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Metaphor Comprehension: A Critical Review of Theories and Evidence

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We review psychological research bearing on major theories of metaphor comprehension. A broad survey of behavioral studies is coupled with findings from recent meta-analyses of neuroimaging studies of metaphor processing. We identify three broad theoretical positions that have been the foci of research efforts: analogy, categorization, and conceptual mapping. The first two of these emphasize relatively well-specified information-processing models; the third links metaphor comprehension to embodied cognition. Our review evaluates the evidence that has been taken as support for each view, and then critically examines studies that bear on competing hypotheses derived from opposing theories. Finally, we discuss issues that future research on metaphor should address. In particular, we call for greater consideration of the pragmatic functions of metaphor in context, of its emotional impact, and of its links to literary interpretation. We suggest ways in which mechanisms based on analogy and conceptual combination might be integrated to create a richer conception of metaphor understanding.

Public Significance Statement
This review critically assesses evidence for and against three major theoretical approaches to metaphor that have dominated psychological studies over the past four decades: analogy, categorization, and conceptual mapping. Simple metaphors are generally interpreted as category statements, but more complex metaphors are likely to be treated as analogies. Multiple mechanisms should be integrated to create a richer conception of metaphor understanding in reading literature and other everyday contexts.

Keywords: metaphor, analogy, categorization, conceptual combination, conceptual mapping

Metaphor is the use of language to describe one thing in terms of something else that is conceptually very different, as in "The streets were a furnace; the sun an executioner" (from the short story "Rosa" by Cynthia Ozick [1983]). The Greek root, *metaphora*, means "to carry over" or transfer from one domain to another. Aristotle (c. 335 BCE) claimed that ". . . the greatest thing by far is to have a command of metaphor. This alone cannot be imparted by another; it is the mark of genius, for to make good metaphors implies an eye for resemblances" (see Levin, 1982, for a discussion of Aristotle's views). Over the ensuing centuries, metaphor has proved to be a perennial source of fascination for philosophers, poets, linguists, computer scientists, and psychologists. In recent years metaphor and related cognitive processes have been linked to creative thinking in many different fields (e.g., Dunbar & Klahr, 2012). In education, metaphors can provide a potent tool for teaching abstract concepts in terms of concrete models (e.g., Gilbert, 1989; Low, 2008). Metaphors can also shape people's intuitions about issues of social policy (Landau, Meier, & Keefer, 2010; Schön, 1979/1993). In the field of artificial intelligence, the goal of automatically detecting and comprehending metaphors encountered in text corpora represents a current frontier (e.g., Gagliano, Paul, Booten, & Hearst, 2016).

Over the past four decades, a substantial body of theoretical work and psychological studies directed at the process of metaphor comprehension has emerged. This work lies at the interface of psychology, linguistics, and philosophy. Over this same period, numerous books have considered metaphor from a variety of perspectives, generally emphasizing linguistic approaches (e.g., Cohen, 2008; Dancygier & Sweetser, 2014; Gibbs, 2008; Goatly, 1997; Kittay, 1987; Kövecses, 2005, 2010; Lakoff & Johnson, 1980; Lakoff & Turner, 1989; Ricœur, 1977; Ritchie, 2013; Stern, 2000). But although reviews directed at selected subtopics have appeared (Hoffman & Kemper, 1987; Kertész, Rákosi, & Csatár, 2012; Landau et al., 2010; Meier & Robinson, 2004; Patterson, 2016), the field has not been the focus of a broad review of theories and evidence. Accordingly, the present article aims to provide a

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critical review of major theories of metaphor comprehension in light of empirical evidence that has accumulated over the past four decades.

Scope of Review and Procedure for Selection of Articles

Our goal was to undertake a comprehensive survey of psychological research on the comprehension of conceptual metaphors by adults as it bears upon major theories. We set aside work on metaphors that are very directly grounded in perception, such as studies relating light, sound, and other senses (e.g., Clark, 1973; Marks, 1974; Weger, Meier, Robinson, & Inhoff, 2007), those involving sound symbolism (e.g., Antović, 2009; Dingemanse, Schuerman, Reinisch, Tufvesson, & Mitterer, 2016; Dolscheid, Shayan, Majid, & Casasanto, 2013; Zbikowski, 2002), and the phenomenon of synesthesia (e.g., Hubbard & Ramachandran, 2005; Ramachandran & Hubbard, 2001). Our focus is on semantic processing of verbal metaphors (though we will consider how such metaphors may be linked to sensorimotor processes). Because studies have almost exclusively examined comprehension rather than metaphor production, we limited our review to the former process. The relationship between cognitive development and metaphor ability is certainly important; however, to make the present review tractable we excluded developmental studies. We did not fully review research taking a neuroscience approach because several excellent recent meta-analyses are available (Bohrn, Altmann, & Jacobs, 2012; Rapp, Mutschler, & Erb, 2012; Vartanian, 2012). We use the findings of these meta-analyses, as well as relevant individual articles, as the basis for evaluating neural hypotheses that arise from alternative theories of metaphor comprehension.

Our selection procedure is schematized in Figure 1. An initial survey of major articles on metaphor identified three major theoretical positions that have guided psychological studies over the past four decades. We refer to these positions (described below) as the *analogy*, *categorization*, and *conceptual mapping* views, which serve as the foci of our review.

To garner relevant articles reporting empirical findings that bear on the theoretical views, we performed a systematic literature search using key words and phrases associated with one or more of these positions. This search was conducted from October 2016 to December 2016; a few more articles were added subsequently. Our

