, 1971; Henley, 1969; Rips, Shoben, & Smith, 1973; Rumelhart & Abrahamson, 1973). We found it necessary to generalize the notion of a semantic space by introducing a concept of "orders" of spaces so as to accommodate our theory of what makes some metaphors more apt than others. These orders represent the various levels of abstraction of the terms of the various spaces. For example, mammals and birds might each form subspaces in a hyperspace of animals. We tested our representational theory in two experiments. In Experiment 1, subjects rated the aptness of metaphors such as "A wildcat is a hawk among mammals." The prediction relevant in our present context was that metaphors would be rated as more apt to the extent that the location of the tenor (here, "wildcat") in its semantic subspace (here, "mammals") was analogous to the location of the vehicle (here, "hawk") in its subspace (here, "birds"). In other words, the terms of the metaphor were hypothesized to form a cross-subspace analogy (see also Rips, Shoben, & Smith, 1973). This prediction was confirmed. In Experiment 2, metaphors were presented in a format exemplified by "A wildcat is a ____ among mammals," where multiple possible response options were provided for the missing term, e.g., "(a) robin, (b) ostrich, (c) hawk, (d) bluejay." Subjects were asked to rank-order the options in terms of their goodness of fit. An exponential model of response choice
such as that used for analogies by Rumelhart and Abrahamson (1973) was found to provide a good fit to the response-choice data.

Billow (1975) presented children in the age range from 5 to 13 with proportional metaphors such as "My head is an apple without any core." These metaphors were hypothesized to have implicit analogies underlying them, in this case, "head : apple :: brain : core." The subject's task was to interpret each metaphor as accurately as possible. Many of the errors subjects made in comprehending the metaphors were identical in kind to errors made by children in comprehending analogies (see Achenbach, 1970; Gallagher & Wright, 1979; Lunzer, 1965; Piaget with Montangero & Billeter, 1977; Sternberg & Nigro, 1980), for example, global interpretations, associative responding, or convergences on similar features between elements. Some responses showed partially successful efforts to deal with the underlying proportion; for example, elements of the proportion were added, but they were the wrong elements.

Gentner (1977) presented individuals from the preschool to the college level with pictures, and then required the individuals to reason metaphorically about the pictures. For example, she might show the individuals a picture of a mountain, and then ask them, "If this mountain had a knee, where would it be?" In an initial study, she found that preschool children could map such body parts to the inanimate objects as well as adults could do so. She then made the task more difficult by varying the orientation of the pictured objects or by adding misleading features to these objects. In this situation, children actually performed somewhat better than adults. Gentner concluded that even preschool children possess the ability to use analogy in understanding simple metaphors such as those in her study.
Winner, Engel, and Gardner (1980) presented metaphorical grounds in five different linguistic (surface-structural) formats: predicative metaphors (e.g., "The skywriting was a scar marking the sky"), topicless metaphors (e.g., "The ____ was a scar marking the sky"), similes (e.g., "The skywriting was like a scar marking the sky"), quasi-analogies (e.g., "A scar marks the skin and ____ marks the sky"), and riddles (e.g., "What is like a scar but marks the sky?"). Subjects—children aged 6, 7, and 9 years—were asked either to explain the meaning of the sentence, to fill in the blank, or to answer the question. There were two basic conditions in which these tasks were presented. In one, the subject had to fill in a blank or to answer a question, as appropriate; in the other, the subject had to choose the best of four alternative answer options. The investigators found that topicless metaphors were of about the same difficulty as the quasi-analogies in the first, explication condition, but more difficult than the analogies in the second, multiple-choice condition. The second finding confirmed their prior prediction that topicless metaphors would be more difficult than analogies; the first finding did not confirm their prior prediction.

Turning now to the second question posed earlier—that of whether there is an interaction between the tenor and vehicle of a metaphor—we offer what we consider to be at least tentative evidence that a metaphor differs from a straightforward analogy in the presence of an interaction between the domains of its tenor and vehicle.

Malgady and Johnson (1976) presented subjects with metaphors couched in five different formats. In one format, nouns in the metaphors were modified
by adjectives that related to both of the nouns, e.g., soft hair and shiny silk; in a second format, nouns in the metaphors were modified by adjectives that related only to the individual nouns to which they were paired, e.g., long hair and elegant silk; in a third format, each noun in a metaphor was modified by an adjective that was inappropriate to that noun, but that was appropriate to the other noun in the metaphor, e.g., elegant hair and long silk; in a fourth format, nouns in a metaphor were modified by adjectives that were not related to either noun, e.g., distant hair and fatal silk; and in a fifth format, the metaphor consisted only of two unmodified nouns. In three parts of an experiment, subjects were asked either to give similarity judgments between groups of words, to rate goodness of metaphors, or to interpret metaphors. The authors found that it was possible to predict metaphor goodness and interpretability from changes in similarity induced by different patterns of adjective modification. Metaphor goodness and interpretability were highest where both adjectives were consonant with both nouns (e.g., soft hair and shiny silk could be recast as shiny hair and soft silk and still make sense), and respectively lower as overall consonance between adjectives and nouns decreased. Most relevant here was the finding that goodness and interpretability were lower when adjectives were consonant with the noun they were modifying but not the other noun that they were not modifying than when adjectives were consistent with both nouns. Malgady and Johnson interpreted these results as being consistent with Johnson's (1970) proposal that

elementary cognitive features which encode the meaning of each metaphor constituent are summed to form a single representation, qualitatively distinct from that of the constituents. As Johnson, [Malgady, and Anderson (Note 3)] suggested, the act of juxtaposing two words, whether in word association or metaphor, creates a single meaning. (Malgady & Johnson, 1976, p. 51)
Verbrugge (1977) has made a proposal similar to that advanced by Black (196?) and by Johnson et al. (Note 3), namely, that metaphor "involves a fusion of both events [tenor and vehicle], and thus a transformation or warping of each domain according to the particular constraints of the other" (p. 385). Verbrugge based this position on a series of studies of prompted recall by Verbrugge (Note 4) and by Verbrugge and McCarrell (1973), in which people, when given metaphors such as "skyscrapers are the giraffes of a city," actually visualized a huge giraffe in the middle of a city skyline, with the neck of the giraffe extending far above the "other" buildings. The more compatible the tenor and vehicle were, the more the fusion that took place.

To conclude, there is at least some evidence to suggest that (a) at least some metaphors are processed in ways highly similar to the ways in which analogies are processed, and that (b) to the extent there is dissimilarity, it may be due in part to a special kind of interaction between tenor and vehicle that takes place in analogical correspondences that are peculiarly metaphoric in nature. The present article seeks to extend the theoretical and empirical data base supporting these contentions. In particular, a metaphor is seen as based upon an underlying analogy for which some of the terms may be implicit, but is seen as differing from this analogy in the interaction of the tenor with the vehicle. Whereas this view probably does not apply to all possible metaphors, it seems to apply to a large and interesting enough subset of them to make pursuit of the point of view worthwhile.

The present article may be viewed as a companion paper to the Tourangeau and Sternberg (in press) paper, in that whereas that article refines and augments the representational theory of metaphor presented in
Sternberg, Tourangeau, and Nigro (1979) and Tourangeau and Sternberg (in press), the present article refines and augments the information-processing theory presented in Sternberg, Tourangeau, and Nigro (1979). This theory uses as its conceptual basis the theory of analogical reasoning processes proposed by Sternberg (1977a, 1977b); the theory has since been extended to other forms of inductive reasoning processes as well (Sternberg, 1979, 1980; Sternberg & Gardner, Note 2). A discussion of the interface between representation and process in metaphoric comprehension and appreciation can be found in Sternberg, Tourangeau and Nigro (1979).

**Information-processing Theory of Metaphoric Comprehension**

On the present view, the information-processing components used to comprehend "proportional" metaphors (which are believed to constitute a large subset, but certainly not the whole set, of metaphors) are highly similar to those used to comprehend analogies. We will consider first how the theory applies to analogies, and then extend it to various kinds of metaphors.  

**Analogy**

Consider an analogy presented earlier as re-expressed in multiple-choice format: "lion : beasts :: king : (a) rulers, (b) humans." An individual solving this analogy must encode the terms of the problem, identifying the terms and retrieving from long-term memory the attributes that may be relevant for analogy solution. The individual must also infer the relation between the first two analogy terms, ascertaining what relation "lion" bears to "beasts." Next, the individual must map the higher-order relation that links the domain (first half) to the range (second half) of the analogy, ascertaining, for example, that the analogy is about the roles of lions and kings in their respective domains. Then, the individual takes the relation previously inferred from the first to the second term of the analogy and as mapped to the third term (second half) of the analogy and applies it from the third term in order to generate an ideal possible completion of the analogy. Suppose, for example, that a given subject
imagines this ideal completion to be "people." Then this term will be generated as a proposed completion. The individual must now compare the two (or whatever number of) answer options to the ideal in order to determine which is correct. If neither is identical to the ideal, as in the present instance, then the subject must justify one of the options, hero, "human," as closer to the ideal, although not itself the ideal. Finally, the subject must respond, communicating his or her response to the outside world.

Metaphors

All terms of underlying analogy explicit. Suppose the basic proposition relating lions to kings had been stated in the form, "A lion among beasts is a king among (a) rulers, (b) humans." In this event, the information-processing components needed to comprehend the metaphor are proposed to be the same as those required to comprehend the analogy described earlier. The subject must encode the given terms, infer the relation of lion to beasts, map the higher-order relation that links a lion in its domain to a king in its domain, apply the previously inferred relation as mapped to the new domain to generate an ideal answer, compare this answer to each of the alternatives, justify one of the given answers as better than the other, although possibly nonideal, and respond. The theorized identity of components does not imply equivalence in the difficulty of the metaphor and its corresponding analogy.

On the one hand, the additional verbal material contained in the metaphor increases the reading load of this presentation format; on the other hand, this additional mediating context may make the metaphor more readily comprehensible. Hence, the relative difficulties of the two presentation formats will depend upon the relative effects of increased reading load and increased mediating context. Normally, we would expect the presentation of more mediating context to increasing processing latency (through added reading time) at the same time that it increases rated comprehensibility of a metaphor.
Some terms of underlying analogy implicit. Proportional types of metaphors are often presented in ways that leave at least some of the terms of the underlying analogy implicit. The "lion and king" metaphor, for example, could be presented in any of the following formats (among others), where either no terms or some terms are left implicit:

1. A lion among beasts is a king among people.
2. A lion among beasts is a king.
3. A lion is a king among people.
4. A lion is a king.
5. A lion is a king among beasts.

Multiple-choice format could be introduced into these metaphors by allowing multiple answer options in place of a single last (or other) term. The exact set of components used would depend upon the response format. Comparison and justification, for example, are used only if multiple-choice rather than free-response format is used. Where in the metaphor the components are actually executed can also vary as a result of presentation format. In the metaphorical forms, "A lion is a king among _____" and "A _____ is a king among beasts," inference occurs in the vehicle, since it is a term in the topic that is missing. Inference of relations in the vehicle is actually fairly common, since it is the new information in the tenor that is presented most often in terms of the old information in the vehicle: One infers relations between known elements and then applies them to unknown elements.

