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Alignment in the Processing of Metaphor

Dedre Gentner and Phillip Wolff

Northwestern University

This research investigates the process of metaphor comprehension. We compare two classes of processing algorithms: those that begin by accessing or deriving an abstraction from the base (or *vehicle*) and then project it to the target (or *topic*) and those that begin by aligning the representations of the terms and then project further inferences from the base to the target. To decide between these accounts, we recorded subjects' time to interpret metaphors primed by either the base term or the target term (or both or neither). Abstraction-based models predict that priming by the base should lead to faster metaphor comprehension than priming by the target; alignment-based models predict no such advantage. Across a series of experiments, the results were most consistent with alignment-first processing. No base advantage was found, with the single exception of metaphors having highly conventional meanings and low (metaphorical) similarity. Further, high-similarity metaphors were interpreted faster than low-similarity metaphors, consistent with the alignment view. We conjecture that this pattern may result from a shift in processing with conventionalization: novel metaphors may be understood by alignment and conventional metaphors by abstraction.

People readily link unlike ideas. We may use the notion of a journey to understand the notion of love (Lakoff & Johnson, 1980) or our knowledge of space to understand the notion of time (Clark, 1973; Gentner & Imai, 1992). In this paper, we examine the processes by which metaphors such as these are understood. A metaphor's interpretation arises from the interaction of its base and target[1] concepts (Black, 1979). The target and base might interact in one of three ways: *pure matching*, *abstraction-first* processing, and *alignment-first* processing (Gentner, 1989; Wolff & Gentner, 1992). Pure matching models involve a search for common properties between the base and the target. Abstraction-first models entail a projection of properties from the base to the target. Alignment-first models evoke both kinds of processing: an initial search for common properties and a later projection of further properties from the base. In a series of experiments, we evaluate these models by testing their predictions concerning the role of the target and base in the time course of processing.

Pure Matching Models

Pure matching models specify that metaphors are interpreted by matching identical elements in the target and base. There is ample precedent for this view of metaphor comprehension. For example, Aristotle considered that metaphors are based on nonobvious kinds of commonalities (Aristotle, trans. 1932, pp. III, x, 4ff.) and Demetrius held that good metaphors were those that were not ''far-fetched, but natural and based on a true analogy'' (Demetrius, trans. 1927, pp. II, 78). Several modern models of metaphor comprehension draw heavily on matching processes. In an exten-

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Address correspondence and reprint requests to Dedre Gentner, Department of Psychology, Northwestern University, Evanston, IL 60208. E-mail: gentner@nwu.edu.

[1] In a metaphor such as ''A rumor is a virus'' the entity being described, *rumor,* is the *target* (or *topic*) and the entity from which the description is taken, *virus,* is the *base* (or *vehicle* or *source*). In some metaphors, the division is implicit (Miller, 1979): for example, in ''He flew across the room,'' the target may be the person's motion and the base the activity of flying. This research focuses on metaphors that express the target and the base directly in a sentence.

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sion of his contrast model of similarity, Tversky (1977) suggested that metaphors are understood by an assessment of the similarity between the base (or vehicle) and target (or topic) and that this assessment involved a search for features that optimized the quality of this resemblance. Malgady and Johnson (1976) and Johnson and Malgady (1979) proposed that comprehension involves an additive summation of the features between the two terms, with shared features given greater weight. Ortony (1979a), in his influential salience imbalance model, proposed that metaphors, like literal similarity assertions, are comprehended in terms of shared features. With metaphors, however, these shared features are of high salience in the base term and low salience in the target term. In a metaphorical statement like ‘‘Billboards are like warts,’’ for example, the shared feature of *ugly* is assumed to be of high salience in the base term (warts) and of low salience in the target term (billboards).

There is empirical support for matching processes in metaphor comprehension. Studies have found that metaphors judged high in similarity were also judged to be of high goodness (Johnson & Malgady, 1979; Malgady & Johnson, 1976; Marschark, Katz, & Paivio, 1983). Further, metaphors rated high in similarity have been found to have a greater number of shared features (Johnson & Malgady, 1979), and metaphors with many shared features have been judged to be of higher goodness than those with few (Tourangeau & Rips, 1991). In studies by Marschark et al. (1983) and Johnson and Malgady (1976, 1979), participants who rated metaphors high in semantic relatedness also tended to rate them as easier to interpret. Ortony, Vondruska, Foss, and Jones (1985), found that similarity can aid in the selection of an interpretation. Ortony et al. also found that the matching features tended to be of higher salience in the base than in the target (but see Gentner & Clement, 1988, and Tourangeau & Rips, 1991, for contradictory findings).

However, pure matching models fail to capture some important metaphoric phenomena. Several of these phenomena are laid out by Glucksberg and Keysar (1990, 1993). The first problem is feature selection. According to pure matching models, those features that enter into an interpretation are those that are shared by both of the terms. But not every shared feature is included in an interpretation (Camac & Glucksberg, 1984; Gentner & Clement, 1988; Glucksberg & Keysar, 1990; Tourangeau & Sternberg, 1981; Tourangeau & Rips, 1991). In a metaphor like ‘‘A surgeon is a butcher,’’ for instance, surgeons and butchers share a number of characteristics: both wear white coats, breathe air, and belong to service professions, but none of these is relevant to the meaning of the metaphor. A second problem concerns the matching of similar but nonidentical features. In the well-known nonliteral comparison ‘‘Men are like wolves,’’ the way in which wolves are predators is different from the way in which men are predators (Black, 1962). If metaphors are comprehended as pure comparisons, it is not clear how nonidentical but similar properties are matched (Black, 1962, 1979; Ortony, 1979a, 1979b; Ortony et al., 1985; Tourangeau & Sternberg, 1981, 1982; Verbrugge & McCarrell, 1977; Way, 1991). One could maintain that metaphors involve similar rather than identical features (e.g., Ortony et al., 1985), but this requires a process for determining the similarity of features, leading to a potential infinite regress (Gentner, 1983).

A third problem for pure matching models is that they cannot adequately explain the phenomenon of asymmetry. Metaphors often have different interpretations (or become anomalous) when reversed: ‘‘Most surgeons are butchers’’ conveys that surgeons are clumsy, whereas ‘‘Most butchers are surgeons’’ conveys that butchers are precise; and ‘‘A sermon is a sleeping pill’’ sounds odd at best if it is reversed to form the statement ‘‘A sleeping pill is a sermon.’’ In particular, pure matching models cannot explain why metaphors are more asymmetric than are literal comparisons (Glucksberg, McGlone, & Manfredi, 1997; Ortony et al., 1985). Without additional assumptions, pure matching models are ill-equipped to handle this important phenomenon. The fourth and perhaps most serious problem for pure matching models is that they fail to predict *feature importation* (or projection of *candidate inferences*): the fact that features apparently present in only one of the terms can enter into an interpretation (Glucksberg & Keysar, 1990). For example, given the metaphor ‘‘Richard is a tiger,’’ we can derive an interpretation (e.g., ‘‘Richard is ferocious and energetic’’) without knowing anything about Richard in advance. The issues listed above—feature selection, the matching of nonidentical features, asymmetry in interpretation, and feature importation—present important challenges to models based on pure matching. Both the abstraction-first and the alignment-first models offer solutions to most of these problems. We begin by describing the abstraction-first class of processing algorithms.

Abstraction-First Models

Abstraction-first models assume processing begins with the base. In these models, an interpretation is constructed by (1) finding or deriving an abstraction associated with the base; (2) projecting this abstraction from the base to the target; and then (3) verifying the information in the target typically, by matching the selected abstraction with the target representation. Algorithms of this kind have been proposed for computational models of analogy (Burstein, 1983; Carbonell, 1986; Greiner, 1988; Hobbs, 1983a, 1983b; Keane & Brayshaw, 1988; Kedar-Cabelli, 1985) and for models of metaphor (Carbonell, 1982; Kennedy, 1990; Shen, 1989, in press; Way, 1991). The theory of metaphor proposed by Glucksberg and Keysar (1990) fits into the abstraction-first framework. According to these authors, metaphors are comprehended by assigning the target to an abstract category associated with the base—either stored with the base or derived from the base as an ad hoc category—which permits the inheritance of features by the target. In the metaphor ‘‘My job is a jail,’’ for instance, the base (*jail*) is used to identify the category of which it is a prototypical member—e.g., an institution that confines one against one’s will, is unpleasant, and so on. These properties are then conveyed to the target (*my job*) by assigning the target as a member of the category defined by the base. A later version of this model is more complex. It specifies two early processes: category projection from the base as above and, simultaneously, dimension specification from the target (see Glucksberg et al., 1997).