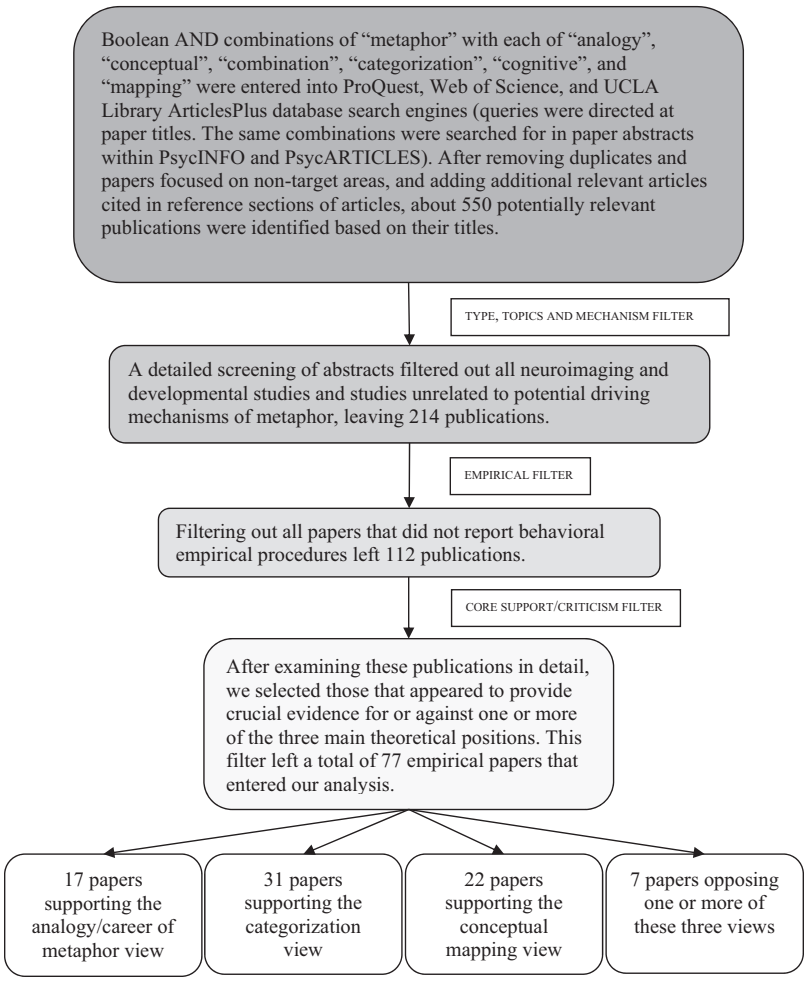

Figure 1. Steps in the selection of publications for review.

search made use of the ProQuest, Web of Science, and UCLA Library ArticlesPlus database search engines. ProQuest includes a range of databases relevant to our topic, including PsycINFO, PsycARTICLES, ERIC, LLBA, Periodicals Archive Online, and ProQuest Dissertations & Theses Global. We combined the term "metaphor" with each one in turn of six additional terms ("analogy," "conceptual," "combination," "categorization," "cognitive," and "mapping") using the Boolean operator "AND," targeting article titles. This search returned 5,015 results. Given that we searched three different but overlapping databases, about half of these initial results were duplicates, yielding around 2,400 individual articles. To ensure we did not miss relevant articles in the core databases for psychology, we repeated the query procedure (combining the term "metaphor" with each one in turn of the six additional terms), this time targeting combinations within article abstracts (rather than titles) included in the PsycINFO and PsychARTICLES databases (again using the ProQuest services). This search returned 4,051 results, around 1,500 of which were duplicates of the ones already identified. In total, the searches of titles and of abstracts identified about 4,900 unique articles.

We next examined each of these article titles and removed those that clearly belonged to disciplines other than psychology, linguistics, or neuroscience, as well as articles that were published prior to 1976. We also filtered articles that from their title were clearly unrelated to the theories on which we wished to focus (e.g., "The teaching of phonetics and phonology through analogies and metaphors"). At this point we also scanned the lists of references in recent articles representing the three theoretical positions (e.g., Gibbs & Ferreira, 2011; Glucksberg & Haught, 2006a, 2006b; Wolff & Gentner, 2011). This augmented search served to identify relevant articles published outside of major journals that had not been returned by our initial search (e.g., conference articles, chapters in edited volumes, and articles outside the PsycINFO and PsycARTICLES databases with titles that did not include the Boolean combinations of key terms that we used).

The search up to this point yielded about 550 potentially relevant articles and dissertations published since 1976. In accord with the scope of our review as summarized above, we carefully read all 550 abstracts and removed articles dealing with metaphor production, developmental aspects of metaphor comprehension, and neuroimaging. These restrictions reduced the set under consideration to 214 publications. These were skimmed one by one, and only those reporting behavioral studies were retained for primary review. The articles eliminated at this step were either entirely theoretical or were summaries of previous research (although we also made use of several theoretical and review articles). This procedure left 112 articles, each of which was carefully read. From these, we selected those articles that (in the view of their own authors) provided empirical evidence either corroborating or refuting one of the three main theoretical positions. This final selection yielded 77 articles that provide the basis for our critical review of evidence for and against the three positions. In addition to these core empirical articles, we considered work in allied areas (notably analogy and conceptual combination) that is relevant to evaluating alternative theories of metaphor comprehension. Our keyword-based search procedure for selecting articles for review does not guarantee that every relevant article published in the past 40 years was identified, but it does support confidence that the selection was unbiased with respect to the three basic positions that we evaluate.

The present article is a narrative review. The theories emphasize predictions involving different factors, and empirical studies (summarized in Appendices A1–A4) vary greatly both in the dependent measures that were examined and in the techniques and instruments employed. Interpretation of the various independent measures is made more challenging by the fact that norming of materials frequently was either not done or not reported (a problem discussed by Roncero & de Almeida, 2015). To increase the complexity exponentially, the studies we reviewed instantiate many combinations of measures, tasks, and instruments.

Metaphor: Preliminary Background

It will be useful to begin with a brief account of background assumptions about metaphor that are largely shared across the three theoretical positions. These assumptions are based primarily on work in linguistics and philosophy prior to the current review period, plus some early psychological studies. We will also introduce some basic terms that we will use throughout the present article.

Basic Concepts and Definitions

Historical Development

The history of ideas about metaphor highlights a tension between a view of metaphor as a purely figurative embellishment of literal language (e.g., "the sun's golden face" might simply add a descriptive flourish), and a view of it as a creative force in human thinking that finds its expression in language. The latter view, which emphasizes that metaphors can convey new insights, might be exemplified by the poet Theodore Roethke's metaphor "my memory, my prison" which suggests a view of personal memory as a potential trap (perhaps for someone suffering from clinical depression). The view of metaphor as a creative force came to the fore around the dawn of the 19th century, primarily through the writings of the Romantic poet and philosopher Samuel Taylor Coleridge (1817). In the 20th century this approach was refined by the literary critic I. A. Richards (1934/1962, 1936) and the philosopher Max Black (1962, 1979). These two scholars provided a systematic analysis of the components of metaphor that became the basis for psychological investigations.