An important thing to notice in these various metaphorical forms is that different terms are left implicit in different forms of presentation. These different forms may differ in their comprehensibility, as well as in their aptness, as a function of the terms that are left implicit, and, in the fifth form, as a function of the reordering of terms: "Beasts," the second term of the implicit analogy, is presented last. On the present theory, the reason for
these variations in comprehensibility and information-processing difficulty would be found in the fact that these forms require not only comprehension of the explicit terms and of the relations that can be formed between these terms, but also the generation of terms that are left implicit, and the comprehension of relations between these pairs of terms (as well as between implicit and explicit ones). Miller (1979) seems to share a similar view.

As mentioned earlier, there are two possible effects of presenting additional context on comprehensibility. One is that reading load may be increased, presumably adding to processing time if not difficulty; the other is that the need to generate new terms can make processing of metaphors more difficult either through the sheer time and effort expended on this generation, or through the generation of incorrect terms, which can reduce the meaningfulness of the metaphor. Overall, adding additional terms should probably increase processing latency, but also increase comprehensibility by making more clear the nature of the implicit analogy.

The effects of presenting additional context on aptness can also work one of two ways: On the one hand, part of the satisfaction one derives from a metaphor may result from the insertion of missing terms—in effect, one actively participates in the construction (for oneself) of the metaphor; on the other hand, subjects' incorrect or inadequate constructions may decrease the aptness of the various forms, or aptness may be decreased by the subject's failure to make the constructions at all. Given the positive relationship between aptness and comprehensibility (Tourangeau & Sternberg, in press), we would expect that the increase in context should increase the aptness of a metaphor by making more clear what the underlying analogy is, and by decreasing the risks of mistakes in insertion of terms.

Relations between comprehensibility and aptness. As mentioned above, comprehensibility and aptness of metaphors are positively related: Tourangeau and
Sternberg (in press) found them to be highly correlated, and found that ratings of comprehensibility increased predictability of ratings of aptness, even after all parameters of their representational theory were entered into the prediction equation (but see Gerrig and Healy (Note 5)). On our theory, aptness is in part a function of comprehensibility. A metaphor cannot be viewed as apt if it is not understood. One way of increasing comprehensibility is to increase the number of terms of the underlying analogy that are made explicit rather than left implicit; a second way is to make more clear or vivid the nature of the interaction between tenor and vehicle. Resulting increases in comprehensibility should lead to derivative increases in aptness.

**Interaction.** We suggest that quality and clarity of interaction between tenor and vehicle in a metaphor can increase the aptness of that metaphor, beyond the aptness attained by the quality and clarity of the analogy underlying the metaphor. Hence, any manipulation that increases the probability of a subject's appreciating the interaction between tenor and vehicle should increase aptness of a metaphor.

**Hypotheses.** We performed two experiments to investigate several hypotheses suggested by the theoretical analysis above, namely:

1. The information-processing components used in the understanding of metaphors and especially metaphors with relatively fewer implicit terms should be highly overlapping with the components used in the understanding of analogies.

2. Metaphors should become more comprehensible and be viewed as more apt as
   a. the number of terms of the underlying analogy that are made explicit is increased, thereby clarifying the meaning of the metaphor;
   b. the nature of the interaction between tenor and vehicle is clarified by the language in which the metaphor is presented.

3. Ratings of comprehensibility and of aptness of metaphors should be significantly correlated. Comprehensibility is viewed as a necessary, but not
sufficient condition for aptness.

The first experiment investigated in particular the first hypothesis. Base statements were presented either in metaphorical or analogical form with two forced-choice options for completion of the statements. All elements in the metaphors from the underlying analogy were made explicit. Subjects were asked to complete the statements as quickly and as accurately as possible. The second experiment investigated all three hypotheses, concentrating in particular upon the second and third ones. This investigation dealt with intrarelationships among the various metaphorical forms in which differing numbers and identities of terms are left implicit, and investigated also the interrelationships of these metaphorical forms to analogies. This experiment presented subjects with the five metaphorical formats described earlier. These formats differed in the number of terms of the underlying analogy that were made explicit and in the order in which these terms were presented. The critical comparison, for our purposes, was between the second format (e.g., "Bees in a hive are a Roman mob") and the fifth format (e.g., "Bees are a Roman mob in a hive") (see Table 1.) The formats are identical in the numbers and identities of the terms of the underlying analogy that is presented in the metaphor. But in the second format, the terms of the underlying analogy, \( A : B :: C : D \), that are made explicit in the metaphor are presented in the order, \( A-B-C \); in the fifth format, those terms are presented in the order, \( A-C-B \). If correspondence to the underlying analogical form were all that mattered in determining the aptness of a metaphor, then the second format would be rated as more apt than the fifth. Yet, we predicted that metaphors in the fifth format would be rated as more apt than those in the second format, because we believed that the fifth format more encouraged
subjects to form an interactive image relating the tenor and vehicle of the metaphor than did the second format, and that the creation of an interactive image linking tenor and vehicle would contribute more to aptness than would adherence to strict analogical form. This prediction was tested in the second experiment.

We wish to emphasize that we are claiming neither that our theory applies to all possible metaphors, nor that the theory (including representational elements in the Sternberg, Tourangeau, and Nigro, 1979, article) is a complete theory of metaphorical understanding. Rather, we believe that the theory deals with several interesting issues among many others in the metaphorical domain, and that it applies to an interesting subset of metaphors. For reviews of these and other theoretical issues, we refer readers to Billow (1977); Black (1962); Ortony (1979a, 1979b); Ortony, Reynolds, and Arter (1978); Tversky (1977); and Tourangeau and Sternberg (in press, Note 1).

**Experiment 1**

In this experiment, base statements were presented either in metaphorical or analogical form with two forced-choice options. Subjects completed the statements as quickly and accurately as possible, and were timed as they did so. Global and componential aspects of information processing were compared across tasks.

**Method**

**Subjects.** Subjects in the main part of the experiment were 96 students at Yale University who were paid for their participation in the experiment. Another
72 subjects provided various ratings needed in the mathematical modeling of the latency data, and 20 additional subjects provided ratings of interactive imagery for each of the 5 forms of the 50 metaphors used.

**Materials.** Experimental stimuli for subjects providing latencies were sentential metaphors and corresponding analogies typed in large (IBM ORATOR) capital letters on 4" x 6" index cards. All items ended with two possible completions, with subjects required to select the better of the two completions. A complete list of the 50 metaphors used in the experiment is shown in Table 1. The metaphors were gleaned from various psychological experiments reported in the literature, as well as from our own efforts at creation. Analogies were identical to the metaphors except for the deletion of mediating verbal content. For example, the metaphor, "A pear on a sill is a Buddha in a (a) temple, (b) puddle" would be presented as "pear : sill :: Buddha : (a) temple, (b) puddle."

--- Insert Table 1 about here ---

An attempt was made to construct metaphors that varied in their comprehensibility and in their aptness as well as in properties that were relevant to prediction of comprehension difficulty on the basis of the proposed theory of information processing. These aspects included relational distance between

1. the first and second analogy terms (used to estimate inference difficulty);
2. the first and third analogy terms (used to estimate mapping difficulty);
3. the third and ideal terms (used to estimate application difficulty);
4. the ideal and nonkeyed answer option (used to estimate comparison difficulty);
5. the relation between the first two terms and that between the third term and the keyed option (used to estimate justification difficulty).
This last distance should be zero if the analogy is perfect, and diverge from zero as the analogy becomes more imperfect. Encoding difficulty was manipulated by a precueing procedure described below, whereby differing numbers of terms were presented at different times on different experimental trials. Response component difficulty was not manipulated, since response was estimated as the regression constant.

**Design.** The two main independent variables were item format, which could be metaphorical or analogical, and condition of precueing (which could be either uncued or precued). These two variables were crossed with each other. Item format was a between-subjects variable, condition of precueing a within-subjects variable. In the uncued test trials, subjects received no advance information to facilitate their problem solving; in the cued test trials, subjects did receive such information. The main dependent variable was response time.

**Mathematical modeling.** Mathematical modeling was accomplished by predicting solution latencies for various metaphorical or analogical items from the independent variables. All independent variables were ratings except for that used to estimate encoding difficulty: Number of terms to be encoded, as manipulated by condition of precueing, was objectively determined. Modeling was done by linear multiple regression, using the SPSS REGRESSION program (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975). More detailed accounts of comparable mathematical modeling procedures can be found in Sternberg (1977a, 1977b, 1980, in press).
Apparatus. Metaphors and analogies were presented for response-time and response-choice measurement via a Gerbrands two-field tachistoscope with attached centisecond clock. In the ratings task, pairs of words (or in one case, pairs of pairs of words) were presented in booklets.

Procedure. In the metaphorical-presentation condition, subjects were told that they would see an incomplete statement followed by two words, for example, "The moon in the sky is a galleon in the (a) sea, (b) bath." They were then told that their task was to choose the better completion in as little time as possible. They were further told that trials will actually occur in two parts. In the first part of the trial, you will receive some amount of advance information. You should look at this advance information and do as much processing on it as you can. When you have finished looking at the advance information, press the bottom red button, which is in the middle of the button panel. The viewing field will become dark for about a second, and then the second part of the trial will begin. In the second part of the trial, you will always receive the full item. You should complete it, and then press the appropriate button on the button panel, ...

There are two conditions of advance information. Each represents successively more advance information. In one condition, you will see only a lighted blank field in the first part of the trial. Here there is no advance information. When you are ready to see the full problem, press the middle red button and about a second later, the full problem will appear. Solve the problem and press the correct answer button, ... In the other condition, you will see only the phrase on the top line [subjects are shown "The moon in the sky is"] in the first part of the trial. You will not see the phrase in the middle [subjects are shown "a galleon in the"] or the two answer options [subjects are shown "(a) sea, (b) bath"]. You should look at the phrase and do as much processing as you can to help solve the problem. When you are ready, press the bottom red button. The full problem will then appear. Solve the problem and press the correct answer button.
The 48 subjects in this condition received all 50 metaphors in one session. The actual test metaphors were preceded by some practice items, and succeeded by a full debriefing regarding the nature of the experiment. Although a given item was presented to a given subject only once, the items were divided into two quasiparallel forms so that each item type (where a type is defined by the relational distances relevant according to the componential theory of analogical reasoning) was presented once in each cueing condition. Order of cueing conditions was counterbalanced across subjects.

Procedure was the same in the analogical-presentation condition, except that the analogical format was substituted for the metaphorical one in the test items. There were also 48 subjects in this condition.

Subjects supplying ratings were divided into three groups. One group supplied ratings of the distance from the first to second, first to third, second to keyed, and third to keyed analogy terms. Another group supplied ratings of the distance from the third term to the imagined ideal response, from this imagined ideal response to the keyed option, and from the imagined ideal response to the unkeyed option. The third group supplied ratings of the distance between the relation of the first two terms and that of the third and keyed terms. Ratings were on scales of either 0-9 or 1-9, with higher values indicating greater distances. There were 24 subjects in each group.