Abstraction-first processes divide into two cases. In case 1, there is a preexisting abstraction associated with the base. For example, in the metaphor ‘‘My surgeon is a butcher,’’ there may be a stored association between the base term *butcher* and the category *individuals who are clumsy and incompetent in tasks that require finesse*. Such preexisting abstract categories allow processing to proceed via access to a conventionalized meaning. In case 2, there is no preexisting category association: the abstraction must be derived on the spot, as in Kedar-Cabelli’s (1985, 1988) explanation-based analogy. For example, in ‘‘My accountant is a spreadsheet,’’ the implied category (e.g., *something that is systematic and precise*) may need to be created during processing. In either case, once the category is either accessed or instantiated, it is used to attribute information from the base to the target, thus providing an interpretation of the metaphor.

Abstraction-driven models have several appealing properties. First, they address the problem of feature selection: only those properties that are part of the category referred to by the base are incorporated into the interpretation. Second, abstraction-first models predict asymmetry, since reversing the terms should result in an entirely different categorization: ‘‘B as a kind of A’’ vs ‘‘A as a kind of B.’’ Finally, abstraction-driven models explain how metaphors might convey new knowledge about the target. Feature-importation from base to target is possible by inheritance of properties from the abstraction associated with the base.

One line of support for abstraction-first models of metaphor is the fact that metaphors have the syntactic form of class-inclusion statements (Glucksberg & Keysar, 1990). This leads to a suggestive grammatical difference between literal and figurative comparison statements. For literal sentences, a comparison cannot be converted into a category assertion (e.g., 1b has a very different meaning from

1a). In contrast, for figurative statements, comparisons (similes) as in 2a can often be converted into category form (as in 2b). This suggests that simile, like metaphor, should be viewed as a kind of class-inclusion statement.

(1) a. A lime is like a lemon.
    b. *A lime is a lemon.
(2) a. My job is like a jail.
    b. My job is a jail.

A second line of support stems from the linguistic observation that individual terms can come to be associated with abstract categories. As noted by Glucksberg and Keysar (1990), languages can sometimes use prototypical members to refer to the category itself. In American Sign Language (ASL), signers refer to superordinates like *furniture* by signing the prototypical members of the category: e.g., chair, table, and bed. Similarly, in Hopi, the name of the most abundant deciduous tree, ''cottonwood,'' is used as the name for the entire class of deciduous trees. A recent example occurred in Israel when the word ''Demjanjuk'' was extended from from the name of a particularly sadistic guard at the Treblinka death camp to mean an ordinary person capable of committing unspeakable acts (Shinoff, 1987, cited in Glucksberg & Keysar, 1990).

Abstraction-first models address the problems inherent in pure matching models by rejecting matching as an underlying process. But this loses the intuition that metaphors reveal deep commonalities. In the next section, we describe alignment-first models, which attempt to solve the problems of pure matching models while still preserving the claim that comparison processes are fundamental in metaphor.

Alignment-First Models

Alignment-first models assume the process of interpretation begins with an alignment of representations between the base and target. Like pure matching models, they begin by finding commonalities between the base and target. However, alignment-first models match the relations between elements as well as the elements themselves; this allows alignment-first models to place nonidentical elements in correspondence by virtue of their common role in the representational structure. Further, because the match is one of connected structure rather than of individual elements, such models naturally support further inferences.

A model based on these assumptions has been developed by Gentner and her colleagues (Gentner & Clement, 1988; Gentner, Falkenhainer, & Skorstad, 1988; Gentner & Wolff, in press; Wolff & Gentner, 1992). This approach applies structure-mapping theory (Gentner, 1982, 1983, 1989) and the mapping algorithm of Falkenhainer, Forbus, and Gentner's structure-mapping engine (SME) (1986, 1989) to metaphor. Related models have been discussed for the computation of analogy (e.g., Holyoak & Thagard, 1989; Winston, 1980), as well as for metaphor (e.g., Isenberg, 1963; Verbrugge & McCarrell, 1977).

An advantage of structural alignment as a model of metaphor processing is that it is sensitive to the structural bindings in the base and target representations. Further, in the initial stages of its operation, SME's algorithm operates in a rather blind and local manner, allowing the maximal structure to emerge without having to be anticipated. For example, in SME, the process of comprehending a metaphor or analogy occurs in three stages (Falkenhainer et al., 1989). In the first stage, all identical predicates in the target and base representations are matched in parallel without regard for structural consistency. For example, in the figurative comparison ''*Tree trunks are (like) straws*'' (see Fig. 1), the match process would begin by pairing CAUSE_1 in the *tree trunk* representation with both CAUSE_1 and CAUSE_2 in the *straw* representation; TRANSPORTS in the *tree trunk* representation would be matched with TRANSPORTS in the *straw* representation, and so on. Also in the first stage, nonidentical entities and operators (e.g., functions representing dimensions) are placed in correspondence if they fill identical argument positions in the corresponding relational structures.

In the second stage, these local matches coalesce into structurally consistent connected clusters (called *kernels*). In the third stage,

```
tree trunk: (CAUSE1
               (DO (OBJECT(tree trunk)))
                  (ACTIVITY (SUCTION (SUBSTANCE (water))
                                (FROM (ground))
                                (TO (tree))))

            (CAUSE2
               (ACTIVITY (SUCTION (SUBSTANCE (water))
                              (FROM (ground))
                              (TO (tree))))
               (TRANSPORT  (OBJECT (liquid))
                              (FROM (ground))
                              (TO (branches))
                              (THROUGH (tree trunk))))

straw:    (CAUSE1
               (DO (OBJECT (person))
                    (ACTIVITY (SUCTION (SUBSTANCE (water))
                                  (FROM (container))
                                  (TO (mouth))))

          (CAUSE2
               (ACTIVITY (SUCTION (SUBSTANCE (water))
                              (FROM (container))
                              (TO (mouth))))
               (TRANSPORT  (OBJECT (liquid))
                              (FROM (container))
                              (TO (mouth))
                              (THROUGH (straw))))
```

FIG. 1. Structural representations for base and target in ''Tree trunks are (like) straws'' (showing only the matching systems).

these kernels are merged into one or a few maximal structurally consistent interpretations (i.e., mappings displaying *one-to-one correspondences* and *parallel connectivity*). For each interpretation, *candidate inferences* may be carried over from the base to the target. Candidate inferences are predicates connected to the common system in the base, but not initially part of the target's representational structure. They are inserted into the target structure, subject to verification of their correctness. In the example discussed above, if the initial representation of *tree trunks* had not included knowledge of how water enters into the tree (the relational structure under $CAUSE_2$ in Fig. 1) then the comparison would invite projecting these candidate inferences.

A particular comparison may be compatible with more than one alignment. Thus, a given comparison may give rise to more than one interpretation. The choice between interpretations is guided partly by context (Forbus & Oblinger, 1990) but more generally by the *systematicity* principle (Gentner, 1983, 1989), which states that, all else being equal, people prefer the interpretation that preserves the *largest* and *deepest* connected representational structure. In the example discussed above, this would be the interpretation in which $CAUSE_1$ in the tree-trunk representation is matched to $CAUSE_1$ in the straw representation (and not, for instance, the interpretation in which $CAUSE_1$ in the tree-trunk representation is matched with $CAUSE_2$ in the straw representation).

The structure-mapping model addresses many of the problems inherent in pure matching models. First, feature selection is explained by the systematicity principle: Only information that is part of the maximal common connected structure gets included in the interpretation. Second, the problem of feature importation is addressed by the projection of candidate inferences: Information initially unique to the base is transferred to the target by completing the system mapping. Third, the problem of matching similar but nonidentical features is addressed by the fact that nonidentical functions and objects can be placed in correspondence by virtue of common roles in a like relational structure. Finally, alignment-first models offer an explanation for asymmetry—why different ordering of the terms can yield different interpretations. Because candidate inferences are directional (from base to target), reversing the order will change the interpretation. The preferred order is that which is more informative: i.e., that which results in richer and more precise inferences (see Bowdle & Gentner, in press; Gentner & Bowdle, 1994).