Figure 2 introduces some key terms using the metaphor "The streets were a furnace." A metaphor depends on a comparison

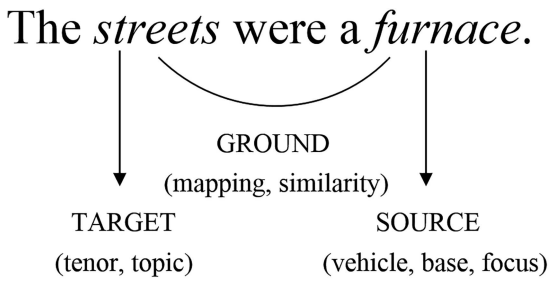

Figure 2. Example illustrating terms commonly used to define parts of a metaphor.

between two parts, for which we will use the terms *target* (what is being talked about) and *source* (the concept used to characterize the target). These terms are commonly used in psychological work on analogy (e.g., Gick & Holyoak, 1980) as well as in discussions of metaphor in cognitive linguistics (e.g., Lakoff & Turner, 1989). As indicated in Figure 2, a number of other terms often appear in the literature as near-synonyms of "source" and "target." In linguistics, Richards (1936) and Black (1962, 1979) contrasted the *tenor* (target) and *vehicle* (source). The target is also sometimes referred to as the *topic*. In the psychological literature, another synonym for "source" is *base*. For short metaphorical expressions, Black (1979) introduced the term *focus* (or *focal word*) to refer to a particular word (i.e., the source considered as a lexical item) that shifts from its literal meaning. In "The streets were a furnace" the word "furnace" undergoes such a meaning shift, and hence is the focus. The surrounding words (i.e., "The streets were a ____"), which largely retain their literal meaning, are called the *frame*.

In the terminology of Richards and Black, whatever preexisting similarities relate the source to the target provide the *ground* for the metaphor (see Figure 2). Within the analogy and conceptual mapping positions, the ground is roughly equivalent to an analogical *mapping* (a set of systematic correspondences between source and target). Within the categorization position, the ground is roughly equivalent to whatever *similarities* (shared features or associations) link the source and target.

In addition to the terminology for the parts of a metaphor, other terms refer to metaphors realized in particular syntactic forms. The syntactic form of metaphors can be extremely varied (Brooke-Rose, 1958; Perrine, 1971; Cardillo, Schmidt, Kranjec, & Chatterjee, 2010). Simpler syntactic forms include *nominal* metaphors ("The stock is a *rollercoaster*," where the focus is a noun), *predicate* metaphors ("The flower *purred* in the sunshine," based on a verb), and *attributive* metaphors ("the *weary* mountain," based on an adjective). The conceptual mapping view extends the concept of metaphor to conventionalized locative expressions (e.g., "He's feeling *up* today," based on a preposition). A slightly more complex variation of the nominal form is a *proportional* metaphor ("Religion is the *opium* of the people"), where the focal word is stated in relation to a concept from the target domain. As noted by Aristotle, by adding an unstated term drawn from the source domain a proportional metaphor can be converted into a four-term analogy (*religion: people: opium: addicts*).

During the present review period, experimental studies have primarily investigated simple nominal metaphors, in which it is transparent how the source and target relate to analogy and categorization. In addition, some studies have investigated how metaphorical expressions influence the comprehension of more extended nonmetaphorical descriptions (e.g., Lee & Schwarz, 2014; Thibodeau & Boroditsky, 2011). It is important to keep in mind that conclusions based on a limited sample of syntactic forms for metaphor may not generalize to all types.

Aptness and Conventionalization

Two dimensions of variation among metaphors are especially prominent in recent psychological work: *aptness* and *conventionalization*. A metaphor can be characterized as "apt" to the extent that the source is perceived as providing a unique and accurate description of the target—that is, salient properties of the source are attributed to relevant dimensions of the target domain (Jones & Estes, 2005, 2006). This property is generally dependent on the degree to which a statement expresses important features related to the target (Gagné, 2002).

Conventionalization refers to the impact of repeated experience with a metaphor. Roughly, a metaphor when first encountered is novel, but with repeated exposure becomes familiar, and in some cases may eventually acquire a new literal sense (Kittay, 1987; Utsumi, 2007). For the "furnace" metaphor (see Figure 2), the Oxford English Dictionary lists "a hot place" as a meaning of *furnace*—the metaphorical extension has become a dictionary entry. As a metaphor becomes conventionalized, at some point it becomes primarily of interest to the field of etymology, rather than psychology. For example, Zharikov and Gentner (2002) traced the evolution of the word *sanctuary* from its Old English meaning of a place of worship (such as a church or temple) to its more abstract meaning of a safe place. Over a longer timespan, the etymology of many relatively abstract English words can be traced back to metaphors in Latin (e.g., the Latin root of "matter" meant "mother;" the root of "subjective" meant "lying under;" see Barfield, 1928/1964).

Timing of Literal and Metaphorical Processing

At the beginning of the present review period, a prominent view in linguistics (Lyons, 1977), philosophy (Searle, 1979), and psychology (Clark & Lucy, 1975) was that metaphor comprehension involves a three-step serial process: People first derive the literal meaning of the statement, then test this meaning against the context, and then (if the literal meaning fails to make sense) seek a nonliteral meaning. This three-stage model was extensively tested and quite conclusively rejected. For example, Glucksberg, Gildea, and Bookin (1982) examined whether the availability of metaphorical meanings interfered with literal false decisions. They found that people were slower to respond "false" to sentences that were literally incongruous but had a possible metaphorical interpretation (e.g., "Some surgeons are butchers") than to false sentences that lacked a metaphorical interpretation (e.g., "Some apples are oranges"). This finding indicates that extraction of metaphorical meaning is sometimes immediate and obligatory, even when it interferes with literal processing (also see Keysar, 1989). Findings from several other studies have provided strong evidence that it is not necessary to recognize literal meaning prior to metaphor comprehension (e.g., Biava, 1991; Harris, 1976; McElree & Nordlie, 1999; Pollio, Fabrizi, Sills, & Smith, 1984).

Nonetheless, metaphor processing is often harder than literal processing. With a prior context, metaphors may be processed about as fast as literal meanings, but without a context, metaphors can take much more time than literal processing (Ortony, Schallert, Reynolds, & Antos, 1978). Metaphorical meanings become active relatively quickly (even without a prior context) when the metaphor is highly familiar, or especially apt (Blasko & Connine, 1993). For a critical review of work comparing processing times for literal and metaphorical sentences, see Hoffman and Kemper (1987). In general, the three approaches to metaphor that we will survey share the basic assumption that metaphors are grasped using augmented versions of the same processes used to comprehend literal language (Ortony et al., 1978; also see Giora, 1997).

Three Views of Metaphor Comprehension

We will now consider each of the three approaches to metaphor that have dominated psychological studies over the past four decades. We will treat them in a two-pass fashion. In this section we will briefly introduce each position, highlighting positive evidence initially offered in favor of each. We will also describe computational models that might realize core theoretical ideas. This introductory review aims to show why each position emerged as a plausible approach to metaphor comprehension. In the following section we will take a second pass, this time critically evaluating studies that provide evidence selectively favoring or opposing each of the positions. We will also evaluate proposals to integrate multiple positions.