Results

Basic statistics. Mean response latencies were 3.84 and 3.90 seconds for the metaphorical and analogical item formats, respectively. The difference between these latencies was nonsignificant, regardless of whether t was computed across subjects or item types (t < 1 in each case). Error rates were .06 in each condition, and these, too, obviously did not differ
significantly across subjects or items ($t < 1$ in each case). These mean data are thus consistent with the notion that similar processing components were used in each task. The correlation between latencies (computed across item types) was .80; that between error rates was not meaningful because of the very low error rates on individual item types. The correlation between latencies needs to be considered in conjunction with the internal-consistency reliability of the latency data, which was .90 for metaphors and .93 for analogies. The comparison between the task intercorrelation and the task reliabilities shows that although processing of metaphors and analogies was probably highly similar in nature, it was not identical in nature, since there was still some systematic variance left unaccounted for. As mentioned earlier, at least some difference would be expected, since the metaphors supplied mediating context that was absent in the analogies, and presumably involved tenor-vehicle interaction.

Mathematical modeling. The data were modeled by predicting response latencies from the independent variables specified by the proposed theory of analogical and metaphorical reasoning. It became obvious that the data were not of sufficient quality to allow estimation of all of the parameters of the model. We therefore retained in the model the strongest four parameters, defined in terms of contribution to fit between predicted and observed data points. These four parameters were encoding, application, comparison, and justification. Fits of the model to the latency data can be determined by an examination of Table 2, which reports parameter estimates and various indices of fit for each condition. Parameters are expressed as standardized coefficients because the use of ratings made the raw coefficients nonmeaningful.

-----------------------------
Insert Table 2 about here
As shown in the table, the overall fit of the model to each data set was quite good: Squared correlations between predicted and observed latencies were quite high, and differed significantly from zero. Root-mean-square deviations of observed from predicted values were reasonable, given the absolute levels of the latencies obtained in this experiment. Although the model fits were good, the models differed significantly in fit from the "true" model: In each data set, the residuals of observed from predicted values were statistically significant. All but one of the parameter estimates differed significantly in value from zero, although only the value of encoding was closely matched across task formats. These results, like the earlier ones, can be interpreted as indicating that the proposed model provides a good fit to the data in each task and that information processing is highly similar, but not identical, in the two tasks.

An interesting feature of these data is that the proposed model fit the latencies for metaphors more closely than it fit the latencies for analogies. An interpretation of this finding that is consistent with the present conceptualization is that the higher fit is due to the metaphors providing more constraining context than do the analogies. This additional constraining context reduces individual differences in interpretation and thus increases uniformity in the way subjects apply the model to the metaphors. The outcome is increased fit of the model to the latency data.

Discussion

The results of this experiment show a high degree of similarity between metaphorical and analogical information processing both at a global and at a componential level. Mean latencies were almost identical, and a single model of information processing based upon the Sternberg (1977a, 1977b) theory of analogical reasoning provides a good fit to the data in each task format. Nevertheless, the subset of metaphors studied in this experiment was extremely restricted, limited as it was to proportional metaphors in which all terms are stated explicitly, the
last as a choice of one of two answer options. One might well ask what relevance the proposed theory has for metaphors in which only some of the terms are explicitly stated. This question is addressed in Experiment 2, which also addresses the question of how useful the theory is in predicting aptness and comprehensibility of metaphors containing different numbers and identities of terms from the analogies underlying them.

Experiment 2

In this experiment, base statements were presented in each of several different metaphorical formats, where the formats differed in the number and identities of the terms of the underlying analogy that were left implicit. Subjects were asked to rate either the aptness or the comprehensibility of each metaphorical statement, and were timed with respect to the duration of the interval between presentation of the metaphor and communication of a rating.

Method

Subjects. Forty-eight Yale students uninvolved in Experiment 1 participated in the experiment, half making aptness ratings and half making comprehensibility ratings. Subjects received course credit for their participation. Ratings of independent variables in the information-processing model were taken from the "ratings" subjects of Experiment 1.

Materials. Stimuli in the second experiment were sentential metaphors adapted from the stimuli in the first experiment. Five forms of each metaphor were generated for the metaphors used in Experiment 1. Only the preferred answer option was used. An example of the five forms for the first metaphor in Table 1 is

1. Bees in a hive are a Roman mob in the Coliseum.
2. Bees in a hive are a Roman mob.
3. Bees are a Roman mob in the Coliseum.
4. Bees are a Roman mob.
5. Bees are a Roman mob in a hive.
Note that all terms of the underlying analogy are presented in Form 1; in the other forms, the missing terms are the fourth in Form 2, the second in Form 3, the second and fourth in Form 4, and the fourth in Form 5. Form 5 differs from Form 2, where the fourth term was also left implicit, in the ordering of the explicitly given terms. All items were typed in large (IBM ORATOR) capital letters on white 9" X 12" construction paper.

**Design.** The two major independent variables were metaphorical form (1-5), which was a within-subjects variable, and type of rating to be made (aptness or comprehensibility), which was a between-subjects variable. Each subject received every one of the 50 metaphors in each of the five forms. Items were blocked by forms, and forms were presented in counterbalanced order via a Latin-square arrangement across subjects. Each subject thus received 250 items to rate. The main dependent variables were response latency to make the ratings and the ratings themselves.

**Mathematical modeling.** Mathematical modeling was done by linear multiple regression, as in Experiment 1.

**Apparatus.** Metaphors were presented via a portable tachistoscope with an attached centisecond clock.

**Procedure.** Subjects were instructed in either the aptness or the comprehensibility task. In the aptness task, subjects were told to rate aptness of the metaphors on a 1-9 scale, where higher ratings were associated with greater aptness. Subjects were told that aptness referred to "how appropriate or fitting a statement is." They were given as an example, "The moon in the sky is a ghostly galleon upon the sea," and asked: "Did this description of the moon immediately strike you as fitting (high in aptness) or did it strike you as inappropriate description of the moon (low in aptness)?" Subjects were told to decide upon an aptness rating, and state it aloud. The experimenter stopped the clock as soon as the rating was made. Instructions in the comprehensibility condition were similar, except that here subjects were told that "by comprehensibility we mean how easily understandable a statement is." The same example...
metaphor was given, and the subject was asked: "Did the meaning of this statement quickly come to mind (high comprehensibility) or did you have to ponder it for a time before its meaning came to mind (low comprehensibility)?" Comprehensibility ratings were stated aloud using a 1-9 scale, with higher numbers referring to higher levels of comprehensibility.

Results

Basic statistics. Table 3 shows mean ratings and response latencies for each of the forms in which the metaphors were presented. We shall consider ratings and latencies of aptness and comprehensibility in turn, and then the relationships between them.

For aptness, the effect of metaphorical form was highly significant both for ratings, \( F(4, 96) = 5.68, p < .001 \), and for latencies to supply these ratings \( F(4, 96) = 18.42, p < .001 \). An examination of the patterns of ratings and latencies makes clear the nature of the effects. Consider first Forms 1-4, those in which the terms are presented in the order corresponding to the underlying analogy. The highest rating and latency is achieved for the metaphors (Form 1) in which no terms are left implicit. Intermediate ratings and latencies are achieved for the metaphors (Forms 2 and 3) in which one term is left implicit. The lowest ratings and latency is achieved for the metaphors (Form 4) in which two terms are left implicit. Thus, when terms are presented in the natural A, B, C, D order corresponding to the order of the terms in the implicit analogy, the presentation of more terms is associated with higher aptness, but also higher latency to make the aptness ratings. Subjects take longer to process the greater amount of information, and presumably, the fuller encoding of the metaphorical relations they obtain is associated with the metaphor being rated as more apt. Form 5, where
the order of the second and third terms is reversed relative to the underlying implicit analogy, is rated as most apt, although its latency for rating is intermediate. The latencies of the various forms seem merely to reflect the amount of reading that is required: The form (4) with the smallest number of explicit terms has the lowest latency; the form (1) with the largest number of explicit terms has the highest latency; and the other forms (2, 3, 5) with intermediate numbers of missing terms have intermediate latencies. But the high Form 5 rating does not merely reflect its intermediate number of terms.

We believe that the Form 5 metaphor is rated as most apt because the juxtaposition of the terms supplies a kind of information additional to that supplied in the other metaphorical forms: In particular, it supplies information about the nature of the interaction between tenor and vehicle. In metaphors such as "A pear is a Buddha on a sill," or "Bees are a Roman mob in a hive," or "Tombstones are teeth in a graveyard," the tenor and vehicle are more easily seen to interact with each other, and it is especially easy in many cases to create an image of the nature of this interaction. One can easily imagine a Buddha transplanted to a window sill, a Roman mob scurrying about mindlessly in a hive, or teeth sticking up from the ground in a graveyard. Black (1962), Tourangeau and Sternberg (in press, Note 1), and others have suggested that metaphors attain one of their special qualities as figurative devices by the interaction between tenor and vehicle: It is this interaction that, in a certain sense, makes the metaphor come alive. The present results are consistent with this notion. The fifth form provides a juxtaposition of terms that facilitates one's understanding of the nature of the interaction between tenor and vehicle, and thus aptness is increased. In the other metaphorical forms, the absence of juxtaposition between the second and third terms leaves it to the reader to supply the nature of the interaction, and aptness is correspondingly reduced.
In order to test our hypothesis that the fifth metaphorical form encourages formation of interactive imagery more than does the second (or any other) metaphorical form, we had a separate group of twenty subjects rate "how vivid the interaction [was] between the two principle nouns" in each metaphor in each format (250 ratings in all). Mean ratings were 4.48 for Form 1 (Bees in a hive are a Roman mob in the Coliseum), 3.24 for Form 2 (Bees in a hive are a Roman mob), 3.00 for Form 3 (Bees are a Roman mob in the Coliseum), 2.91 for Form 4 (Bees are a Roman mob), and 4.77 for Form 5 (Bees are a Roman mob in a hive). A one-way analysis of variance revealed a significant effect of form, $F(4,96) = 70.00$, $p < .001$, and a planned follow-up contrast showed the ratings for Forms 1 and 5 to be higher than those for Forms 2, 3, and 4. The most critical comparison, that between Forms 2 and 5, thus confirmed our prior hypothesis that although these two metaphors contained the same terms, the inversion of the B and C terms in Form 5 relative to the underlying analogy increased the interactive imagery stimulated by Form 5 relative to that stimulated by Form 2.