Comparing Process Models

Both abstraction-first and alignment-first models provide solutions for many of the problems inherent in pure matching models. However, they differ sharply in their processing assumptions. Abstraction-driven models assume an initial process of projection from the base followed by a later verification process. Alignment-driven models assume an initial process of alignment between the base and target representations followed by projection of inferences. Thus, whereas alignment-first models begin with a comparison process, abstraction-first models begin by finding or deriving an abstraction from the base which is then projected to the target.

In Experiment 1, we contrasted these two kinds of process models by priming metaphors with either the base term or the target term. If people process metaphors via an abstraction-first process, they should be faster to interpret a metaphor if it is primed by the base than if it is primed by the target, because the process of deriving an abstract category associated with the base can begin as soon as the base is present. If people process metaphors via an alignment-first process, they should be no faster to interpret a metaphor when it is preceded by the base than when it is preceded by the target, since without both terms, the process of alignment cannot begin.

EXPERIMENT 1

Participants interpreted metaphors preceded by one of four primes: the target, the base, neither the target nor the base (blank lines), or both target and base (the entire metaphor). The main dependent measure was time to begin typing an interpretation of the metaphor. The primary prediction was as follows: If people begin comprehension with just the base, as abstraction-driven models predict, they should be faster to interpret a metaphor when it is preceded by the base than when it is preceded by the target. If people begin comprehension with both the target and the base, as alignment-driven models predict, they should be no faster to interpret a metaphor when it is preceded by the base than when it is preceded by the target. A secondary prediction concerns the both-terms condition: If processing begins with both the target and base, as is predicted by alignment-driven models, then seeing both terms should result in faster processing than seeing either term alone. This prediction does not differentiate between the two models, since seeing both terms should provide a nonspecific head start on encoding in either case. However, *failure* to find this advantage would be evidence against alignment-first models but not abstraction-first models (for which seeing both terms could conceivably provide no advantage over seeing only the base). Another nonspecific prediction made by both models is that seeing either the target or base should be faster than seeing no prime. The key differentiating prediction is that for abstraction-first models, but not alignment-first models, interpretations should be faster with base primes than with target primes.

The predictions can be summarized as follows:

$$\text{Abstraction-first: Both-primes} \leqslant \text{Base-primes} < \text{Target-primes} \leqslant \text{No-primes (Blanks)}$$

$$\text{Alignment-first: Both-primes} < \text{Base-primes} = \text{Target-primes} \leqslant \text{No-primes (Blanks)}$$

Method

Participants. The participants were 60 Northwestern undergraduates who participated for course credit.

Materials. Thirty-two metaphors, listed in Appendix A1, were either drawn from the literature (Gentner & Clement, 1988; Gildea & Glucksberg, 1981; Katz, Paivio, Marschark, & Clark, 1988; Ortony et al., 1985; Ortony, Schallert, Reynolds, & Antos, 1978) or constructed by the authors. Prior to the study, in order to establish the preferred direction of the metaphors, we asked 40 participants to order each pair of terms to make their preferred metaphor. We chose orderings in which the target–base order was preferred over its reverse ordering by at least 60% of the participants. On average, the preferred ordering was chosen by 83% of the participants.

Procedure. Participants were run on DOS-based computers in groups of two to five. Individuals were separated in sound-attenuating carrels. The session began with three practice trials in which participants were guided through the steps of thinking about and entering an interpretation. For the first of these practice items, participants were told (via a message on the screen) that their task was to interpret metaphors and that they should use the prime(s) preceding each metaphor to give them a head start on their interpretations. They were told that they could write interpretations of up to two lines in length and that they should begin typing the metaphor's interpretation as soon as they had it well formulated, but not before. (This was done to discourage participants from beginning typing before they had conceptually interpreted the metaphor. For the same reason, the backspace key was disabled in order to prevent editing.) Participants saw the primes in sentence frames, and null terms were indicated by blank lines. A sample set of prime conditions is shown below.

Prime type	Primes
Both	A job is a jail.
Base	A ________ is a jail.
Target	A job is a ________.
Blank	A ________ is a ________.

After these first three annotated practice trials were completed, there followed four more practice trials in which participants were told to practice typing in their own interpretations. For these trials and the subsequent experimental trials, the method was as follows. First, a line of asterisks appeared on the screen—for example, in the case above, * *** ** * ****. After 500 ms, the line was replaced by the prime. The prime was held for 1500 ms, followed by a blank screen for 100 ms. Then the entire metaphor was presented just below where the prime had been and a cursor appeared below the metaphor with a prompt for the metaphor interpretation. Participants finished typing an interpretation by pressing the ENTER key. After 1500 ms, the above procedure was repeated with another metaphor. The order in which the metaphors appeared was randomized differently for each participant. The dependent measure was the time between the appearance of the metaphor and the first keystroke of the interpretation. We also recorded the time required to type in an interpretation. Millisecond accuracy was achieved using Pascal procedures provided in Brysbaert, Bovens, and d'Ydewalle (1989).

Design. Four levels of Prime type (boths, bases, targets, blanks) were run in a within-subjects design. Four between-subject groups were used to counterbalance the assignment of metaphors to conditions. Each participant received all 32 metaphors in random order.

Results and Discussion

Cases in which participants took longer than 15,000 ms to begin typing their interpretation (3%) were removed from the analyses. We also excluded responses that took more than 20 s to type in (3%), in order to remove cases in which the participants began typing before having fully formulated the metaphor's interpretation. These procedures resulted in exclusion of less than 6% of the data. (The two sources of exclusion, long RTs and missing interpretations, are not mutually exclusive.)

The results provide no support for the abstraction-driven model but are fully consistent with the predictions of the alignment-driven model. As can be seen in Table 1, metaphors were not interpreted faster when preceded by bases than when preceded by targets. Also, both targets and bases were faster than blanks and slower than both-primes.

One-way repeated-measures analyses of variance indicated an overall effect of prime type across both subjects, $F_s(3,117) = 10.42$, $p < .001$, and items, $F_i(3,93) = 10.79$, $p < .001$. The Neuman–Keuls procedure was used

TABLE 1

MEAN RESPONSE TIMES AND STANDARD DEVIATIONS FOR EXPERIMENTS 1, 2, AND 3 (IN MILLISECONDS)

	Prime Type			
	Both	Base	Target	Blank
Experiment 1	3730	4315	4233	4753
	(1418)	(1713)	(1483)	(1160)
Experiment 2	1577	2779	2756	3143
	(1150)	(1245)	(1197)	(1185)
Experiment 3	2894	3706	4389	4601
	(1360)	(1487)	(1729)	(1515)

to test comparisons among the means. Both targets (M = 4233 ms; $p_s < .05$; $p_i < .05$) and bases (M = 4315 ms; $p_s < .05$, $p_i < .01$) resulted in faster interpretations than blanks (M = 4753 ms), indicating that the primes were effective. Alignment-first models necessarily predict that metaphors primed with both terms should be faster than metaphors primed with only one of the terms. Consistent with this prediction, metaphors preceded by both-primes (M = 3730 ms) were faster than metaphors preceded by either targets ($p_s < .01$, $p_i < .05$) or bases ($p_s < .01$, $p_i < .05$). The key prediction of abstraction-first models, that bases should prime interpretations more effectively than targets, did not obtain: base primes resulted in nonsignificantly slower interpretation than target primes.

In summary, the results provide no evidence for abstraction-driven processing and are consistent with the predictions of the alignment-first model. However, one concern about Experiment 1 is the rather brief (100 ms) ISI between when the prime disappeared and when the metaphor appeared. It could be that the abstraction-first model is correct, but that participants required more time to process the primes than was allotted. In Experiment 2, the ISI between the prime and metaphor was increased from 100 to 2500 ms. A second concern was with the dependent measure of time to begin typing the interpretation. In Experiment 2, participants were instructed to press the space bar when they had an interpretation. The dependent measure was thus time from metaphor offset to keypress. We expected that this procedure would reduce the variability of the response time. After pressing the space-bar key, participants entered an interpretation to keep them on task and as a check on the quality of the interpretations.