Analogy Position

Analogical reasoning—the ability to find and exploit similarities based on *relations* among entities, rather than solely on the entities themselves—is a key mechanism underlying human intelligence and creativity (Gentner, Holyoak, & Kokinov, 2001; Holyoak & Thagard, 1995). The idea that metaphor is based on analogy originated with Aristotle, and was advanced in modern times by Black (1962), who proposed an *interaction* theory of metaphor based at least in part on analogy: "a conception of metaphors which postulates interactions between two systems, grounded in analogies of structure (partly created, partly discovered), (Black, 1979, p. 41)." Black (1962) laid emphasis on the idea of *discovered* similarities: "It would be more illuminating in some of these cases to say that the metaphor creates the similarity than to say that it formulates some similarity antecedently existing" (p. 37). The interaction theory has sometimes been contrasted with the Aristotelian view of metaphor as comparison; however, Black (1962) clearly indicated that *some* metaphors (not all) create new similarities *in addition to* preexisting ones that provide the ground for the metaphor.

In psychology, the analogy hypothesis was developed further by Tourangeau and Sternberg (1981, 1982) and Gentner and Clement (1988). For our review period, we identified 17 empirical articles that their authors interpret as providing evidence corroborating the hypothesis that metaphor comprehension is at least partly based on analogy. Appendix B lists these articles with summary information. For the wider field of analogical reasoning, a number of general reviews of empirical research and computational modeling are available (e.g., Gentner, 2010; Halford, Wilson, & Phillips, 2010; Holyoak, 2012).

The earliest modern formulations of the analogy position as applied to metaphor focused on explaining the basic observation that metaphor involves similarity between concepts drawn from dissimilar domains. Tourangeau and Sternberg (1981) performed a study evaluating the impact of both within-domain and between-domain similarity on metaphorical aptness. Participants in their main experiment (Experiment 1) received randomly generated metaphors in the proportional form "The A is the B among C" (e.g., "The shark is the hawk among fish"). Some of the metaphors linked relatively similar domains, such as birds and fish; others linked more dissimilar domains, such as ships and world leaders. Tourangeau and Sternberg (1981) found that aptness was positively correlated with within-domain similarity (i.e., similarity of relative positions within the respective domains of the source and target), and negatively correlated with between-domain similarity.

A study by Sternberg and Nigro (1983) provided further basic support for the analogy position. These investigators timed participants as they read and chose the best of two alternative completions for items presented in the format of complete proportional metaphors (e.g., "The moon in the sky is a galleon in the [a] sea, [b] bath"), or else as matched analogy problems (e.g., "moon: sky: galleon: [a] sea, [b] bath"). Choice reaction times (RTs) were highly correlated across the two forms of the task. In addition, the parameters of a detailed mathematical model of the time to solve analogy problems (Sternberg, 1977) were influenced in similar ways by a variety of manipulations involving interitem similarities and partial precuing. Indeed, the analogy model yielded a somewhat better fit to the data for metaphors than for actual analogy problems. The authors interpreted the latter finding as an indication that the metaphor form provided clearer contextual support. In a second experiment, the analogy model was also able to predict ratings of metaphor aptness and comprehensibility reasonably well. Based on these findings, Sternberg and Nigro (1983) argued that analogy plays a major role in metaphor comprehension (although they were careful to acknowledge that metaphor likely involves additional processes).

The next major development in the analogy position was made by Gentner and Clement (1988), who extended a theory of analogy termed *structure mapping* (Gentner, 1983). These investigators argued that the information underlying metaphor comprehension is much richer and more complex than could be accounted for by the knowledge representations assumed in earlier analogy models. In particular, knowledge about a complex situation typically involves both *attributes* of individual objects and *relations* between objects (as well as "higher-order" relations between relations). Even in a simple nominal metaphor, the source and target nouns are each drawn from a broader conceptual domain in which multiple entities are related to one another. For example, Table 1 schematizes some of the knowledge that might be used to comprehend the metaphor "Tree trunks are straws." The representation includes attributes of individual objects ("water is a substance"), relations between objects ("water is suctioned from ground to tree") and higher-order relations ("action of the tree trunk causes the suctioning").

Of course, people have other information about tree trunks and straws in addition to that depicted in Table 1, much of which will not be helpful in grasping the metaphor (e.g., trees have leaves; straws are made of plastic). However, the structure-mapping theory has been instantiated in an algorithm by which the matching elements of the source and target can be identified despite being embedded within a representation that also includes irrelevant facts about each. This algorithm was implemented in a computer model called structure mapping engine (SME; Falkenhainer, Forbus, & Gentner, 1989). The model has a number of variants, but the basic idea is that a process of *alignment* is used to find maximal consistent subgraphs within the source and target that yield a one-to-one (isomorphic) mapping between one another. Because a relation (especially a higher-order relation) links multiple elements filling the roles associated with the relation, relations will play a dominant role in the alignment process. For the example in Table 1, the entire relational structure shown for the source (domain of

Table 1
Predicate-Calculus-Style Representation of Some of the Knowledge Assumed to be Used in Interpreting the Metaphor Tree Trunks are Straws (Adapted from Gentner & Wolff, 1997)

```
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))))
```

straw) would be successfully aligned with that for the target (domain of tree trunk).

As applied to metaphor by Gentner and Clement (1988), the key prediction was that metaphors (like analogies in general) will primarily depend on relational similarities, rather than on attributes of individual objects. They noted that what Tourangeau and Sternberg (1981) had coded as "within-domain" similarity can be interpreted as a variety of relational overlap (i.e., source and target have similar vector distances to the other objects within their respective domains). Gentner and Clement (1988) performed several experiments that tested their key claim. In Experiment 1, participants first wrote descriptions of individual terms taken from eight metaphors (used previously by Ortony, 1979). Afterward they were presented with the metaphors, either in their natural order (e.g., "Encyclopedias are gold mines") or in the reversed order ("Gold mines are encyclopedias"). Both object descriptions and metaphor interpretations were coded for the presence of attribute versus relational descriptors. Although both attributes and relations were produced in both tasks, the metaphor interpretations were dominated by relational descriptors to a greater degree than the object descriptions, as predicted by the structure mapping theory. In addition, ratings of metaphor aptness were positively correlated with the number of relational descriptors, but not attributional ones. Aptness ratings tended to be higher for normal than reversed metaphors, though the difference was not statistically reliable. Further experiments also yielded evidence that relations dominate the comprehension of metaphors. Nonetheless, Gentner and Clement (1988) acknowledged that metaphors can involve various mixes of relational and attributional matches. Gentner and Clement (1988) also tested an alternative "salience imbalance" theory proposed by Ortony (1979), according to which the most salient features of the source are matched to less salient features of the target. In general, no such imbalance was found.

Several additional studies provided other types of evidence interpreted as support for the proposal that metaphor comprehension is based on analogy. For example, Trick and Katz (1986) found positive correlations between people's scores on a test of analogical reasoning and their ratings of the comprehensibility of metaphors (especially those with low similarity between source and target domains). Gentner and Imai (1992) attributed the latencies for switching between two different metaphor systems that can be applied to the domain of time to a process of mapping followed by remapping. Campbell and Katz (2006) interpreted evidence that reversed metaphors are generally interpretable as supporting the structure mapping model.