For comprehensibility, the effect of metaphorical form was marginally significant for ratings, $F(4,96) = 2.27$, $p = .07$; for latencies to supply these ratings, the effect of form was highly significant, $F(4,96) = 17.81$, $p < .001$. The pattern of comprehensibility ratings echoes the pattern of aptness ratings, except for the inversion of the mean ratings for Forms 3 and 4. It is not clear what, if anything, this inversion means. For latencies, the amount of processing time spent on each form reflects the amount of reading to be done, as for the aptness-rating latencies. In every case, ratings and latencies for comprehensibility were higher than their corresponding values for aptness. This contrast was not built into the analysis of variance, because the psychological meaning of a comparison between these ratings and latencies is not entirely clear. Nevertheless, the result is clearcut, and might be worthy of further exploration at some future time.
To summarize, ratings of aptness and probably of comprehensibility increase as more information regarding implicit elements of the underlying analogy is given. Aptness and comprehensibility also increase as more information is given about the nature of the interaction between tenor and vehicle that makes the metaphor uniquely "metaphorical." Thus, understanding of the nature of metaphors based on analogies requires understanding both of the components of analogical reasoning used in metaphorical information processing, and of the conception of interaction that is unique to metaphor.

**Relations between comprehensibility and aptness.** The correlation between ratings of comprehensibility and of aptness was .61, \( p < .001 \), across the five forms, indicating that comprehensibility and aptness of metaphors are indeed related (as Tourangeau & Sternberg, in press, had found previously). Perhaps more interesting than the overall correlation across forms was the pattern of correlations within forms. For the five respective forms, the correlations (all significant) were .44 (Bees in a hive are Romans in the Coliseum), .63 (Bees in a hive are Romans), .65 (Bees are Romans in the Coliseum), .78 (Bees are Romans), and .48 (Bees are Romans in a hive). Of particular interest is the fact that the pattern of correlations is strongly inversely related to the pattern of means: Metaphorical forms with lower aptness and comprehensibility ratings are those that show the highest correlations within form between comprehensibility and aptness. This relationship between patterns of means and correlations is not an artifact of variance differences, such as those caused by floor and ceiling effects: The variances across the various conditions were practically indistinguishable from each other. Rather, there appears to be a stronger relationship between aptness and comprehensibility for metaphorical forms in which less information (about the underlying analogy or nature of the interaction between the tenor and vehicle) is given than for those in which more information is given. This pattern of results suggests that when metaphors are
at the lower end of the comprehensibility scale, comprehensibility accounts for a relatively larger proportion of the variance in aptness. In these metaphors, there just isn't much other basis for judging metaphorical aptness. Once comprehensibility reaches a certain point, it becomes relatively less important in determining aptness, and more aesthetic kinds of factors may become more important. This pattern of results is consistent with our earlier hypothesis that comprehensibility is a necessary but not sufficient condition for aptness: After a certain threshold is reached, it ceases to make as much of a difference in aptness as it does before this threshold is reached. Gerrig and Healy (Note 5) failed to discover any relationship between comprehensibility and aptness, perhaps because their metaphors were generally more comprehensible than ours, and were thus above the point at which comprehensibility affects aptness. A visual inspection of their metaphors and ours is consistent with this interpretation.

Mathematical modeling. The mathematical modeling of the dependent variables in this experiment (latency, aptness ratings, and comprehensibility ratings) was less central to the data analysis of this experiment than it was to the data analysis of the previous experiment; it is nevertheless of some interest. Results of the mathematical modeling are shown in Table 4 for the two kinds of ratings and the latencies of each of the two kinds of ratings. Modeling was done for three sets of independent variables. The first included all parameters of the model of analogical reasoning plus aptness (used in the prediction
of comprehensibility ratings and latencies) or comprehensibility (used in the prediction of aptness ratings and latencies). The second set included only the full set of parameters of the model of analogical reasoning, but neither aptness nor comprehensibility. The third set included just mapping and justification, which were generally two of the strongest variables in the prediction equations.

Consider first the ratings data. All model fits differed significantly from zero, and most of them were fairly substantial. The full model seems to provide good prediction of the aptness and comprehensibility of metaphors, regardless of the form in which they are presented. This fact is of particular interest because although the full model was based upon all of the terms of the implicit analogy, all but one of the forms contained missing (implicit) terms. These results are consistent with the notion that subjects fill in missing terms. Prediction was best for the form containing two missing terms (e.g., "Bees are a Roman mob"), where mapping and justification alone were able to do quite well. Of particular interest is the great boost in $R^2$ attributable to interactive imagery as a predictor of aptness in Form 5, where interactive imagery was previously hypothesized to be especially important.

Consider next the latency data. Here, prediction was variable, and it was necessary to use the full model to obtain any reasonable level of predictive validity. The fact that the model provides any fit at all is of some interest, since there is no necessary a priori reason to expect it to predict latencies of ratings: The model was formulated only to predict comprehension latencies, which are presumably only one part of the ratings latencies. Indeed, it may be this part that the model successfully predicts.
Discussion

The results of this experiment suggest that metaphors tend to be rated as more comprehensible and more apt when more terms of the underlying implicit analogy are made explicit, and when the nature of the interaction between tenor and vehicle is made more easily perceptible. The experiment also suggests that the proposed model can describe imperfectly some of the factors that contribute to ratings of comprehensibility and aptness. The results are consistent with the notion that analogies underlie certain kinds of metaphors, but that comprehension and appreciation of these metaphors involve an appreciation of an interaction between domains that is not involved in the comprehension and appreciation of typical analogies.

General Discussion

The specific hypotheses posed in the introduction to this article were consonant with the data we obtained. The theory and data presented here were intended to address several broader issues in the theory of metaphor, however, and also have implications for certain other issues. We consider some of these issues here.

Relations between Analogy and Metaphor

On the present view, certain kinds of metaphors (so-called "proportional metaphors") are seen as based upon underlying analogies. The components of information processing used in understanding metaphors are viewed as highly overlapping with those used in understanding analogies. These components include the encoding, inference, mapping, application, comparison, justification, and response processes described earlier. There are also significant differences between the processing of analogies and metaphors, however. First, it is frequently the case that some of the terms of the underlying analogy are left implicit in a metaphor, so that the individual must construct these implicit terms, or closely related ones. Second, interpretation of an analogy usually does not seem to involve an interaction between domain and range (tenor and vehicle):
The two are interrelated but not integrated by the subject. Interpretation of a metaphor seems to involve an interaction between domain and range whereby each changes the perception of the other. Third, whereas the domain (first half) and range (second half) of an analogy may and often do derive from the same semantic subspace, the terms of a metaphor must derive from different semantic subspaces for the metaphor to be nontrivial. For example, the analogy "lion : wolf :: cat : dog" is perfectly acceptable as an analogy, but the metaphor "The lion is the wolf among cats" is trivial and uninteresting. Finally, the quality of an analogy is primarily a function of the fit between the domain and range: The relation between the first two terms must be as nearly parallel as possible to the relation between the second two terms. The quality of a metaphor is also determined in part by the fit between the domain and range (tenor and vehicle, or vice versa), but it is further determined by the distance between them. As shown above, a metaphor is trivial if the tenor and vehicle are from the same semantic subspace; the quality of a metaphor will improve as the semantic distance between tenor and vehicle increases in the semantic hyperspace that contains the two subspaces as points within it, up to the point where the subspaces begin to become unrelated or poorly related to each other (see Tourangeau & Sternberg, in press, Note 1).

The Nature of Interaction

On the present theory, an interaction between tenor and vehicle occurs when the semantic subspace containing the tenor of a metaphor is mentally superimposed upon the semantic subspace containing the vehicle of a metaphor (see Sternberg, Tourangeau, & Nigro, 1979). The domain is not only mapped onto the range of a metaphor (as takes place in an analogy), but also brought into juxtaposition with it: The tenor is seen in terms of the vehicle. This psychological juxtaposition of tenor and
vehicle can result in a shift in one's perceptions of the respective natures of the tenor and vehicle (i.e., in the location of each point within its respective subspace). Presumably, the two points move into closer alignment such that their positions in their respective semantic subspaces become more nearly comparable.

Stages of Processing

A number of students of metaphor have asked whether or not metaphoric understanding occurs in two stages, the first of which is devoted to an attempt at literal interpretation and the second of which is devoted to an attempt at metaphorical interpretation (see Harris, 1976; Kintsch, 1974; Pollio, Barlow, Fine, & Pollio, 1977; Glucksberg, Hartman, & Stack, Note 6). On the present view, the notion of discrete stages of information processing for testing literal and then metaphorical interpretations of a statement is not appropriate. We view the distinction between a literal statement and a metaphorical one as graded. Strictly speaking, a literal statement would equate two elements in a single semantic subspace, whereas a metaphorical one would equate two elements from separate subspaces. The distance within the hyperspace would thus be zero in the first case (since the subspaces are the same point in the hyperspace) and greater than zero in the second case (since the subspaces are distinguishable points). In practice, however, if two terms from very proximal but nonidentical subspaces were equated, it might be difficult to judge whether the statement was intended as a literal or a metaphor. For example, the statement "People are humans" might be interpreted either literally or metaphorically. Surrounding context might help decide which interpretation is appropriate, as might qualification. The statement, "Those people aren't human" is clearly intended to be interpreted metaphorically. On our theory, processing time will generally tend to
Metaphor

increase as the distance between two semantic subspaces in their hyperspace (the identity of which can also be altered by context) increases, but it would be inappropriate to refer to the passage from one amount of distance to another as constituting a transition between stages. Indeed, the hardest statements to interpret might well be those in which the two terms of the statement are from close but nonidentical subspaces, in that these will tend to be the statements in which it is least clear whether a literal or metaphorical meaning is intended. The individual must therefore spend additional time figuring out just which meaning is, in fact, intended.

**Factors Affecting Aptness and Comprehensibility of Metaphors**

The present work in combination with the work of Tourangeau and Sternberg (in press) provides empirical evidence regarding several factors that affect the aptness and comprehensibility of metaphors. These include (a) each other (more apt metaphors are more comprehensible, and vice versa), (b) the degree of correspondence between locations of words in their respective semantic subspaces, (c) the distance between these subspaces in their semantic hyperspace, (d) the amount of information that is supplied about the implicit analogy underlying the metaphor, and (e) the amount of information that is supplied about the nature of the interaction between tenor and vehicle. These are not, by any means, the only factors affecting aptness of metaphors (see, e.g., Ortony, 1979a, 1979b; Tversky, 1977). But it is becoming more clear through research such as ours and that of others in the field that the aptness and comprehensibility of metaphors are complexly determined. Although we certainly do not know the identities of all of the factors that affect our understanding and appreciation of metaphors, we seem to be making headway in identifying them, and in recognizing what it is that distinguishes metaphor from other forms of communication.
Reference Notes


References


Hollan, J. D. Features and semantic memory: Set-theoretic or network model? Psychological Review, 1975, 82, 154-155.

Metaphor

37


Ortony, A. Beyond literal similarity. Psychological Review, 1979, 86, 161-180. (a)


Sternberg, R. J. Component processes in analogical reasoning. Psychological Review, 1977, 84, 353-378. (a)


Metaphor


Footnotes

This research was supported by Contract N0001478C0025 from the Office of Naval Research to Robert J. Sternberg. We are grateful to Andrew Ortony, Roger Tourangeau, and Amos Tversky for conversations that have helped shape our thinking about metaphorical understanding and appreciation. We are also grateful to Elizabeth Charles for assistance in data analysis. Requests for reprints should be sent to Robert J. Sternberg, Department of Psychology, Yale University, Box 11A Yale Station, New Haven, Connecticut 06520. Georgia Nigro is now affiliated with the Department of Psychology, Cornell University.