EXPERIMENT 2

Method

Participants. The participants were 40 Northwestern undergraduates who participated for class credit.

Materials and design. The materials were the same 32 metaphors used in Experiment 1. (See Table A1.) As in Experiment 1, four levels of prime type (both, bases, targets, blanks) were run within subjects. Four between-subject groups were used to counterbalance the assignment of metaphors to conditions. Each participant received the 32 metaphors in random order.

Procedure. The procedure was similar to that of Experiment 1. Participants saw the primes in sentence frames and null terms were indicated by blank lines. The ISI between the prime and metaphor was 2500 ms. When they arrived at an interpretation, participants pressed the space bar and then entered an interpretation. Response time was measured from the offset of the metaphor until the space bar was hit. The time to type in an interpretation was not measured.

Results

As in the previous experiment, response times over 15,000 ms were excluded, as were cases in which subjects' interpretations were missing. These restrictions resulted in the exclusion of less than 1% of the data. Mean response times and standard deviations can be found in Table 1.

As in the prior study, the results failed to bear out the predictions of abstraction-first models. Metaphors were interpreted no faster when primed by bases than when primed by targets. One-way repeated-measures analyses of variance indicated a significant effect of prime type across both subjects, $F_s(3,117) = 32.83$, $p < .001$, and items, $F_i(3,93) = 28.10$, $p < .001$. The Neuman–Keuls procedure was used to test specific predictions. As required by the alignment-first model, seeing both terms ($M = 1577$ ms) led to faster interpretation times than seeing either targets ($M = 2756$; $p_s < .001$, $p_i < .001$) or bases ($M = 2779$; $p_s < .001$, $p_i < .001$). Contrary to general expectations, seeing the target or the base alone did not result in significantly faster processing than seeing neither ($M = 3143$), although the differences were in the predicted direction. The key prediction of abstraction-first models was not supported: bases did not differ from targets.

Discussion

The results from Experiments 1 and 2 offer little encouragement for abstraction-first models. In both experiments, interpretations were no faster when primed with bases than when primed with targets. Further, it seems unlikely that the failure to find a base advantage is due to the particular details of the procedure, because variations of these procedures have resulted in similar findings. Wolff and Gentner (1992) report two experiments in which the ISI was 2500 ms, using 24 of the 32 metaphors used in Experiments 1 and 2 of this paper. In the first experiment, role information was left implicit by displaying the primes without a sentence frame. In the second experiment, role information was made explicit as in Experiments 1 and 2 of this paper (with one procedural difference: the missing term was indicated by the word ''something'' instead of by a blank line). In neither experiment was a base advantage found. These results, taken together with the present results, argue against abstraction-first models as a general account of metaphor processing.

However, there still remains the possibility that abstraction-driven processing may apply within a limited range of metaphors. Recall that there are two subcases within the abstraction-first model. In the first case, a preexisting metaphorical abstraction or category associated with the base term is accessed in the course of comprehending the metaphor. In the second case, there is no preexisting associated metaphorical category, and an ad hoc category must be derived from the base term in order to process the metaphor. Perhaps the problem lies with the assumption that ad hoc categories are created on-line from the base concept. It may be that abstraction-driven processing occurs only when there is a preestablished metaphoric interpretation of the base, with novel metaphors being processed via alignment. If so, abstraction-first models might fare better for conventional or ''stock'' metaphors, for which a base category is likely to be available.

This account would be in line with Swinney and Cutler's (1979) lexical representation hypothesis, according to which idioms and other conventionalized ''stock'' expressions have stable nonliteral meanings that can be accessed directly without needing to be derived anew. This hypothesis is supported by findings indicating that the nonliteral meanings of idioms are processed as fast or faster than their literal meanings (Bobrow & Bell, 1973; Cacciari & Tabossi, 1988; Gibbs, 1980). Parallel results have been found for conventionalized metaphors (Blank, 1988, Blasko & Connine, 1993), suggesting that stock metaphors that rely on conventionalized base meanings may also have lexicalized meanings associated with their bases. Such metaphors seem likely candidates for base-first processing.

In Experiment 3, we examined this possibility using stock metaphors whose base terms have strongly associated conventional categories. For example, the term *rocket* is often used to indicate metaphorically that something is very fast. Similarly, *skyscraper* often conveys tallness. Metaphors with highly conventional bases—such as ''Johnny is a rocket'' and

''That waiter is a skyscraper''—readily convey these conventional meanings. If abstraction-driven processing occurs for stock metaphors, then we should see an advantage for base priming for metaphors whose intended meanings are preassociated with the base.

An additional constraint imposed in this study was that the metaphors be low in metaphorical similarity. By *metaphorical similarity,* we mean the degree to which the target already shares the central abstraction conveyed by the base. We can illustrate the idea of metaphorical similarity by comparing the metaphors ''That soldier is a pawn'' and ''The senator is a pawn.'' In these metaphors, the base term *pawn*, conveys the idea of *being controlled by a master whose purposes may not be known.* The idea is already present within the representation of *soldier*. However, it is not likely to be prominently included in the prior representation of *senator*. As noted above, a strong prediction of alignment-driven models is that metaphors with high metaphorical similarity should be processed faster than those with low metaphorical similarity, because high similarity of the abstract relational system will promote alignment. Thus in order to give abstraction-first models every chance of succeeding, we restricted the materials to metaphors of low metaphorical similarity, thus rendering processing by alignment more difficult. Metaphors with high base conventionality and low metaphorical similarity seem maximally likely to yield the pattern predicted by abstraction-driven models, namely, that base priming will be more facilitative than target priming.

EXPERIMENT 3

Experiment 3 used the same method as the prior studies. It differed in that the metaphors were selected to be high in base conventionality and low in metaphorical similarity. The question was whether this ideal set of metaphors would provide evidence for abstraction-driven processing. As in Experiment 1, the dependent measure was the time to press the first key of an interpretation. The ISI between the prime and the metaphor was 2500 ms, as in Experiment 2. Finally, the word ''something'' was used as a filler, rather than a blank as in Experiments 1 and 2.

Method

Participants. Forty Northwestern undergraduates participated for course credit.

Materials. Twenty metaphors were constructed, shown in Appendix A2, that on average possessed a higher base conventionality and a lower similarity than the metaphors used in Experiments 1 and 2. Metaphorical similarity and base conventionality ratings were assessed as follows.

Similarity rating task. Metaphorical similarity ratings were collected from 24 Northwestern undergraduates for course credit. We asked participants to rate *relational similarity* because this instruction best characterized the kind of commonalities (or the kinds of categories) present in the metaphors and because of evidence suggesting that people prefer relational similarity in interpreting metaphors (Gentner, 1988; Gentner & Clement, 1988; Tourangeau & Rips, 1991). For example, in the metaphor ''A spine is a pillar,'' adult participants are likely to appeal to the relational commonalities of *providing support against the force of gravity* rather than to the attributional commonalities of being long and thin. Also, pilot tasks indicated that this description was less confusing than the notion of *metaphorical similarity.* Relational similarity was explained to the participants as follows: ''Things are relationally similar when they participate in the same relationships. For example, a *cigarette* and a *time bomb* are relationally similar because they both can cause harm after a period of apparent harmlessness. In contrast, an *orange* and the *sun* may look similar but they do different things; thus, they are not relationally similar.''

Three more examples with explanations were provided. During the rating task, participants rated the pairs in the frame: ''How <u>relationally</u> similar are a *spine* and a *pillar?''* and rated them from 1 (completely dissimilar) to 7 (highly similar). Participants received one of four randomized sets that contained all 32 metaphors used in Experiments 1 and 2 and the 20 pairs used in this experiment (52 pairs in all). The results showed that the metaphorical pairs used in this experiment were rated less relationally similar ($M = 2.31$) than the metaphors used in Experiments 1 and 2 ($M = 4.06$).

Conventionality rating task. Conventionality ratings were collected from 32 Northwestern undergraduates for pay. Participants saw a randomized list of the bases used in Experiments 1 and 2 and in this experiment and rated the degree of association between these bases and their likely interpretations. Specifically, they read sentences like the following: ''When we say something is a *rocket*, how conventional is the interpretation that this is *something that moves very fast?* Participants chose a rating between 1 and 7 where 1 was ''very unconventional,'' and 7 was ''highly conventional.'' The interpretations used to construct these ratings items were obtained by taking the interpretation most frequently provided by a separate group of ten participants for each of the metaphors used in Experiments 1, 2, and 3. Each participant in the rating task rated a list containing half of the metaphors used in Experiments 1 and 2 and half the metaphors used in Experiment 3. Four such lists were used so as to counterbalance the two sets and vary the order of items.