One further major development in the analogy position, made about a decade later, is noteworthy. In reaction to evidence supporting the rival categorization view (to be reviewed shortly), Bowdle and Gentner (1999, 2005) proposed the *career of metaphor* hypothesis. The authors began by examining the relationship between metaphor and polysemy, drawing attention to the widely supported hypothesis that novel metaphoric mappings can create new word meanings that function as domain-general categories (as in the example of the word *sanctuary*, discussed above). Early work on analogical problem solving (Gick & Holyoak, 1983) had shown that comparison of disparate analogs can generate a more abstract schema that functions much like an abstract category, facilitating transfer to additional new domains. Bowdle and Gentner (1999, 2005) argued that metaphor, like analogy in general, has two generative functions—structural enhancement of the target based on the source when a metaphor is first encountered, and the lexical extension of the source, which provides the kernel for an abstract category. According to the career-of-metaphor hypothesis, a novel metaphor is understood using analogy. However, after repeated encounters have led to its conventionalization, the metaphor is understood more like a category statement.

Bowdle and Gentner (1999, 2005) as well as other studies provided evidence interpreted as support for the career-of-metaphor hypothesis, which provides a potential compromise between the analogy and categorization positions. Because this work is directly relevant to the assessment of both positions, we will defer reviewing it until we introduce the latter.

Categorization Position

The second major view of metaphor that arose during the present review period claims that metaphors (at least some of them) are interpreted as category statements (Glucksberg & Keysar, 1990). Whereas the analogy view assumes that even a nominal metaphor involves a mapping between multiple elements of the source and target domains (see Table 1), the categorization view assumes that metaphor comprehension operates on a comparison of the two individual concepts alone. The categorization view is thus computationally less demanding. The prima facie argument for this position is that nominal metaphors, such as "My job is a jail," have the same syntactic form as literal category statements, such as "My job is a profession." Glucksberg and Keysar (1990) noted that literal comparison statements typically relate entities at the same level of abstraction (e.g., "Plums are like peaches"), and

cannot sensibly relate an instance to a category (e.g., *"Plums are like fruit"). In contrast, a metaphorical comparison (e.g., "My job is a jail") can also be expressed in simile form as a comparison ("My job is like a jail").

Glucksberg and Keysar (1990) interpreted this difference between literal comparisons and similes as evidence that a metaphorical source has two meanings: its literal concrete meaning ("a jail is a secure building that houses prisoners") and also a more abstract categorical meaning ("a jail is a cause of unwanted loss of freedom"). The simile form elicits a comparison based on the concrete meaning of the source, whereas the metaphor form is a category statement. A related observation is that metaphors usually change their meaning radically when source and target are reversed (e.g., The meaning of "My job is a jail" is not conveyed by "A jail is my job," which seems anomalous). Such irreversibility is a natural feature of category statements, since the two terms differ in level of abstraction (e.g., *"A fruit is a plum" is anomalous). Appendix C summarizes 31 empirical behavioral studies that claim to provide support for the categorization position.

Glucksberg, McGlone, and Manfredi (1997) provided the first direct experimental test of the categorization position. One prediction was that metaphors should generally be nonreversible (because the source, not the target, is interpreted as a category label). In their first experiment, native speakers of English were presented with metaphors, their corresponding similes, and literal similarity statements, each in both possible orders. Participants rated the expressions for sensibleness; and for each statement that was rated at least somewhat sensible, participants were asked to provide a paraphrase. Mean ratings indicated that literal similarity statements were far more reversible than metaphoric statements (in either metaphor or simile form). Indeed, less than 4% of metaphoric statements were considered acceptable when reversed, compared to 82% of the literal comparisons. The findings thus confirmed that metaphors are generally nonreversible. In a second experiment, Glucksberg et al. (1997) found that the effectiveness of the source as a prime depended on it being relatively unambiguous, whereas the effectiveness of the target depended on the extent to which it provides constraints on the sorts of properties that can be plausibly attributed to it (e.g., "lawyer" is more constraining than "brother"). These ambiguity/constraint effects were also interpreted as evidence for the categorization view.

The categorization position requires some computational process that could in effect extract an abstract meaning from the source. Typical models of categorization construct a category representation incrementally over a series of examples. But the categorization approach to metaphor, if it is to be applicable to *novel* metaphors, requires a process that can operate in "one-shot" fashion on a single example. The leading candidate for such a mechanism proposed during this review period is *conceptual combination*. In general, sentence meanings (whether literal or metaphorical) are understood as systematic combinations of the meanings of constituent words. The simplest examples of conceptual combination involve integrating the meaning of an adjective with that of the noun it modifies (e.g., "brown shoe"). In slightly more complex cases, even a literal conceptual combination of an adjective with a noun can be a nonadditive function of the properties of the individual words (Medin & Shoben, 1988). In this respect, conceptual combination begins to approximate Black's (1962) interaction theory.

This holistic quality becomes yet more apparent in noun–noun combinations, where one noun serves as a modifier of a head noun. A great deal of evidence (e.g., Gagné & Shoben, 1997; Wisniewski, 1997; Wisniewski & Bassok, 1999; Wisniewski & Gentner, 1991; Wisniewski & Love, 1998) indicates that when trying to make sense of a novel noun–noun combination, like "robin hawk," people follow one of two main strategies. One strategy, *property transfer*, is to interpret the modifier much like an adjective, extracting some salient property from it, which is than applied to the head. Thus, a robin hawk might be a kind of hawk with a red breast similar to that of a robin. A second strategy, *relation formation*, is to find a plausible relation in which each noun plays a role. A robin hawk might then be understood as a kind of hawk that preys upon robins.

Costello and Keane (2000, 2001) demonstrated that people prefer property-transfer interpretations in which the information used is uniquely salient in the modifier, and the overall meaning is plausible yet informative (i.e., conveys something new). For example, a "cactus fish" might plausibly be a fish that has sharp spines like those of a cactus. "Has spines" is uniquely salient to cactus, and plausible (but not so expected as to be uninformative) as a property of a species of fish. This interpretation is preferable to the alternative possibility that a cactus fish is a green fish—though a cactus is likely to be green, "green" is not very specific, as it is the color of many other types of plants besides cacti.

Estes and Glucksberg (2000) argued that the categorization view of metaphor can be interpreted as a type of conceptual combination. In their *interactive property attribution model*, the head concept provides relevant dimensions and the modifier concept provides candidate features for attribution. The interpretation is guided by the interaction of dimensions and features, rather than by the overall similarity between the concepts. Maguire, Maguire, and Cater (2010) investigated interactional semantic patterns in compound phrases, and found that interpretation is easier when the modifier is compatible with the relation preference of the head noun.