1 The use of a spatial representation for information is a theoretical and practical convenience rather than a claim about the way in which information is represented in the head. As is well known, different forms of representation are extremely difficult to distinguish (Anderson, 1978; Hollan, 1975), and we have shown how many of the concepts presented spatially in Tourangeau and Sternberg (in press) can be presented featurally instead (Tourangeau & Sternberg, Note 1). Thus, we look at a spatial representation as one of probably a number of difficult-to-distinguish representations people use in evaluating metaphors.

2 No claim is made that this analogy uniquely generates any single metaphor, or that only one possible analogy underlies any given metaphor. Obviously, various logical permutations of terms are possible, as well as various insertions of terms left implicit in one or the other format.

3 Results are presented from all data, including erroneous responses, which were a small proportion (.06) of responses. Results were practically identical when analyses were performed upon responses for correctly answered items only.

4 Significance of residuals was determined by randomly dividing subjects into
two groups, fitting the proposed model to the data for each group, calculating the residuals of observed from predicted latencies in each group, correlating the residuals for the two groups, and correcting the obtained correlation by the Spearman-Brown formula. This correlation indicates the extent to which the residuals contain systematic variance within them.
<table>
<thead>
<tr>
<th>Metaphor</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bees in a hive are a Roman mob in the</td>
<td>coliseum</td>
</tr>
<tr>
<td></td>
<td>aqueduct</td>
</tr>
<tr>
<td>2. A pear on a sill is a Buddha in a</td>
<td>temple</td>
</tr>
<tr>
<td></td>
<td>puddle</td>
</tr>
<tr>
<td>3. Blood on a wound is plush on a</td>
<td>carpet</td>
</tr>
<tr>
<td></td>
<td>magazine</td>
</tr>
<tr>
<td>4. Cattails in a field are nerves in a</td>
<td>body</td>
</tr>
<tr>
<td></td>
<td>dish</td>
</tr>
<tr>
<td>5. Tombstones in a graveyard are teeth in a</td>
<td>mouth</td>
</tr>
<tr>
<td></td>
<td>chair</td>
</tr>
<tr>
<td>6. The night before day is a sentinel before a</td>
<td>camp</td>
</tr>
<tr>
<td></td>
<td>test</td>
</tr>
<tr>
<td>7. Clouds in the sky are wedding dresses in a</td>
<td>window</td>
</tr>
<tr>
<td></td>
<td>radiator</td>
</tr>
<tr>
<td>8. A cactus in the desert is a candelabra on a</td>
<td>table</td>
</tr>
<tr>
<td></td>
<td>ceiling</td>
</tr>
<tr>
<td>9. A lamp on a dresser is a mushroom on a</td>
<td>stump</td>
</tr>
<tr>
<td></td>
<td>salad bowl</td>
</tr>
<tr>
<td>10. Stars in the heavens are carbonation in a</td>
<td>drink</td>
</tr>
<tr>
<td></td>
<td>lemon</td>
</tr>
<tr>
<td>11. Fungus on a rock is lace on a</td>
<td>dress</td>
</tr>
<tr>
<td></td>
<td>plate</td>
</tr>
<tr>
<td>12. Eyes of a head are turrets of a</td>
<td>castle</td>
</tr>
<tr>
<td></td>
<td>garden</td>
</tr>
<tr>
<td>13. Railroad tracks on the landscape are zippers on a</td>
<td>garments</td>
</tr>
<tr>
<td></td>
<td>sneakers</td>
</tr>
<tr>
<td>14. The Milky Way in the heavens is foam on a</td>
<td>tide</td>
</tr>
<tr>
<td></td>
<td>pillow</td>
</tr>
<tr>
<td>15. A butterfly on the lawn is a bow in the</td>
<td>hair</td>
</tr>
<tr>
<td></td>
<td>hand</td>
</tr>
<tr>
<td>16. Crows on a wire are letters on a</td>
<td>line</td>
</tr>
<tr>
<td></td>
<td>pencil</td>
</tr>
<tr>
<td>17. An apricot on a tree is buttocks on a</td>
<td>body</td>
</tr>
<tr>
<td></td>
<td>portrait</td>
</tr>
<tr>
<td>18. Leaves on branches are kites on</td>
<td>strings</td>
</tr>
<tr>
<td></td>
<td>benches</td>
</tr>
<tr>
<td>19. Poppies in a field are flames of a</td>
<td>fire</td>
</tr>
<tr>
<td></td>
<td>stove</td>
</tr>
<tr>
<td>20. Crickets in the grass are gossips at a</td>
<td>party</td>
</tr>
<tr>
<td></td>
<td>rocket</td>
</tr>
<tr>
<td>21. Clouds in the sky are jowls on a</td>
<td>face</td>
</tr>
<tr>
<td></td>
<td>plant</td>
</tr>
<tr>
<td>Metaphor</td>
<td>Options</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>The SST among jets is Howard Cosell among</td>
<td>sports announcers friends</td>
</tr>
<tr>
<td>Idi Amin among leaders is a piranha among</td>
<td>fish children</td>
</tr>
<tr>
<td>Billboards on the roadside are warts on the</td>
<td>skin nail</td>
</tr>
<tr>
<td>Dentists fighting decay are exorcists fighting</td>
<td>devils churches</td>
</tr>
<tr>
<td>Snow on the ground is paste on a</td>
<td>board napkin</td>
</tr>
<tr>
<td>The moon in the sky is a knuckle on a</td>
<td>hand boot</td>
</tr>
<tr>
<td>A lighthouse at sea is a garnet in a</td>
<td>brooch chimney</td>
</tr>
<tr>
<td>Encyclopedias of knowledge are mines of</td>
<td>gold yarn</td>
</tr>
<tr>
<td>Cliches among expressions are hamburgers among</td>
<td>food books</td>
</tr>
<tr>
<td>Hours of life are leaves of a</td>
<td>tree can</td>
</tr>
<tr>
<td>Stomachs of bodies are dungeons of</td>
<td>castles vases</td>
</tr>
<tr>
<td>Man on the earth is a feather in the</td>
<td>wind branch</td>
</tr>
<tr>
<td>The heart in a body is a sponge in a</td>
<td>sink television</td>
</tr>
<tr>
<td>The sky above land is a sail above a</td>
<td>deck platform</td>
</tr>
<tr>
<td>The brain of a person is a spire of a</td>
<td>cathedral blackboard</td>
</tr>
<tr>
<td>Polliwogs in the water are commas on a</td>
<td>page shade</td>
</tr>
<tr>
<td>Memories in our heads are yellow pages in a</td>
<td>phonebook blender</td>
</tr>
<tr>
<td>Sap from a tree is tears from a</td>
<td>child flower</td>
</tr>
<tr>
<td>Spring for lovers is catnip for</td>
<td>cats worms</td>
</tr>
<tr>
<td>Waves on the surf are ruffles on a</td>
<td>dress baseball</td>
</tr>
<tr>
<td>Gems on a necklace are dew on a</td>
<td>spiderweb snowflake</td>
</tr>
<tr>
<td>Man among creatures is a wolf among</td>
<td>animals plants</td>
</tr>
<tr>
<td>Howard Hughes among men is the Big Foot among</td>
<td>animals mountains</td>
</tr>
<tr>
<td>Cocaine of drugs is the caviar of</td>
<td>foods drinks</td>
</tr>
<tr>
<td>Metaphor</td>
<td>Options</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td><strong>46. Leonardo DaVinci among painters is the Rolls Royce among</strong></td>
<td>Keyed cars</td>
</tr>
<tr>
<td><strong>47. A nose on a face is a shell on a</strong></td>
<td>Keyed beach</td>
</tr>
<tr>
<td><strong>48. Bandages on a body are moths on a</strong></td>
<td>Keyed wall</td>
</tr>
<tr>
<td><strong>49. Levis for college students are fatigues for</strong></td>
<td>Keyed soldiers</td>
</tr>
<tr>
<td><strong>50. Skyscrapers in a city are giraffes among</strong></td>
<td>Keyed animals</td>
</tr>
<tr>
<td></td>
<td>Nonkeyed jewels</td>
</tr>
<tr>
<td></td>
<td>Nonkeyed porch</td>
</tr>
<tr>
<td></td>
<td>Nonkeyed fern</td>
</tr>
<tr>
<td></td>
<td>Nonkeyed musicians</td>
</tr>
<tr>
<td></td>
<td>Nonkeyed animals</td>
</tr>
<tr>
<td></td>
<td>Nonkeyed roses</td>
</tr>
</tbody>
</table>
Table 2
Mathematical Modeling of Latency Data in Experiment 1

<table>
<thead>
<tr>
<th></th>
<th>Metaphorical Format</th>
<th>Analogical Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Fit:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>.86*</td>
<td>.75*</td>
</tr>
<tr>
<td>RMSD</td>
<td>.30 sec</td>
<td>.60 sec</td>
</tr>
<tr>
<td>Parameter Estimates:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encoding</td>
<td>.46*</td>
<td>.46*</td>
</tr>
<tr>
<td>Application</td>
<td>.25*</td>
<td>.58*</td>
</tr>
<tr>
<td>Comparison</td>
<td>.22*</td>
<td>.13</td>
</tr>
<tr>
<td>Justification</td>
<td>.68*</td>
<td>.24*</td>
</tr>
</tbody>
</table>

Note: $R^2$ represents the squared correlation between predicted and observed latencies for each data point. RMSD represents the root-mean-square deviation between predicted and observed latencies for each data point.