Results from these ratings indicated that the bases for the metaphors used in Experiments 1 and 2 were fairly high in conventionality ($M = 4.86$). The bases for the new metaphors constructed for Experiment 3 were rated somewhat higher in conventionality ($M = 5.72$).

Metaphor interpretation task. The procedure was similar to that of the prior studies. The dependent measure was time between metaphor offset and the first key-press of an interpretation. The ISI between the prime and metaphor was 2500 ms. Blanks were indicated by the word ''something.''

Design. Four levels of Prime type (both, bases, targets, blanks) were run within subjects. Four between-subject groups were used to counterbalance the assignment of metaphors to conditions. All participants received all 20 metaphors.

Results

As in the previous experiments, response times over 15,000 ms (1%), missing interpretations (1 case), and interpretations that required longer than 20 seconds to enter (2%) were excluded from the analysis. These restrictions resulted in the exclusion of less than 3% of the data. Means and standard deviations can be found in Table 1.

For the first time, clear support was obtained for abstraction-first models. Metaphors preceded by bases were interpreted faster than metaphors preceded by targets. Further, base primes led to faster interpretation times than did blanks, while targets did not. This result suggests that abstraction-first processing may obtain when base conventionality is high and metaphorical similarity is low.

A one-way repeated measures analysis of variance indicated an overall significant effect of prime type for both subject, $F(3,117) = 22.32$, $p < .001$, and item analyses, $F(3,57) = 11.90$, $p < .001$. Using the Neuman–Keuls procedure, it was found that metaphors primed by bases ($M = 3706$ ms) were faster than metaphors primed by targets ($M = 4389$ ms) for both subjects and items, ($p_s < .01$, $p_i < .05$). Further, metaphors primed by bases were faster than metaphors preceded by blanks ($M = 4601$ ms; $p_s < .01$, $p_i < .05$). However, metaphors primed by targets were no faster than those preceded by blanks. These results are consistent with the hypothesis that seeing the base first allows processing to begin early, while seeing the target does not. Finally, consistent with both models and with the results of Experiment 1, participants were faster to interpret a metaphor when it was preceded by both terms ($M = 2894$ ms) than when it was preceded by either the target ($p_s < .001$; $p_i < .001$) or the base ($p_s < .01$, $p_i < .01$).

Discussion

The results of Experiment 3 suggest that abstraction-first models may apply to metaphors that already have an associated metaphorical meaning. Thus, it appears that abstraction-driven processing may occur for conventional metaphors, whose bases have prestored stock meanings (cf. Bobrow & Bell, 1973; Cacciari & Tabossi, 1988; Gibbs, 1980; Swinney & Cutler, 1979). Although the abstraction-driven model can be applied to novel metaphors as well, by postulating that an ad hoc abstract category is derived from the base and then applied to the target (Glucksberg & Keysar, 1990), the results of the first two studies are not encouraging for this possibility. It appears that abstraction-driven processing may occur only for metaphors whose bases have lexicalized stock meanings (cf. Bobrow & Bell, 1973; Cacciari & Tabossi, 1988; Gibbs, 1980; Swinney & Cutler, 1979).

The pattern of results could be explained by positing an evolution in the career of a metaphor (Gentner & Wolff, in press; Bowdle & Gentner, 1995; in preparation). For a novel metaphor, the comprehension process is one of structural alignment and projection. At this stage, the common abstraction is the result of a structural alignment process. If the base term is used repeatedly to yield this interpretation, then the metaphoric abstraction will gradually come to be stored as an alternate sense of the base term. When the conventionalized sense becomes sufficiently accessible, it can be accessed as part of the process of metaphor comprehension. Viewed in this way, our results suggest that novel metaphors are processed by alignment between the literal base and target representations but that an abstraction-guided process may apply to stock metaphors.

These conclusions must be tentative, for two reasons. First, the results on which they are based are drawn across several experiments. Second, two different factors were controlled in Experiment 3: Not only was base conventionality required to be high, but relational similarity was required to be low. In order to determine whether base conventionality is a sufficient determinant of abstraction-driven processing, in Experiment 4 we systematically varied base conventionality and relational similarity, using the same priming technique as in previous studies. Four conditions were constructed by crossing the factors of base conventionality (high and low) and metaphorical similarity (high and low). If the strong abstraction-driven model is correct, then we will see a base advantage in all four cells. (Such a result would contravene our prior results.) At the other extreme, we might fail to find a base advantage anywhere, casting doubt on the existence of abstraction-driven processes in metaphor. Two intermediate cases are of interest. If abstraction-first processing applies only when conventionalized base abstractions exist, then a base advantage will obtain in the two cells that have high conventional metaphorical meanings (yielding a Conventionality × Prime-type interaction). Finally, it could be that abstraction-driven processing occurs only when base conventionality is high and relational similarity is low (as in Experiment 3), so that a base advantage occurs in only one cell. Such a result would hold, for example, if abstraction-driven and alignment-driven processes were carried out simultaneously during metaphor processing, with the first process to finish yielding an interpretation.

The career of metaphor hypothesis states that metaphors are initially processed as full structural alignments of the literal representations of the terms, but that with repeated metaphoric usage, the abstraction can come to be stored as a further word sense of the base and to facilitate subsequent metaphoric interpretation. This view predicts (1) no base advantage for novel metaphors and (2) a base advantage either for all high-conventional metaphors or only for those whose terms are of low similarity. This design also tests the alignment-driven model's prediction that metaphors high in relational similarity should be faster to comprehend than low-similarity metaphors.

EXPERIMENT 4

Experiment 4 investigated priming patterns for different levels of conventionality and similarity, using methodology similar to that in the previous three experiments. A new set of metaphors, shown in Appendix A3, was constructed to meet the conditions of this experiment. A large set of potential base terms was rated for conventionality as described below. This resulted in two sets of 16 bases, one high in conventionality and the other low. Each set of bases was paired with two targets. One target had high relational similarity with the base (e.g., ''That sauna is an oven'') and the other pair had low relational similarity (e.g., ''That room is an oven''). Care was taken to choose pairs of targets that resulted in metaphors that had highly similar meanings. We first describe the rating tasks used to confirm the similarity assignments.

Rating Tasks

Relational similarity rating task. Relational similarity ratings were collected from 24 Northwestern undergraduates for course credit. Participants received one of four randomized ratings sheets. Each sheet contained half high-similarity and half low-similarity metaphors (as judged intuitively), with no sheet containing two metaphors with the same base. Each participant rated 32 metaphors varying in a priori similarity, each with a different base. Relational similarity was explained as in Experiment 3. Items were presented in the form ''How *relationally* similar are a *spine* and a *pillar?*'' Participants used a 1 and 7 scale, where 1 was ''completely dissimilar'' and 7 was ''highly similar.'' On the basis of these ratings, one high-similarity and one low-similarity target were selected for each metaphor base. The mean ratings for the high- and low-similarity sets were $M = 3.57$ and $M = 2.34$, respectively.

Conventionality rating task. Prior to collecting conventionality ratings, interpretations were collected from a separate group of 20 participants. Each participant interpreted 32 metaphors, each with a different base (i.e., half of the 64 metaphors). Each base was used to make two metaphors (a high- and low-similarity version). In total, 10 interpretations were collected for each metaphor. The most frequent interpretation for each of these metaphors was used in the base conventionality rating task.

Base and target conventionality ratings were collected from 12 Northwestern undergraduates for course credit. In the conventionality rating task, participants were told to rate the conventionality of a word with respect to the modal interpretation of that word when used as the base of a metaphor. Specifically, they read sentences like the following: ''When we say something is a *rocket,* how conventional is the interpretation that this is ''*something that moves very fast*''? Participants chose a rating between 1 and 7 where 1 was ''very unconventional'' and 7 was ''highly conventional.'' Each participant saw half the bases and half the targets. The complete list of bases and targets was counterbalanced across participants using eight different randomizations. On the basis of these ratings, the bases were classified as either high conventional ($M = 6.02$) or low conventional ($M = 4.8$).