Analogy and conceptual combination each apply much more broadly than to metaphor alone. Both rely on decomposing the source and target into elements, which are then compared and somehow integrated so as to create coherence (for discussion of other processes guided by coherence-seeking, see Holyoak & Powell, 2016; Kintsch, 1988). However, it has been argued that conceptual combination cannot be reduced to analogy (Keane & Costello, 2001). Whereas analogy depends on structured representations of relations among multiple entities (as illustrated in Table 1), a conceptual combination can potentially be derived using unstructured feature vectors attached to individual words (Kintsch, 2000). The basic idea is that the meaning of any individual word depends on the meanings of the other words in its semantic neighborhood. The stable meaning of a word in semantic memory can be viewed as a large vector (in typical simulations, perhaps 300 features). Meaning vectors can be derived empirically from the frequencies with which words co-occur in texts, using statistical techniques such as latent semantic analysis (LSA; Landauer & Dumais, 1997), or more recent approaches such as Word2vec (Mikolov, Yih, & Zweig, 2013).

To model conceptual combination, it is necessary to assume that a word's stable vector is modified by the context in which the word appears. That is, each word's meaning-in-use is a combination of

its stable meaning and the meanings of the other words with which it co-occurs in a linguistic expression. This mechanism begins to capture the context sensitivity of word meanings. Using this general framework, Kintsch (2000, 2001; Kintsch & Bowles, 2002; Kintsch & Mangalath, 2011) developed a computational model of how the meaning of simple nominal metaphors can be constructed by a form of conceptual combination. Kintsch's (2000) model is highly compatible with Glucksberg and Keysar's (1990) categorization theory. For a nominal metaphor, such as "My lawyer is a shark," Kintsch's (2000) model involves three basic steps: (a) starting with the stable vectors for the target ("lawyer") and source ("shark"), spreading activation serves to identify those words that are most closely associated with the source (perhaps the top 500); (b) the intersection set is identified: those associates of the source that are also associated (above some criterion value) with the target; and (c) the stable vectors for the target and source are merged with those for the words in the intersection set to create a new vector, which represents the meaning of the metaphor as a whole.

Applied to "My lawyer is a shark," Kintsch's (2000) model alters the stable meaning vector for "lawyer" so that the metaphoric conceptual combination becomes more similar to "vicious"—a property transferred from shark. But other salient properties of sharks, like "swims," are *not* transferred because they do not have associative links to lawyer. The model thus creates coherent conceptual combinations, enhancing those properties that link source to target and suppressing those that do not. Because only some of the properties of the source are transferred to the target, the source itself (here "shark") acts like an abstract category ("vicious creature").

Kintsch's (2000) model treats metaphor as an extension of literal text comprehension, because the same basic algorithm can also handle contextual disambiguation of word senses. The model captures a number of important phenomena about metaphor comprehension. First, they are generally not reversible (Glucksberg et al., 1997; Ortony, 1979). Directional differences in meaning are explained by Kintsch's (2000) model because it transfers meaning asymmetrically—the strong associates of the source have a greater impact on the constructed interpretation than do the strong associates of the target. Also, people have more trouble finding a metaphorical interpretation if the metaphor is preceded by a literal sentence that primes features of the source that prove to be irrelevant to the metaphor (Glucksberg et al., 1997; McGlone & Manfredi, 2001). For example, reading "Sharks can swim" interferes with understanding "My lawyer is a shark." Interference is created because the literal sentence causes "swim" to become highly active, which interferes with access to other associates of "shark" (some of which connect to "lawyer"). Conversely, if the metaphor "My lawyer is a shark" precedes the literal statement "Sharks can swim," reading the metaphor makes people slower to agree that the literal statement is true (Gernsbacher, Keysar, Robertson, & Werner, 2001). Interestingly, such filtering of irrelevant information after metaphor comprehension is observed even for older adults, who in other cognitive tasks generally show deficits in inhibitory control (Newsome & Glucksberg, 2002).

In keeping with Black's (1962) interaction view, the metaphorical combination of concepts can create similarities that did not preexist. Kintsch (2000) discusses the example (due to Gibbs, 1994) "That girl is a lollipop"—a metaphor that arguably can be interpreted as meaning something like "That girl is frivolous." In this case, not only are the stable meanings of "girl" and "lollipop" dissimilar, but the source ("lollipop") is not associated with the property "frivolous." Nonetheless, a few associates of the source, like "friendly," "smiled," and "carnival" intersect with those of "girl," and these cause the derived feature vector for the compound to move in the direction of "frivolous." In other words, multiple weak and indirect associations that cohere with one another can create an emergent meaning. This possibility is in accord with the empirical findings of Goldvarg and Glucksberg (1998), which indicated that similarity of constituents is neither a necessary nor sufficient condition for property construction.

Although Kintsch's (2000) model was only applied to nominal metaphors, he termed it *predication theory*, and argued that it can be extended to predicate metaphors (e.g., "The flower purred in the sunshine"). In such cases the verb (focal word) would act as the source. The model in principle would shift the meaning vector of the verb to emphasize those properties consistent with the target domain (in essence, inhibiting the "cat" properties of "purr" to create a more abstract action, roughly "respond positively to soft contact"). In a nominal metaphor, the source noun plays the logical role of a predicate. Thus, the categorization view could be interpreted as positing a general process for creating an abstract predicate in a one-shot fashion by merging meaning vectors for the source with the target, while emphasizing associates of the source that are also associated with the target.

Kintsch (2000) acknowledged that his model would not suffice to account for more complex literary metaphors. Nonetheless, for the simple nominal metaphors that have been the focus of psychological studies, his model provides a concrete computational instantiation of the categorization approach.

Conceptual Mapping Position

The third major position on metaphor in this review period differs from the first two in that its roots lie in linguistics—in particular, the subfield of cognitive linguistics—rather than in psychology. Nonetheless, the conceptual mapping view has also inspired a considerable number of psychological studies. The view is mainly associated with the linguist George Lakoff and his collaborators (Lakoff, 1987, 1993, 1994, 2014; Lakoff & Johnson, 1980, 1999; Lakoff & Turner, 1989; Turner, 1987). However, the basic ideas were anticipated by Embler (1966) and Reddy (1979). Similar early proposals were made by the Argentine writer Jorge Luis Borges (in a 1967 lecture entitled "The Metaphor" published in Borges, 2000), and by the Serbian mathematician Mihailo Petrović (1933/1967). Table A3 summarizes 22 empirical studies that claim to provide support for the conceptual mapping position.