*p < .01
### Table 3

Mean Ratings and Response Latencies

<table>
<thead>
<tr>
<th>Form</th>
<th>Example</th>
<th>Rating</th>
<th>Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Aptness</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Bees in a hive are a Roman mob in the Coliseum.</td>
<td>5.12</td>
<td>4.88</td>
</tr>
<tr>
<td>2</td>
<td>Bees in a hive are a Roman mob.</td>
<td>4.67</td>
<td>4.48</td>
</tr>
<tr>
<td>3</td>
<td>Bees are a Roman mob in the Coliseum.</td>
<td>4.66</td>
<td>4.66</td>
</tr>
<tr>
<td>4</td>
<td>Bees are a Roman mob.</td>
<td>4.32</td>
<td>3.93</td>
</tr>
<tr>
<td>5</td>
<td>Bees are a Roman mob in a hive.</td>
<td>5.27</td>
<td>4.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Form</th>
<th>Example</th>
<th>Rating</th>
<th>Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Comprehensibility</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Bees in a hive are a Roman mob in the Coliseum.</td>
<td>5.53</td>
<td>5.11</td>
</tr>
<tr>
<td>2</td>
<td>Bees in a hive are a Roman mob.</td>
<td>5.30</td>
<td>4.63</td>
</tr>
<tr>
<td>3</td>
<td>Bees are a Roman mob in the Coliseum.</td>
<td>5.01</td>
<td>4.86</td>
</tr>
<tr>
<td>4</td>
<td>Bees are a Roman mob.</td>
<td>5.17</td>
<td>4.13</td>
</tr>
<tr>
<td>5</td>
<td>Bees are a Roman mob in a hive.</td>
<td>5.70</td>
<td>4.66</td>
</tr>
</tbody>
</table>

Note: Ratings are expressed on a 1=low to 9=high scale. Latencies are expressed in seconds.
Table 4
Mathematical Modeling of Ratings of Aptness and Comprehensibility

<table>
<thead>
<tr>
<th>Model</th>
<th>Form</th>
<th>Aptness</th>
<th>Comprehensibility</th>
<th>Latencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rating</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Latencies</td>
</tr>
<tr>
<td>Full Analogical Model</td>
<td>1</td>
<td>.71</td>
<td>.78</td>
<td>.60</td>
</tr>
<tr>
<td>+ Rating of Aptness</td>
<td>2</td>
<td>.77</td>
<td>.80</td>
<td>.39</td>
</tr>
<tr>
<td>or Comprehensibility*</td>
<td>3</td>
<td>.69</td>
<td>.73</td>
<td>.61</td>
</tr>
<tr>
<td>+ Rating of Interactive Imagery</td>
<td>4</td>
<td>.78</td>
<td>.86</td>
<td>.40</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>.71</td>
<td>.82</td>
<td>.58</td>
</tr>
<tr>
<td>Full Analogical Model</td>
<td>1</td>
<td>.71</td>
<td>.77</td>
<td>.60</td>
</tr>
<tr>
<td>+ Rating of Aptness</td>
<td>2</td>
<td>.75</td>
<td>.79</td>
<td>.30</td>
</tr>
<tr>
<td>or Comprehensibility*</td>
<td>3</td>
<td>.54</td>
<td>.67</td>
<td>.60</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>.78</td>
<td>.83</td>
<td>.40</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>.51</td>
<td>.77</td>
<td>.45</td>
</tr>
<tr>
<td>Full Analogical Model</td>
<td>1</td>
<td>.68</td>
<td>.75</td>
<td>.53</td>
</tr>
<tr>
<td>Model</td>
<td>2</td>
<td>.67</td>
<td>.73</td>
<td>.29</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>.44</td>
<td>.60</td>
<td>.38</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>.75</td>
<td>.80</td>
<td>.38</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>.50</td>
<td>.77</td>
<td>.40</td>
</tr>
<tr>
<td>Mapping and Justification</td>
<td>1</td>
<td>.38</td>
<td>.51</td>
<td>.07</td>
</tr>
<tr>
<td>Only</td>
<td>2</td>
<td>.49</td>
<td>.62</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>.35</td>
<td>.49</td>
<td>.00</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>.73</td>
<td>.67</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>.39</td>
<td>.65</td>
<td>.04</td>
</tr>
</tbody>
</table>

Note: Model fits are expressed as squared correlations between predicted and observed data points.

* Aptness was used as an independent variable in the prediction of comprehensibility; comprehensibility was used as an independent variable in the prediction of aptness.
<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Published Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intelligence Research at the Interface between Differential and Cognitive Psychology.</td>
<td>Sternberg, R. J. Intelligence research at the interface between differential and cognitive psychology. <em>Intelligence</em>, 1978, 2, 195-222.</td>
</tr>
<tr>
<td>5</td>
<td>A Transitive-Chain Theory of Syllogistic Reasoning.</td>
<td>UNPUBLISHED TO DATE</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Published Reference</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>11</td>
<td>Understanding and Appreciating Metaphors. June, 1978.</td>
<td>UNPUBLISHED TO DATE.</td>
</tr>
<tr>
<td>18</td>
<td>Unities in Inductive Reasoning. October, 1979.</td>
<td>UNPUBLISHED TO DATE.</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Published Reference</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>23</td>
<td>Intelligence and Nonentrainment. April, 1980.</td>
<td>UNPUBLISHED TO DATE.</td>
</tr>
<tr>
<td>26</td>
<td>Interaction and Analogy in the Comprehension and Appreciation of Metaphors. October, 1980.</td>
<td>UNPUBLISHED TO DATE.</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Published Reference</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>30</td>
<td><strong>Reasoning with Determinate and Indeterminate Linear Syllogisms.</strong></td>
<td>NOT YET PUBLISHED.</td>
</tr>
</tbody>
</table>
Dr. Ed Aiken  
Navy Personnel R&D Center  
San Diego, CA 92152

Meryl S. Baker  
NPRDC  
Code P309  
San Diego, CA 92152

Dr. Jack R. Borsting  
Provost & Academic Dean  
U.S. Naval Postgraduate School  
Monterey, CA 93940

Dr. Robert Preaux  
Code N-711  
NAVTRAQECGEN  
Orlando, FL 32813

Chief of Naval Education and Training  
Liaison Office  
Air Force Human Resource Laboratory  
Flying Training Division  
WILLIAMS AFB, AZ 85224

Dr. Larry Dean, LT, MSC, USN  
Psychology Department  
Naval Submarine Medical Research Lab  
Naval Submarine Base  
Groton, CT 06340

Dr. Richard Elster  
Department of Administrative Sciences  
Naval Postgraduate School  
Monterey, CA 93940

DR. PAT FEDERICO  
NAVY PERSONNEL R&D CENTER  
SAN DIEGO, CA 92152

Mr. Paul Foley  
Navy Personnel R&D Center  
San Diego, CA 92152

Dr. John Ford  
Navy Personnel R&D Center  
San Diego, CA 92152

Dr. Henry M. Halff  
Department of Psychology, C-009  
University of California at San Diego  
La Jolla, CA 92093

LT Steven D. Harris, MSC, USN  
Code 6021  
Naval Air Development Center  
Warminster, Pennsylvania 18974

Dr. Patrick R. Harrison  
Psychology Course Director  
LEADERSHIP & LAW DEPT. (7b)  
DIV. OF PROFESSIONAL DEVELOPMENT  
U.S. NAVAL ACADEMY  
ANNAPOLIS, MD 21402

Dr. Jim Hollan  
Code 304  
Navy Personnel R&D Center  
San Diego, CA 92152

CDR Charles W. Hutchins  
Naval Air Systems Command Hq  
AIR-34OF  
Navy Department  
Washington, DC 20361

CDR Robert S. Kennedy  
Head, Human Performance Sciences  
Naval Aerospace Medical Research Lab  
Box 29407  
New Orleans, LA 70189

Dr. Herman J. Kerr  
Chief of Naval Technical Training  
Naval Air Station Memphis (75)  
Millington, TN 38054

Dr. William L. Halcy  
Principal Civilian Adviser for  
Education and Training  
Naval Training Command, Code COA  
Pensacola, FL 32508

Dr. Kneale Marshall  
Scientific Advisor to DCNO(NPT)  
OP01T  
Washington DC 20370
Navy

1  CAPT Richard L. Martin, USN
   Prospective Commanding Officer
   USS Carl Vinson (CVN-70)
   Newport News Shipbuilding and Drydock Co
   Newport News, VA 23607

1  Dr. James McBride
   Navy Personnel R&D Center
   San Diego, CA 92152

1  Dr. George Moeller
   Head, Human Factors Dept.
   Naval Submarine Medical Research Lab
   Groton, CN 06340

1  Dr William Montague
   Navy Personnel R&D Center
   San Diego, CA 92152

1  Library
   Naval Health Research Center
   P. O. Box 85122
   San Diego, CA 92138

1  Naval Medical R&D Command
   Code 44
   National Naval Medical Center
   Bethesda, MD 20014

1  CAPT Paul Nelson, USN
   Chief, Medical Service Corps
   Bureau of Medicine & Surgery (MED-23)
   U. S. Department of the Navy
   Washington, DC 20372

1  Ted H. I. Yellen
   Technical Information Office, Code 201
   NAVY PERSONNEL R&D CENTER
   SAN DIEGO, CA 92152

1  Library, Code P201L
   Navy Personnel R&D Center
   San Diego, CA 92152

6  Commanding Officer
   Naval Research Laboratory
   Code 2627
   Washington, DC 20390

Navy

1  Psychologist
   ONR Branch Office
   Bldg 114, Section D
   666 Summer Street
   Boston, MA 02210

1  Psychologist
   ONR Branch Office
   536 S. Clark Street
   Chicago, IL 60605

1  Office of Naval Research
   Code 437
   800 N. Quincy Street
   Arlington, VA 22217

1  Office of Naval Research
   Code 441
   800 N. Quincy Street
   Arlington, VA 22217

5  Personnel & Training Research Programs
   (Code 458)
   Office of Naval Research
   Arlington, VA 22217

1  Psychologist
   ONR Branch Office
   1030 East Green Street
   Pasadena, CA 91101

1  Office of the Chief of Naval Operations
   Research Development & Studies Branch
   (OP-115)
   Washington, DC 20350

1  Dr. Ronald F. Parker
   Graduate School of Business Administration
   University of Michigan
   Ann Arbor, MI 48109

1  LT Frank C. Petho, MSC, USN (Ph.D)
   Code L51
   Naval Aerospace Medical Research Laboratory
   Pensacola, FL 32503
1 Roger W. Remington, Ph.D  
Code L52  
NAHRL  
Pensacola, FL 32508

1 Dr. Bernard Rimland (03B)  
Navy Personnel R&D Center  
San Diego, CA 92152

1 Mr. Arnold Rubenstein  
Naval Personnel Support Technology  
Naval Material Command (08T244)  
Room 1044, Crystal Plaza #5  
2221 Jefferson Davis Highway  
Arlington, VA 20360

1 Dr. Worth Scanland  
Chief of Naval Education and Training  
Code N-5  
NAS, Pensacola, FL 32508

1 Dr. Sam Sohiflett, SY 721  
Systems Engineering Test Directorate  
U.S. Naval Air Test Center  
Patuxent River, MD 20670

1 Dr. Robert G. Smith  
Office of Chief of Naval Operations  
OP-987H  
Washington, DC 20350

1 Dr. Alfred F. Snede  
Training Analysis & Evaluation Group (TAEG)  
Dept. of the Navy  
Orlando, FL 32813

1 W. Gary Thomson  
Naval Ocean Systems Center  
Code 7132  
San Diego, CA 92152

1 Dr. Ronald Weitzman  
Code 54 WZ  
Department of Administrative Sciences  
U.S. Naval Postgraduate School  
Monterey, CA 93940

1 Dr. Robert Wisher  
Code 309  
Navy Personnel R&D Center  
San Diego, CA 92152

1 DR. MARTIN F. WISKOFF  
NAVY PERSONNEL R&D CENTER  
SAN DIEGO, CA 92152

1 Mr. John H. Wolf  
Code P310  
U. S. Navy Personnel Research and Development Center  
San Diego, CA 92152
Army

1 Technical Director
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 HQ USAREUR & 7th Army
ODCSOPS
USAREUR Director of GED
APO New York 09403