These relational similarity and base-conventionality ratings provided a basis for the creation of four sets, each consisting of 16 metaphors: high conventionality/high similarity, high conventionality/low similarity, low conventionality/high similarity, and low conventionality/low similarity. We then applied the priming technique from previous experiments.

Method

Participants. One-hundred and twelve Northwestern undergraduates participated for course credit.

Materials. Thirty-two metaphor pairs were constructed having the same bases, as shown in Appendix A3. One member of each pair had a low-similarity target; the other, a high-similarity target. Half the metaphor pairs had high-conventionality bases and half had low-conventionality bases.

Procedure. The procedure was like that of the previous studies. The ISI between the prime and metaphor was 0 ms; that is, the metaphor appeared immediately after the prime disappeared. Null terms were indicated by a blank line (as in Experiments 1 and 2). Response times were measured from the offset of the metaphor until the space bar was pressed indicating comprehension, as in Experiment 2. After pressing the space bar, participants typed in an interpretation for the metaphor.

Design. A 2 (Conventionality: high, low) $\times$ 2 (Relational Similarity: high, low) $\times$ 4 (Prime type: boths, bases, targets, blanks) design was used. All three factors—Conventionality, Relational similarity, and Prime

TABLE 2

Means and Standard Deviations for Experiment 4

	Prime Type				
	Both	Base	Target	Blank	Overall
High conventionality					
High similarity	2487	3143	3358	3750	3181
	(2161)	(1749)	(3358)	(2062)	(2200)
Low similarity	2947	3403	3897	4130	3598
	(2630)	(2052)	(2667)	(2208)	(2439)
Low conventionality					
High similarity	3158	3636	3516	4353	3668
	(2397)	(2882)	(2665)	(2750)	(2536)
Low similarity	3613	4538	4049	4860	4276
	(2875)	(2882)	(2849)	(2875)	(2739)
Overall means	3048	3677	3718	4274	
	(2552)	(2303)	(2535)	(2514)	

type—were within-subject. Four assignments of subjects to groups were used to achieve counterbalancing over the first two factors. Each participant received one member of each of the 32 metaphor sets.

Results and Discussion

Response times greater than 16,000 ms (3%) were removed from the analyses, as were cases in which interpretations were not supplied or which required longer than 20 s to enter (4%). In combination, these procedures resulted in the exclusion of 6% of the data.

Means and standard deviations can be found in Table 2. The strong version of the abstraction-first model was not supported: Overall, metaphors primed by their bases were comprehended no faster than metaphors primed by their targets, consistent with previous studies. Even the more limited possibility that abstraction-driven processing holds whenever base conventionality is high (but not necessarily when base conventionality is low) was not supported. However, for one specific subclass of metaphors we did find evidence for abstraction-based processing: When base conventionality was high and metaphorical similarity was low, interpretation was faster after priming by the base than after priming by the target, replicating Experiment 3 (see Footnote 2). Thus, abstraction-driven processing may hold within a highly limited scope.

Analyses of variance were carried out over subjects and items. As predicted by alignment-driven models, metaphors with high relational similarity (M = 3425) were comprehended faster than metaphors with low relational similarity (M = 3937), significant across both subjects and items, $F_s(1,92) = 23.2$, $p < .001$, $F_i(1,30) = 10.2$, $p < .01$. The main effect was somewhat less robust for conventionality. High-conventionality metaphors (M = 3390) were comprehended faster than low-conventionality metaphors (M = 3972), significant across subjects, $F_s(1,92) = 51.14$, $p < .001$, and marginally significant across items, $F_i(1,30) = 3.5$, $p = .07$. Finally, as in previous experiments, there was a main effect of prime type, $F_s(3,276) = 22.54$, $p < .001$; $F_i(3,90) = 17.27$, $p < .001$.

As mentioned above, there was no overall base advantage, so the results again fail to bear out a general abstraction-driven model. What about the abstraction-driven model restricted to high-conventional metaphors? This version also fails; there was no significant Conventionality × Prime type interaction. Rather, the effect of prime type depended as much or more on similarity as on conventionality. Three interactions were significant across subjects (though not across items): Similarity × Prime type, $F_s(3,276) = 4.44$, $p < .01$; Similarity × Conventionality, $F_s(3,276) = 4.44$, $p < .05$; and Similarity × Conventionality × Prime type, marginally significant across subjects $F_s(3,276) = 2.59$, $p = .054$. No other interactions were significant.

Differences implied by these interactions were tested using the Bonferroni method of error protection. We found a base advantage in only one of the four cells: namely, that of high base conventionality and low relational similarity. Only in this cell were metaphors faster to be processed when primed by the base ($M = 3403$) than when primed by the target ($M = 3897$). In the other three cells, no base advantage was found. There was either no difference or, in one case (the low-conventionality, high-similarity condition), a reverse result: target primes led to faster processing than base primes, $t_s(111) = 3.04$, $p < .01$; $t_i(15) = 3.85$, $p < .01$. The fact that no base advantage was found for metaphors with high relational similarity and low base conventionality accords with the findings of Experiments 1 and 2, which utilized comparable stimulus materials.[2]

These results are consistent with the career of metaphor hypothesis, which holds that novel metaphors are processed in alignment-first manner and that conventional metaphors may (but need not) be processed in abstraction-first manner. That is, when a metaphor becomes conventionalized, so that the base has associated with it a stock metaphorical meaning, then this abstraction can be accessed early and can drive initial processing. However, the fact that no base advantage was found for the high-conventional, high-similarity cell implies that the existence of a metaphorical abstraction associated with the base is not enough to guarantee abstraction-driven processing. Even for highly conventional metaphor bases, abstraction-driven processing fails to dominate under conditions of high metaphorical similarity. One plausible account is that alignment-driven and abstraction-driven processes can occur simultaneously, as in the race models discussed by Cacciari and Tabossi (1988) and Swinney and Cutler (1979). Then the existence of a prestored metaphorical abstraction for the base term permits abstraction-driven processing; accessing that base category can occur early in the metaphor comprehension process. On the other hand, the more similar the two terms, the greater the likelihood that alignment-driven processing will finish first. On this account, we would not expect a consistent base advantage in the high-conventionality, high-similarity cell.

GENERAL DISCUSSION

This research contrasted abstraction-driven and alignment-driven processing models of metaphor understanding. We conclude that each has its place but that abstraction-driven processes may have a limited sphere of explanatory sway. We began by considering the strong version of abstraction-driven processing, in which a category associated with the base term can either be accessed or derived on line during metaphor comprehension. The failure to find an across-the-board base advantage in Experiments 1 and 2 argues against this strong version. We then asked whether a weaker version of the abstraction-first theory could be retained, one in which base abstractions can be *accessed* (but not derived *de novo*) during online comprehension. In this case, base-first processing would hold for conventional metaphors, though not for novel metaphors. But the results of Experiment 4 force even a further restriction in the scope of abstraction-first models, because no base advantage was found for high-conventional, high-similarity metaphors. Thus the presence of a prior metaphorical abstraction associated with the base term is not enough to guarantee abstraction-driven processing. The metaphor must also be low in relational similarity. Even for metaphors with stock bases, high-similarity seems to promote align-

[2] The mean base conventionality ratings in Experiments 1 and 2 ($M = 4.86$) and Experiment 3 ($M = 5.72$) are comparable to those of Experiment 4's low-conventionality ($M = 4.8$) and high-conventionality ($M = 6.02$) conditions, respectively. Similarly, the mean similarity ratings in Experiments 1 and 2 ($M = 4.06$) and Experiment 3 ($M = 2.31$) are comparable to those in Experiment 4's high-similarity ($M = 3.57$) and low-similarity ($M = 2.34$) conditions.

ment-driven processing. We return to this point below. The more similar the two terms, the greater the likelihood that the alignment process will finish first.

The Career of Metaphor

These results are consistent with the proposal that there is an evolution in how metaphors are understood: Novel metaphors are understood via alignment of the full literal representations, but as the interpretation becomes conventionalized, prestored metaphoric abstractions can facilitate processing (Bowdle & Gentner, 1996; in preparation). This explains why the base-priming advantage held only for stock, conventionalized metaphors (Experiments 3 and 4) and not for novel metaphors (Experiments 1, 2 and 4).