The main thesis of the conceptual metaphor mapping is that metaphors occur much more widely in language and thought than has generally been recognized. Conceptual mappings are distinguished from metaphorical linguistic expressions, which represent realizations in language of underlying metaphorical patterns in thought (Kövecses, 2010). Conceptual mappings specify both source and target, and are generally summarized by slogans such as LOVE IS A JOURNEY or ARGUMENT IS WAR. For each conceptual mapping, a source conceptual domain is mapped onto a target conceptual domain—the former generally more concrete, and the latter more abstract (see

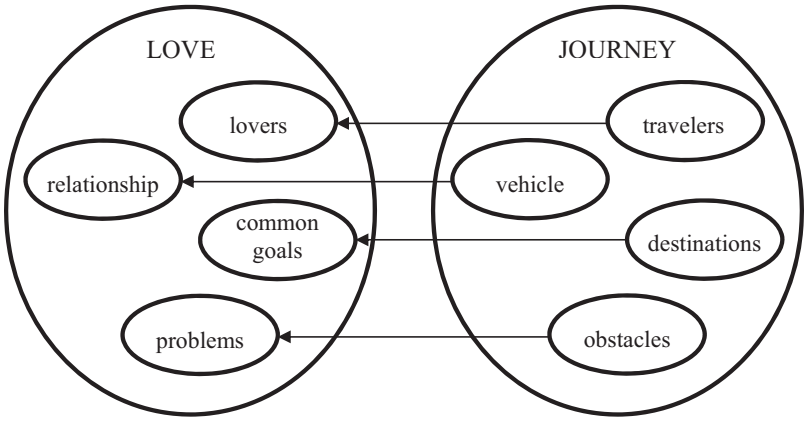

Figure 3. Hypothetical conceptual mapping based on LOVE IS A JOURNEY.

Figure 3). Note that conceptual mappings are stated in the form of category statements (in accord with the categorization approach), though they are typically interpreted as mappings (in accord with the analogy approach).

Much of the work on conceptual mappings has been descriptive, aiming to characterize the particular conceptual metaphors that people use routinely. Lakoff and Johnson (1980) distinguished between three main kinds of metaphor—*orientational*, *structural,* and *ontological* (though these kinds might overlap and in some cases be combined). Orientational (i.e., spatial) metaphors have a source based on the spatial organization of the world, the spatial properties of human bodies, and the way in which people interact with their environment. Examples of orientational metaphors include HAPPY IS UP, SAD IS DOWN, CONSCIOUS IS UP, UNCONSCIOUS IS DOWN, and FORESEEABLE FUTURE EVENTS ARE UP OR AHEAD. Structural metaphors are nonspatial, but transfer relations from one basic domain of experience to another—that is, the structure of the source domain is mapped onto the target domain to help grasp the latter. Examples of structural metaphors include ARGUMENT IS WAR, THEORIES ARE BUILDINGs, and LIFE IS A JOURNEY. Ontological metaphors involve ways of viewing intangible or abstract concepts (e.g., feelings, activities, and ideas) as entities or substances—they in effect "give being" to concepts that do not physically exist (e.g., INFLATION IS AN ENTITY, IDEAS ARE OBJECTS).

Experimental studies motivated by the conceptual mapping approach are exemplified by work aimed at demonstrating the psychological reality of the conceptual mapping ANGER IS HEATED FLUID IN A CONTAINER (Gibbs & Nayak, 1991; Gibbs & O'Brien, 1990; Lakoff, 1987; Nayak & Gibbs, 1990; for a general discussion see Gibbs, 1992). Gibbs and O'Brien (1990) found that people's images of idioms apparently based on this conceptual mapping for anger ("blow your stack," "flip your lid," "hit the ceiling") share similar characteristics despite their superficial differences. Notably, stacks are blown, lids are flipped, and ceilings hit because of internal pressure that causes some substance to be released violently and involuntarily in an upward direction. In contrast, people's images for literal (nonidiomatic) phrases using matched verbs were more disparate, presumably because they lacked a unifying conceptual mapping.

Although slogans like LIFE IS A JOURNEY are always nominally stated as categorizations, the mechanism proposed to enable such links (based on conceptual mappings) is closer to that described within the analogy position. The conceptual mapping view focuses on conventional metaphors, for which conceptual mappings are assumed to be prestored. Metaphor comprehension is thus treated as a kind of constrained analogical reasoning in which the relevant mappings are retrieved, rather than computed by complex reasoning (Barnden, 2008; Fischer, 2017). A number of computational models based on conceptual mappings have been developed. These models have generally used hand-coded representations of the knowledge hypothesized to underlie the metaphors, including the assumed mappings (e.g., Barnden & Lee, 2001; Feldman & Narayanan, 2004; Loenneker-Rodman & Narayanan, 2009; Narayanan, 1997, 1999). Goatly (1997), one of the proponents of this view of metaphor, calls conceptual metaphors "root analogies," suggesting they have the properties of being undetectable and "extending deep underground" (pp. 43–45). A major limitation of the computational models inspired by the conceptual mapping view is that they have not specified learning mechanisms that might generate conceptual mappings. In our critical discussion (below), we will consider whether the conceptual mapping position should be viewed as a special case of the analogy position.

Rather than focusing on well-specified computational models, theorists advocating the conceptual mapping position have treated metaphor within a general framework termed "embodied" or "grounded" cognition (Barsalou, 2008; Gibbs, 2006; Maturana & Varela, 1987; Wilson, 2002). Under this view (Ackerman, Nocera, & Bargh, 2010; Lakoff, 1987; Lakoff & Johnson, 1980, 1999; Wilson & Gibbs, 2007), the process of metaphor understanding involves simulations based on modality-specific sensorimotor systems in the brain. Lakoff (2014) argued that embodied experience leads to what he calls "embodied primary metaphors" (p. 2). These embodied primary metaphors can, in turn, be combined to generate more complex conceptual mappings. The embodied view of conceptual mappings thus at least hints at a process by which abstract concepts could arise from sensorimotor inputs. This proposal, which leads to neural hypotheses, will be evaluated as part of our critical analysis of the three positions.

Critical Analysis of Evidence for and Against Each Position

Each of the three positions has garnered evidence in favor of and against it. We will organize our critical analysis in two broad sections. First, we will consider evidence that bears on an extended debate between proponents of the analogy and categorization positions, as well as on an attempt to find a compromise between the two. Second, we will consider evidence that bears on the claims of the conceptual mapping position, including efforts to clarify its status with respect to the analogy position.

In both sections, we will consider two sorts of evidence: (a) behavioral studies that directly test opposing predictions of the alternative positions; and (b) studies on allied topics that bear on underlying claims of each position (including evidence from neural investigations). The studies of the first type include those listed in Appendices A1–A3. In addition, we consider seven additional studies that claim to provide evidence *against* one or more positions (without necessarily supporting any particular one of the three major positions). These are summarized in Appendix A4.