1 Dr. RALPH DUSEK
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333

1 Dr. Michael Kaplan
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333

1 Dr. Milton S. Katz
Training Technical Area
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Harold F. O'Neil, Jr.
Attn: PERI-OK
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Robert Sasmor
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Frederick Steinheiser
U. S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Joseph Ward
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Air Force

1 Air University Library
AUL/LSE 75/443
Maxwell AFB, AL 36112

1 Dr. Earl A. Alluisi
HQ, AFHRL (AFSC)
Brooks AFB, TX 78235

1 Dr. Genevieve Haddad
Program Manager
Life Sciences Directorate
AFOSR
Bolling AFB, DC 20332

1 Dr. Ronald G. Hughes
AFHRL/OTR
Williams AFB, AZ 85224

1 Dr. Ross L. Morgan (AFHRL/LR)
Wright - Patterson AFB
Ohio 45433

1 Dr. Malcolm Ree
AFHRL/MP
Brooks AFB, TX 78235

1 Dr. Marty Rockway
Technical Director
AFHRL(OT)
Williams AFB, AZ 85224

2 7700 TCHTH/TTGH Stop 22
Sheppard AFB, TX 76311

1 Jack A. Thorp, Maj., USAF
Life Sciences Directorate
AFOSR
Bolling AFB, DC 20332
Marines

1 H. William Greenup
   Education Adviser (E031)
   Education Center, MCDEC
   Quantico, VA 22134

1 Headquarters, U. S. Marine Corps
   Code MPI-20
   Washington, DC 20380

1 Special Assistant for Marine Corps Matters
   Code 100M
   Office of Naval Research
   800 N. Quincy St.
   Arlington, VA 22217

1 DR. A.L. SLAFKOSKY
   SCIENTIFIC ADVISOR (CODE RD-1)
   HQ, U.S. MARINE CORPS
   WASHINGTON, DC 20380

Coast Guard

1 Chief, Psychological Research Branch
   U. S. Coast Guard (G-P-1/2/TP42)
   Washington, DC 20593

1 Mr. Thomas A. Warm
   U. S. Coast Guard Institute
   P. O. Substation 13
   Oklahoma City, OK 73169
Other DoD

12 Defense Technical Information Center
Cameron Station, Bldg 5
Alexandria, VA 22314
Attn: TC

1 Dr. Dexter Fletcher
ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BLVD.
ARLINGTON, VA 22209

1 Military Assistant for Training and Personnel Technology
Office of the Under Secretary of Defense for Research & Engineering
Room 3D129, The Pentagon
Washington, DC 20301

Civil Govt

1 Dr. Susan Chipman
Learning and Development
National Institute of Education
1200 19th Street NW
Washington, DC 20201

1 Dr. Joseph I. Lipson
SEDR U-630
National Science Foundation
Washington, DC 20550

1 William J. McLaurin
Rm. 301, Internal Revenue Service
2221 Jefferson Davis Highway
Arlington, VA 22202

1 Dr. Andrew R. Molnar
Science Education Dev. and Research
National Science Foundation
Washington, DC 20550

1 Personnel R&D Center
Office of Personnel Management
1900 E Street NW
Washington, DC 20415

1 Dr. H. Wallace Sinulko
Program Director
Manpower Research and Advisory Services
Smithsonian Institution
801 North Pitt Street
Alexandria, VA 22314

1 Dr. Frank Withrow
U.S. Office of Education
400 Maryland Ave. SW
Washington, DC 20202

1 Dr. Joseph L. Young, Director
Memory & Cognitive Processes
National Science Foundation
Washington, DC 20550
Non Govt

1 Dr. John R. Andersen
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213

1 Anderson, Thomas H., Ph.D.
Center for the Study of Reading
174 Children's Research Center
5: Gerty Drive
Champaign, IL 61820

1 Dr. John Annett
Department of Psychology
University of Warwick
Coventry CV4 7AL
ENGLAND

1 DR. MICHAEL ATWOOD
SCIENCE APPLICATIONS INSTITUTE
40 DENVER TECH. CENTER WEST
7035 E. PRENTICE AVENUE
ENGLEWOOD, CO 80110

1 1 psychological research unit
Dept. of Defense (Army Office)
Campbell Park Offices
Canberra ACT 2600, Australia

1 Dr. Alan Paddeley
Medical Research Council
Applied Psychology Unit
15 Chaucer Road
Cambridge CB2 2EF
ENGLAND

1 Dr. Patricia Baggett
Department of Psychology
University of Denver
University Park
Denver, CO 80209

1 Mr Avron Parr
Department of Computer Science
Stanford University
Stanford, CA 94305

Non Govt

1 Dr. Jackson Fawcett
Department of Psychology
University of California
Los Angeles, CA 90024

1 Dr. Isaac Bejar
Educational Testing Service
Princeton, NJ 08540

1 Dr. Nicholas A. Bond
Dept. of Psychology
Sacramento State College
600 Jay Street
Sacramento, CA 95819

1 Dr. Lyle Bourne
Department of Psychology
University of Colorado
Boulder, CO 80309

1 Dr. Robert Brennan
American College Testing Programs
P. O. Box 168
Iowa City, IA 52240

1 Dr. John S. Drown
XEROX Palo Alto Research Center
3333 Coyote Road
Palo Alto, CA 94304

1 Dr. Bruce Buchanan
Department of Computer Science
Stanford University
Stanford, CA 94305

1 DR. C. VICTOR BUNDESON
WICAT INC.
UNIVERSITY PLAZA, SUITE 10
1160 SC. STATE ST.
OREGON, UT 84057

1 Dr. Pat Carpenter
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213
<table>
<thead>
<tr>
<th>Non Govt</th>
<th>Non Govt</th>
</tr>
</thead>
</table>
| 1 Dr. John D. Carroll  
Psychometric Lab  
Univ. of N.C. Carolina  
Davie Hall 013A  
Chapel Hill, NC 27514 | 1 Dr. Lynn A. Cooper  
LRDC  
University of Pittsburgh  
3939 O'Hara Street  
Pittsburgh, PA 15213 |
| 1 Charles Myers Library  
Livingstone House  
Livingstone Road  
Stratford  
London E15 2LJ  
ENGLAND | 1 Dr. Morodith P. Crawford  
American Psychological Association  
1200 17th Street, N.W.  
Washington, DC 20036 |
| 1 Dr. William Chase  
Department of Psychology  
Carnegie Mellon University  
Pittsburgh, PA 15213 | 1 Dr. Kenneth R. Cross  
Anacapa Sciences, Inc.  
P.O. Drawer Q  
Santa Barbara, CA 93102 |
| 1 Dr. Micheline Chi  
Learning R & D Center  
University of Pittsburgh  
3939 O'Hara Street  
Pittsburgh, PA 15213 | 1 Dr. Emmanuel Donchin  
Department of Psychology  
University of Illinois  
Champaign, IL 61820 |
| 1 Dr. William Clancey  
Department of Computer Science  
Stanford University  
Stanford, CA 94305 | 1 Dr. Hubert Dreyfus  
Department of Philosophy  
University of California  
Percise, CA 94720 |
| 1 Dr. Kenneth E. Clark  
College of Arts & Sciences  
University of Rochester  
River Campus Station  
Rochester, NY 14627 | 1 LCOL J. C. Eggenberger  
DIRECTORATE OF PERSONNEL APPLIED RESEARCH  
NATIONAL DEFENCE HQ  
101 COLONEL BY DRIVE  
OTTAWA, CANADA K1A OK2 |
| 1 Dr. Norman Cliff  
Dept. of Psychology  
Univ. of So. California  
University Park  
Los Angeles, CA 90007 | 1 ERIC Facility-Acquisitions  
4833 Rugby Avenue  
Bethesda, MD 20014 |
| 1 Dr. Allan H. Collins  
Bolt Beranek & Newman, Inc.  
50 Moulton Street  
Cambridge, Ma 02138 | 1 Dr. Ed Feigenbaum  
Department of Computer Science  
Stanford University  
Stanford, CA 94305 |
| 1 | 1 Dr. Richard L. Ferguscn  
The American College Testing Program  
P.O. Box 163  
Cedar Falls, IA 52240 |
<table>
<thead>
<tr>
<th>Non Govt</th>
<th>Non Govt</th>
</tr>
</thead>
</table>
| 1 Dr. Edwin A. Fleishman  
Advanced Research Resources Organ.  
Suitetheg 900  
4330 East West Highway  
Washington, DC 20014 | 1 Dr. Harold Hawkins  
Department of Psychology  
University of Oregon  
Eugene OR 97403 |
| 1 Dr. John R. Frederiksen  
Delt Borenek & Newman  
50 Houlton Street  
Cambridge, MA 02138 | 1 Dr. Barbara Hayes-Roth  
The Rand Corporation  
1700 Main Street  
Santa Monica, CA 90406 |
| 1 Dr. Alinda Friedman  
Department of Psychology  
University of Alberta  
Edmonton, Alberta  
CANADA T6G 2E9 | 1 Dr. Frederick Hayes-Roth  
The Rand Corporation  
1700 Main Street  
Santa Monica, CA 90406 |
| 1 Dr. R. Edward Geiselman  
Department of Psychology  
University of California  
Los Angeles, CA 90024 | 1 Dr. James R. Hoffman  
Department of Psychology  
University of Delaware  
Newark, DE 19711 |
| 1 Dr. Robert Glaser  
LRDC  
UNIVERSITY OF PITTSBURGH  
3939 O'HARA STREET  
PITTSBURGH, PA 15213 | 1 Glenda Greenwald, Ed.  
"Human Intelligence Newsletter"  
P. O. Box 1163  
Birmingham, MI 48012 |
| 1 Dr. Marvin D. Glock  
217 Stone Hall  
Cornell University  
Ithaca, NY 14853 | 1 Dr. Lloyd Humphreys  
Department of Psychology  
University of Illinois  
Champaign, IL 61820 |
| 1 Dr. Daniel Gopher  
Industrial & Management Engineering  
Technion-Israel Institute of Technology  
Haifa  
ISRAEL | 1 Library  
HumRRO/Western Division  
27857 Berwick Drive  
Carmel, CA 93921 |
| 1 Dr. James G. Greeno  
LRDC  
UNIVERSITY OF PITTSBURGH  
3939 O'HARA STREET  
PITTSBURGH, PA 15213 | 1 Dr. Earl Hunt  
Dept. of Psychology  
University of Washington  
Seattle, WA 98105 |
| 1 Dr. Ron Hambleton  
School of Education  
University of Massachusetts  
Amherst, MA 01002 | 1 Dr. Steven W. Keele  
Dept. of Psychology  
University of Oregon  
Eugene, OR 97403 |
| 1 Dr. Walter Kintsch  
Department of Psychology  
University of Colorado  
Boulder, CO 80302 | 1 Dr. James G. Greeno  
LRDC  
UNIVERSITY OF PITTSBURGH  
3939 O'HARA STREET  
PITTSBURGH, PA 15213 |
Non Govt