However, the career of metaphor hypothesis should not be taken to imply that processing shifts entirely to abstraction-driven processing with conventionalization. On the contrary, our results are more consistent with a model in which alignment-driven and abstraction-driven processes occur simultaneously in processing conventional metaphors, as in the race models proposed for the processing of idioms (Cacciari & Tabossi, 1988; Gibbs, 1980). It is also possible that the process continues to be alignment-driven, even for conventional metaphors. Assuming that (a) conventional metaphor bases possess an abstract metaphorical sense and (b) for a well-formed metaphor, this base abstraction expresses the point of the metaphor, we would then predict that priming with the base might facilitate alignment-driven processing. Computationally, beginning with an abstract base representation should result in a small set of mutually consistent match kernels (Forbus & Oblinger, 1990), reducing the time required to compute a coherent metaphorical interpretation. Since by design the high-similarity targets, but not the low-similarity targets, afford the same abstraction as the base, we should see an advantage for base priming over target priming only for high-conventional low-similarity metaphors. Such a model would also predict the finding of the rapid alignment of high-conventional high-similarity metaphors (Wolff & Gentner, in preparation). This possibility of alignment processing for conventional metaphors is consistent with findings suggesting that even idioms can retain some semantic productivity (see Gibbs, 1994, pp. 265–318, for a review).

The career of metaphor hypothesis is consistent with recent work on the effects of conventionality on the processing of metaphors (Blank, 1988; Blasko & Connine, 1993; Camac & Glucksberg, 1984; Gildea & Glucksberg, 1983; Glucksberg, Gildea, & Bookin, 1982; Martin, 1992) and idioms (Cacciari, 1993; Cacciari & Tabossi, 1988; Clark & Lucy, 1975; Gibbs, 1979, 1980; Hoffman & Kemper, 1986; Swinney & Cutler, 1979), suggesting that conventionalization results in a shift in the dominant processing mode from on-line active interpretation to retrieval of stored meanings. For example, Blank (1988) and Blasko and Connine (1993) found processing-time differences between metaphors that were familiar or lexicalized and those that were novel. Metaphorical sentences from highly conventionalized domains such as ‘‘time is money’’ were responded to as quickly as literal sentences, but metaphors that lacked a conventionalized metaphorical meaning were responded to slower than literal targets. Our results suggest that metaphors with highly conventional bases can be understood by accessing preexisting metaphorical senses, but that alignment processes can still take place.

Creating Categories by Comparison

Structural alignment processes could provide a means by which metaphorical categories are created (Gentner & Wolff, in press; Johnson & Malgady, 1979). When two representations are aligned, schema abstraction processes can heighten the salience of the common relational structure (Gick & Holyoak, 1983; Kotovsky & Gentner 1996; Ross, 1989a, 1989b). Repeated comparison processes may give rise to a conventional abstraction, which then can permit subsequent metaphors to be processed via category access rather than by comparing the normal full meanings of the terms. In this way, a conventionalized or ''stock'' metaphor may develop.

To the extent that such metaphorical interpretations become entrenched, they can come to be lexicalized—associated with the base term as an alternative meaning sense (Lakoff, 1987; Lehrer, 1990; Miller, 1993; Swinney & Cutler, 1979). When this happens, such preassociated abstractions may be accessed during metaphor comprehension like any other word sense (Blank, 1988; Blasko & Connine, 1993; Gentner & Wolff, in press). For example, Miller (1993) suggests that ''leg of a table'' was once understood as a metaphorical comparison between the support of a table and the leg of an animal, but that ''leg'' has since acquired a secondary metaphorical meaning. Likewise, one sense of the term ''sanctuary'' refers to a sacred edifice; the other, to a location of safety. One can imagine this second sense evolving from implicit or explicit metaphorical comparisons like ''This cave will be our sanctuary.'' The abstract metaphoric sense may even supplant the original sense, as for words like ''sanguine,'' ''choleric,'' and ''humorous,'' whose reference to bodily fluids is barely remembered. Indeed, it may even contradict the still extant literal sense, as in Searle's (1979) example of calling someone a gorilla, meaning ''fierce, nasty, prone to violence and so forth,'' when, in fact, it is known that gorillas are ''shy, sensitive creatures, given to bouts of sentimentality.'' In cases like this, it is clear that the stock abstraction has taken on a life of its own.

Structural alignment is a means of category formation and a source of metaphorical polysemy in word meaning. This brings us full circle to connect the abstraction-driven position with the alignment-driven position. Metaphoric categories, we suggest, come about as a result of a comparison process. Structural alignment provides the mechanism for the initial extraction of abstract commonalities from novel metaphors. If this common system becomes institutionalized, then it can eventually function as a metaphoric category, thereby facilitating metaphor comprehension.

Do Metaphors Require Special Processing?

The view that metaphors require two stages of processing—a literal stage followed by additional effort when the literal interpretation fails (Clark & Lucy, 1975; Searle, 1979)—despite its initial plausibility, has failed to garner consistent support. As reviewed by Hoffman and Kemper (1986) and by Gibbs and Gerrig (1989), metaphors do not appear to require more time than literal comparisons, as would be expected if they involved more processing stages (Ortony et al., 1978; Inhoff, Lima, & Carroll, 1984). Further, metaphoric processing does not appear to be optional: Participants told to focus only on literal meaning are nonetheless unable to ignore metaphoric interpretations (Gildea & Glucksberg, 1981; Glucksberg et al., 1982; Keysar, 1989). Thus, many researchers have been drawn to the position that literal and metaphoric interpretations may use the same processes (Falkenhainer et al., 1989; Gentner, 1983; Gentner & Clement, 1988; Gentner et al., 1988; Gibbs & Gerrig, 1989; Medin, Goldstone & Gentner, 1993; Ortony, 1979b; Ortony et al., 1978; Rumelhart, 1979; Verbrugge, 1977; however, see Janus & Bever, 1985).

Structure-mapping offers a way in which metaphorical and literal comparisons can be captured within a single mechanism. The process of alignment, as modeled in SME, typically creates two or three simultaneous interpretations (which are the largest and deepest systems of interconnected predicates plus their candidate inferences). These may be either literal or metaphorical; the processing mechanism is indifferent to this distinction. Thus it is possible to arrive at both a literal and a metaphorical interpretation for the same comparison. For example, on hearing ''That husky is a wolf,'' one may arrive at both the interpretation ''He is a ferocious dog'' and the interpretation ''He is a near descendent of wolves.'' Further, the candidate inference mechanism allows for projection of further knowledge from the base, for both literal and metaphorical interpretations. On this account, the same mechanism is involved in literal inference projection—for example, inferring from ''This Chevy is (like) a Cadillac'' that the Chevy has a luxurious ride—as in nonliteral inference projection—for example, inferring from ''This job is (like) a jail'' that the job is particularly onerous. There is considerable support for this unified view of similarity and metaphoric or analogical processing (e.g., Bowdle & Gentner, in press; Gentner & Bowdle, 1994; Gentner & Markman, 1993, 1994, 1996, 1997; Gentner & Rattermann, 1991; Goldstone, 1994; Goldstone & Medin, 1994; Goldstone, Medin, & Gentner, 1991; Markman & Gentner, 1993a, 1993b, 1996; in press; Medin, Goldstone, & Gentner, 1990, 1993).

A study by Onishi and Murphy (1993) on the processing of metaphors in text produced further results consistent with the predictions of the alignment and mapping account. According to the alignment view, comparison processing should be facilitated when the two terms being compared are close in the text. Indeed, Onishi and Murphy found that when the two terms of a metaphor were located in the same sentence (e.g., *That boxer is a cream puff*), metaphors were understood as quickly as literals. Conversely, comparison processing should be more difficult when the two terms being compared are separated in the surface structure. Consistent with this prediction, metaphors were harder to interpret than literal comparisons when the two terms of a metaphor were expressed in separate sentences: specifically, when the base was used as an anaphoric reference for the target (e.g., *The cream puff didn't even show up*). It's not clear how this pattern could be explained by an abstraction-driven process.