1 Dr. David Kieras
Department of Psychology
University of Arizona
Tuscon, AZ 85721

1 Dr. Stephen Kosslyn
Harvard University
Department of Psychology
33 Kirkland Street
Cambridge, MA 02138

1 Mr. Marlin Kroger
1117 Via Goleta
Palos Verdes Estates, CA 90274

1 Dr. Jill Larkin
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213

1 Dr. Alan Lesgold
Learning R&D Center
University of Pittsburgh
Pittsburgh, PA 15260

1 Dr. Charles Lewis
Faculteit Sociale Wetenschappen
Rijksuniversiteit Groningen
Oude Boteringestraat
Groningen
NETHERLANDS

1 Dr. James Lumsden
Department of Psychology
University of Western Australia
Nedlands W.A. 6009
AUSTRALIA

1 Dr. Mark Miller
Computer Science Laboratory
Texas Instruments, Inc.
Mail Station 371, P.O. Box 225936
Dallas, TX 75265

1 Dr. Allen Munro
Behavioral Technology Laboratories
1845 Elena Ave., Fourth Floor
Redondo Beach, CA 90277

Non Govt

1 Dr. Donald A. Norman
Dept. of Psychology C-009
Univ. of California, San Diego
La Jolla, CA 92093

1 Dr. Melvin R. Novick
356 Lindquist Center for Measurement
University of Iowa
Iowa City, IA 52242

1 Dr. Jesse Orlansky
Institute for Defense Analyses
400 Army Navy Drive
Arlington, VA 22202

1 Dr. Seymour Papert
Massachusetts Institute of Technology
Artificial Intelligence Lab
545 Technology Square
Cambridge, MA 02139

1 Dr. James A. Paulson
Portland State University
P.O. Box 751
Portland, OR 97207

1 Mr. Luigi Petrullo
2431 N. Edgewood Street
Arlington, VA 22207

1 Dr. Martha Polson
Department of Psychology
University of Colorado
Boulder, CO 80302

1 Dr. Peter Polson
DEPT. OF PSYCHOLOGY
UNIVERSITY OF COLORADO
BOULDER, CO 80309

1 Dr. Steven E. Poltrack
Department of Psychology
University of Denver
Denver, CO 80208

1 Dr. Diane Ramsay-Klee
R-K Research & System Design
3947 Ridgemont Drive
Malibu, CA 90265
Non Govt

1 MINRAT M. L. RAUCH
P II 4
BUNDESMINISTERIUM DER VERTEIDIGUNG
POSTFACH 1328
D-53 BONN 1, GERMANY

1 Dr. Mark D. Reckase
Educational Psychology Dept.
University of Missouri-Columbia
4 Hill Hall
Columbia, MO 65211

1 Dr. Fred Reif
SESAME
c/c Physics Department
University of California
Berkeley, CA 94720

1 Dr. Andrew M. Rose
American Institutes for Research
1055 Thomas Jefferson St. NW
Washington, DC 20007

1 Dr. Ernst Z. Rothkopf
Bell Laboratories
600 Mountain Avenue
Murray Hill, NJ 07974

1 PROF. FUMIKO SAMEIMA
DEPT. OF PSYCHOLOGY
UNIVERSITY OF TENNESSEE
KNOXVILLE, TN 37916

1 Dr. Irwin Sarason
Department of Psychology
University of Washington
Seattle, WA 98195

1 DR. WALTER SCHNEIDER
DEPT. OF PSYCHOLOGY
UNIVERSITY OF ILLINOIS
CHAMPAIGN, IL 61820

1 Dr. Alan Schoenfeld
Department of Mathematics
Hamilton College
Clinton, NY 13323

Non Govt

1 Committee on Cognitive Research
% Dr. Lonnie R. Sherrod
Social Science Research Council
605 Third Avenue
New York, NY 10016

1 Robert S. Siegler
Associate Professor
Carnegie-Mellon University
Department of Psychology
Schenley Park
Pittsburgh, PA 15213

1 Dr. Robert Smith
Department of Computer Science
Rutgers University
New Brunswick, NJ 08903

1 Dr. Richard Snow
School of Education
Stanford University
Stanford, CA 94305

1 DR. ALBERT STEVENS
BOLT BERANEK & NEWMAN, INC.
50 MOULTON STREET
CAMBRIDGE, MA 02138

1 Dr. Thomas G. Sticht
Director, Basic Skills Division
HUMIRO
300 N. Washington Street
Alexandria, VA 22314

1 Dr. David Stone
ED 236
SUNY, Albany
Albany, NY 12222

1 DR. PATRICK SUPPES
INSTITUTE FOR MATHEMATICAL STUDIES IN
THE SOCIAL SCIENCES
STANFORD UNIVERSITY
STANFORD, CA 94305
<table>
<thead>
<tr>
<th>Non Govt</th>
<th>Non Govt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Dr. Hariharan Swaminathan</td>
<td>1 Dr. Howard Wainer</td>
</tr>
<tr>
<td>Laboratory of Psychometric and Evaluation Research</td>
<td>Bureau of Social Science Research</td>
</tr>
<tr>
<td>School of Education</td>
<td>1990 M Street, N.W.</td>
</tr>
<tr>
<td>University of Massachusetts Amherst, MA 01003</td>
<td>Washington, DC 20036</td>
</tr>
<tr>
<td>1 Dr. Kikumi Tatsuoka</td>
<td>1 Dr. Phyllis Weaver</td>
</tr>
<tr>
<td>Computer Based Education Research Laboratory</td>
<td>Graduate School of Education</td>
</tr>
<tr>
<td>252 Engineering Research Laboratory</td>
<td>Harvard University</td>
</tr>
<tr>
<td>University of Illinois</td>
<td>200 Larson Hall, Appian Way</td>
</tr>
<tr>
<td>Urbana, IL 61801</td>
<td>Cambridge, MA 02138</td>
</tr>
<tr>
<td>1 Dr. David Thisson</td>
<td>1 Dr. David J. Weiss</td>
</tr>
<tr>
<td>Department of Psychology</td>
<td>N660 Elliott Hall</td>
</tr>
<tr>
<td>University of Kansas</td>
<td>University of Minnesota</td>
</tr>
<tr>
<td>Lawrence, KS 66044</td>
<td>75 E. River Road</td>
</tr>
<tr>
<td>1 Dr. John Thomas</td>
<td>Minneapolis, MN 55455</td>
</tr>
<tr>
<td>IBM Thomas J. Watson Research Center</td>
<td>1 Dr. Keith T. Wesocurt</td>
</tr>
<tr>
<td>P.O. Box 219</td>
<td>Information Sciences Dept. Dept.</td>
</tr>
<tr>
<td>Yorktown Heights, NY 10598</td>
<td>The Rand Corporation</td>
</tr>
<tr>
<td>1 DR. PERRY THORNDYKE</td>
<td>1700 Main St.</td>
</tr>
<tr>
<td>THE RAND CORPORATION</td>
<td>Santa Monica, CA 90406</td>
</tr>
<tr>
<td>1700 MAIN STREET</td>
<td>1 DR. SUSAN E. WHITELY</td>
</tr>
<tr>
<td>SANTA MONICA, CA 90406</td>
<td>PSYCHOLOGY DEPARTMENT</td>
</tr>
<tr>
<td>1 Dr. Douglas Towne</td>
<td>UNIVERSITY OF KANSAS</td>
</tr>
<tr>
<td>Univ. of Sc. California Perceptronics, Inc.</td>
<td>LAWRENCE, KANSAS 66044</td>
</tr>
<tr>
<td>Behavioral Technology Labs</td>
<td>1 Dr. Christopher Wickens</td>
</tr>
<tr>
<td>1845 S. Elona Ave.</td>
<td>Department of Psychology</td>
</tr>
<tr>
<td>Redondo Beach, CA 90277</td>
<td>University of Illinois</td>
</tr>
<tr>
<td>1 Dr. J. Uhlaner</td>
<td>Champaign, IL 61820</td>
</tr>
<tr>
<td>Perceptronics, Inc.</td>
<td>1 Dr. J. Arthur Woodward</td>
</tr>
<tr>
<td>6271 Varie Avenue</td>
<td>Department of Psychology</td>
</tr>
<tr>
<td>Woodland Hills, CA 91364</td>
<td>University of California</td>
</tr>
<tr>
<td>1 Dr. Benton J. Underwood</td>
<td>Los Angeles, CA 90024</td>
</tr>
<tr>
<td>Dept. of Psychology</td>
<td>1 Dr. William R. Uttal</td>
</tr>
<tr>
<td>Northwestern University</td>
<td>University of Michigan</td>
</tr>
<tr>
<td>Evanston, IL 60201</td>
<td>Institute for Social Research</td>
</tr>
<tr>
<td>1 Dr. William R. Uttal</td>
<td>Ann Arbor, MI 48106</td>
</tr>
<tr>
<td>University of Michigan</td>
<td>1 Dr. Howard Wainer</td>
</tr>
<tr>
<td>Institute for Social Research</td>
<td>Bureau of Social Science Research</td>
</tr>
<tr>
<td>1990 M Street, N.W.</td>
<td>Washington, DC 20036</td>
</tr>
<tr>
<td>1 Dr. Phyllis Weaver</td>
<td>1 Dr. David J. Weiss</td>
</tr>
<tr>
<td>Graduate School of Education</td>
<td>N660 Elliott Hall</td>
</tr>
<tr>
<td>Harvard University</td>
<td>University of Minnesota</td>
</tr>
<tr>
<td>200 Larson Hall, Appian Way</td>
<td>75 E. River Road</td>
</tr>
<tr>
<td>Cambridge, MA 02138</td>
<td>Minneapolis, MN 55455</td>
</tr>
<tr>
<td>1 Dr. David J. Weiss</td>
<td>1 Dr. Keith T. Wesocurt</td>
</tr>
<tr>
<td>N660 Elliott Hall</td>
<td>Information Sciences Dept. Dept.</td>
</tr>
<tr>
<td>University of Minnesota</td>
<td>The Rand Corporation</td>
</tr>
<tr>
<td>75 E. River Road</td>
<td>1700 Main St.</td>
</tr>
<tr>
<td>Minneapolis, MN 55455</td>
<td>Santa Monica, CA 90406</td>
</tr>
<tr>
<td>1 DR. SUSAN E. WHITELY</td>
<td>PSYCHOLOGY DEPARTMENT</td>
</tr>
<tr>
<td>PSYCHOLOGY DEPARTMENT</td>
<td>UNIVERSITY OF KANSAS</td>
</tr>
<tr>
<td>1 Dr. Christopher Wickens</td>
<td>LAWRENCE, KANSAS 66044</td>
</tr>
<tr>
<td>Department of Psychology</td>
<td>1 Dr. J. Arthur Woodward</td>
</tr>
<tr>
<td>University of Illinois</td>
<td>Department of Psychology</td>
</tr>
<tr>
<td>Champaign, IL 61820</td>
<td>University of California</td>
</tr>
<tr>
<td>1 Dr. J. Arthur Woodward</td>
<td>Los Angeles, CA 90024</td>
</tr>
</tbody>
</table>