Structure-mapping theory also addresses some theoretical weaknesses of abstraction-driven models. For example, an abstraction-first approach to comprehension involves the target concept only during the last stages of processing, when the correctness of the interpretation is checked against the target. Such an approach could prove computationally expensive. It is not clear, for example, how an abstraction-first process would easily yield different interpretations for metaphors having the same base but different targets; as in ''My surgeon is a butcher'' and ''Genghis Khan was a butcher.'' One might propose that a given base term can have several abstractions; but then the question arises of how these are coordinated during processing. A related problem is described by Murphy (1996). For example, in the metaphor ''Arguments are like wars'' not everything in the concept of *wars* is applicable to the concept of *arguments:* arguments do not normally involve armed conflict, disease, or death. Targets must have a role in constraining information from the base. If the role of targets occurs late in processing, many inferences may need to be created and rejected before an acceptable inference is found.

Glucksberg, Manfredi, and McGlone (1996) have recently proposed a variant of the class-inclusion model that could solve the base constraint problem. In this model, as in alignment models, the base and target are both active from the outset of metaphor comprehension. However, the process is not one of comparison; rather, the base and target each independently provide separate aspects of the information required for an interpretation. As in the class-inclusion model discussed here, in the first stages of metaphor processing the base provides the metaphoric category abstraction and, simultaneously, the target provides its preferred dimensions of attribution. In the case of ''My job is a jail,'' the category abstraction of *confining institution* from the base meets the preferred dimensions of attribution from the target—type of supervision, workplace environment, etc.—to arrive at the interpretation. This model is untouched by the current failure to find a base advantage in priming, since both target and base should be effective early primes, though for different reasons. However, one drawback of this proposed model is that it is difficult to separate from a comparison model.

Of course, with highly conventional metaphors, the problem of constraining the base category may not arise. The present results suggest that for a stock base, the intended interpretation is fixed. It would typically be conversationally inappropriate to try to convey a different meaning, even if such a meaning is perfectly derivable from the base. To return to Searle's (1979) example, even if the speaker and hearer both know gorillas to be shy and retiring, the appropriate interpretation of ''Fred is a gorilla'' is that he is a surly brute. On the career of metaphor account, novel metaphors require early involvement (via alignment processing) of both base and target to select which aspects of the base enter into the joint interpretation, but with conventional metaphors the base abstraction can safely be assumed almost independently of the target.

Metaphoric Systems

Another challenge to abstraction-driven models is linguistic evidence suggesting large-scale conventionalized mappings between different domains (Fauconnier, 1990, Gibbs, 1992, 1994; Lakoff, 1988, 1990; Lakoff & Johnson, 1980; Lakoff & Turner, 1989; Turner, 1988). For example, spatial language may be used to discuss health, as in ''He fell sick'' and ''Her headache lifted'' (Lakoff & Johnson, 1980; Nagy, 1974) or time, as in ''Christmas comes before New Year's'' (Bennett, 1975; Fillmore, 1971; Lehrer, 1990). The precise psychological status of these conceptual metaphorical systems remains unclear (e.g. Keysar & Bly, in press; Murphy, 1996; Glucksberg, Keysar, & McGlone, 1992). However, recent studies suggest that connected metaphoric mappings from one domain to another may have psychological force. For example, Gentner and Boronat (1992; Boronat & Gentner, in preparation; see also Gentner & Imai, 1992) found that people were more fluent at reading sentences that extended the existing structural alignment than at reading sentences based on a different mapping. Participants read passages containing extended metaphors such as ''Anger is a beast'' and their sentence-by-sentence reading time was recorded. The last sentence of each passage was always a metaphorical comparison, which was either consistent or inconsistent with the metaphoric mapping underlying the passage. Participants read the last sentence significantly faster when it extended the existing mapping than when it drew on a new metaphoric mapping. Similar findings were obtained by Allbritton, McKoon, and Gerrig (1995). In their study, participants read passages that either did or did not instantiate a conceptual metaphor such as *Crime is a disease.* In a primed recognition task, participants were faster to recognize a sentence when it and its priming sentence shared a metaphor-based schema than when they did not. Finally, Kelly and Keil (1987) found that giving participants metaphors between two domains led to an increase in the rated similarity of other consistent metaphors from the two domains. Such evidence of extended system-mappings can readily be accommodated within the structure-mapping account, which is geared toward the alignment of relational systems. As Murphy (1996) discusses, to the extent that two domains are structurally similar, large-scale mappings between the two domains become possible. Further, structural alignment as a process model readily encompasses extended metaphors. (See Forbus, Ferguson, & Gentner, 1994, for a computational extension of SME that performs such incremental mappings.) It is difficult to see, however, how an abstraction-driven class-inclusion model could handle large-scale parallel structures, because of its emphasis on a single, specific class-inclusion relationship, rather than a system of relationships.

Conclusions

The results indicate that alignment is basic to the comprehension of metaphors. For novel metaphors, we suggest that the meaning is typically discovered via structural alignment and projection. With repeated usage, the common abstraction may come to be associated with the base as a conventionalized metaphorical sense. Late in the career of a metaphor, when there exists a conventionalized meaning, comparison can be replaced by categorization.

APPENDIX A1

Materials Used in Experiment 1 and 2

A library is a fountain.
A diploma is a passport.
A rumor is a virus.
An exam is a filter.
A stagecoach is a dinosaur.
A lawyer is a sponge.
A spine is a pillar.
An audition is a door.
A job is a jail.
A groupie is a satellite.
A horoscope is a map.
A conscience is a harness.
A salesman is a bulldozer.
A parent is a roof.
A soldier is a pawn.
A rooster is a clock.
A submarine is a fish.
A lie is a dagger.
A brain is a warehouse.
A temper is gasoline.
A vacation is a drug.
A ferry is a bridge.
A desk is a junkyard.
A camel is a cactus.
A robot is a servant.
A inventor is a mother.
A lion is an eagle.
A butcher is a surgeon.
A billboard is a wart.
A zoo is a museum.
A picture is a mirror.
A resort is a hospital.

APPENDIX A2

Materials Used in Experiment 3

That dentist is a butcher.
That mechanic is a gorilla.
That clerk is a tortoise.
That computer is a dinosaur.
That car is a rocket.
That cook is a blimp.
That cowboy is a skunk.
That mayor is a jellyfish.
That receptionist is a mouse.
That book is a compass.
That building is a fossil.
That town is a magnet.
That senator is a pawn.
That busboy is a skyscraper.
That manager is a donkey.
That janitor is a clown.
That florist is an encyclopedia.
That lawyer is an ant.
That child is a computer.
That teacher is an icicle.

APPENDIX A3
Metaphors Used in Experiment 4

High Conventionality		*Low Conventionality*	
High similarity	Low similarity	High similarity	Low similarity
That argument is a war.	That conversation is a war.	That philanthropist is a fountain.	That developer is a fountain.
That lawyer is a sponge.	That teacher is a sponge.	That desk is a junkyard.	That table is a junkyard.
That lie is a boomerang.	That statement is a boomerang.	That casino is a drug.	That resort is a drug.
That hippopotamus is a blimp.	That lion is a blimp.	That submarine is a fish.	That transport is a fish.
That horoscope is a map.	That book is a map.	That ballerina is a top.	That dancer is a top.
That sauna is an oven.	That room is an oven.	That island is a cork.	That can is a cork.
That ferry is a bridge.	That boat is a bridge.	That detective is a ferret.	That policeman is a ferret.
That dragster is a rocket.	That moped is a rocket.	That sailboat is a cat.	That bicycle is a cat.
That exam is a filter.	That application is a filter.	That groupie is a satellite.	That women is a satellite.
That suburb is a parasite.	That town is a parasite.	That genius is an eagle.	That student is an eagle.
That giraffe is a skyscraper.	That busboy is a skyscraper.	That mosquito is a dart.	That nurse is a dart.
That audition is a door.	That play is a door.	That fisherman is a spider.	That mariner is a spider.
That baby is an angel.	That child is an angel.	That moat is a fence.	That river is a fence.
That librarian is a mouse.	That receptionist is a mouse.	That slum is a tumor.	That neighborhood is a tumor.
That stagecoach is a dinosaur.	That train is a dinosaur.	That canary is a violin.	That bird is a violin.
That salesman is a bulldozer.	That merchant is a bulldozer.	That camel is a cactus.	That vase is a cactus.

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