It is important to note that all three positions have evolved across the past four decades. Each includes multiple variants, which sometimes need to be considered individually. Our aim here is not to reconstruct the history of theory development, but rather to critically evaluate the status of psychological theories of metaphor from the vantage point of the present. In many cases later findings have altered the interpretation of earlier studies; sometimes we disagree with both sides of a debate. We emphasize that our own critical analyses are not intended to undermine the importance of any of this body of work. Rather, our critiques reflect our efforts (admittedly imperfect) to extract what has been learned from past work that may now guide future research on metaphor.

Is Metaphor Based on Analogy, Categorization, or Both?

The analogy and categorization positions appear to make different claims about the overall sequence of processing in metaphor comprehension. The analogy view posits an initial lateral comparison of source and target domains, followed by potential abstraction of a schema that embraces both. The categorization view posits an initial abstraction process applied to the source, the result of which is then predicated of the target. Whereas the analogy view emphasizes a comparison of multiple elements that constitute a relational structure within each domain, the categorization view emphasizes direct application of a single source concept to the target.

Is Analogy Equivalent to Comparison?

Depending on the specific algorithm used to instantiate each position, any processing differences between them may be subtle. One key concept that has played a role in the debate between the analogy and categorization positions is *comparison*. The analogy position has often been equated with the claim that metaphor comprehension involves a comparison of the source and target. This assumption has been shared by proponents of both the analogy view (e.g., Gentner & Bowdle, 2008) and the categorization view (e.g., Glucksberg & Haught, 2006b). For example, Gentner, Bowdle, Wolff, and Boronat (2001) use the terms "comparison" and "alignment" (the process of finding relational correspondences) interchangeably in claiming that analogy provides the primary basis for metaphor. And indeed, the structure mapping model (Gentner & Clement, 1988) involves comparison, whereas some prominent models based on the categorization view (Glucksberg & Keysar, 1990; Glucksberg et al., 1997) apparently do not assume a direct comparison of properties of the source and target (at least during initial processing). The categorization view has sometimes been characterized as an alternative to the traditional comparison view of metaphor tracing to Aristotle (e.g., Glucksberg & Haught, 2006b). Nonetheless, proponents of the analogy view (e.g., Gentner & Wolff, 1997) have sometimes characterized the categorization view as involving "matching" of features (without clarifying how matching is distinct from comparison). The fact that the categorization models under discussion have been formulated only verbally, rather than as computational models, doubtless has contributed to the apparent lack of clarity regarding their processing assumptions.

In fact, comparison (of features, relations, or both) is a far more general process than either side in the debate seems to have acknowledged. For example, a honeybee is capable of some sort of comparison between the color of a new flower and that of one encountered earlier (being more likely to alight on the new blossom if a previous one of the same color had yielded nectar). But it would surely be an overreach to claim that honeybees (which lack a prefrontal cortex) are capable of the sort of alignment involved in human analogical reasoning (Penn, Holyoak, & Povinelli, 2008). Conversely, Kintsch's (2000) predication model of metaphor comprehension (the best-specified computational realization of the categorization view) is based on a comparison of the relatively strong associates of the source with associates of the target to identify those that overlap. Thus, comparison is neither restricted to analogical reasoning nor excluded from categorization. Accordingly, arguments based on whether or not metaphor comprehension requires comparison are unlikely to provide decisive evidence for or against either position.

Directionality in Metaphor Processing

One line of debate has focused on the nature and timing of the directionality of processing the source versus target during metaphor processing. There has been general agreement, both in linguistics and psychology, that metaphors primarily involve transfer from source to target rather than vice versa (e.g., "My job is a jail" is saying something about a job, based on knowledge about jails). Metaphors generally cannot be reversed without loss or alteration of meaning (e.g., Chiappe, Kennedy, & Smykowski, 2003a). But irreversibility per se is consistent with either position (analogy: Analogical transfer proceeds from source to target; categorization: The source provides the abstract category to be applied to the target).

Nonetheless, efforts have been made to distinguish the two approaches based on some aspect of directionality. Gentner and Wolff (1997) argued that the analogy and categorization positions (at least for some instantiations of each) differ in regard to the temporal priority of processing the source and target. They claimed that the categorization model of Glucksberg and Keysar (1990, 1993) predicts that the source must be processed first (to abstract

a categorical meaning). In contrast, the SME model of analogy (Falkenhainer et al., 1989) posits an initial alignment process that is symmetrical (identifying matching elements of the two analogs). Gentner and Wolff (1997) tested this apparent difference between the algorithms using a priming paradigm. They argued that according to the categorization view, the processing of a metaphor (e.g., "A job is a jail") should be facilitated to a greater degree if it is presented immediately after brief exposure to the source (e.g., "A ____ is a jail") rather than after exposure to the target (e.g., "A job is a ____"). In apparent contradiction to this hypothesis, results of several experiments revealed that both types of primes yielded equal facilitation relative to a baseline condition. The sole case that yielded an advantage for the source prime (Experiment 3) involved metaphors that were highly conventional and low in source-target similarity. Gentner and Wolff (1997) argued that only in such limited cases was a prestored categorical meaning of the source available to guide metaphor interpretation.

However, Gentner and Wolff's (1997) interpretation of their findings was challenged by Glucksberg et al. (1997). As noted earlier, the latter investigators found that the effectiveness of the source as a prime depended on it being relatively unambiguous, whereas the effectiveness of the target depended on the extent to which it provides constraints on the sorts of properties that can be plausibly attributed to it. These researchers therefore argued that there is no universal regularity regarding whether source or target is more effective in priming metaphor comprehension. Rather, both terms potentially provide useful information, but only if an individual term is unambiguous (for source) or constraining (for target; also see McGlone & Manfredi, 2001). This exchange between advocates of the two positions exemplifies a recurring issue in studies of metaphor comprehension: Materials chosen to instantiate a certain type of metaphor are almost inevitably accompanied by variations on other dimensions that may prove to be important in moderating the empirical findings.

However, Wolff and Gentner (2000) provided a different type of evidence suggesting that early processing of metaphors may be symmetrical in some cases. They adopted a paradigm introduced by Glucksberg et al. (1982), who had demonstrated that people are relatively slow to judge sentences that have a metaphorical interpretation to be literally false. That finding had been interpreted as evidence that metaphor processing is obligatory. Wolff and Gentner (2000) compared the magnitude of interference with literal judgments caused by standard metaphors (e.g., "Some suburbs are parasites") versus reversed metaphors (e.g., "Some parasites are suburbs"). For metaphors rated high in relational similarity (such as the example here), the forward and reversed versions both caused interference of the same magnitude. For low-similarity metaphors (e.g., "Some towns are parasites"), neither the forward nor reversed version caused reliable interference.

Wolff and Gentner (2011) found additional evidence for symmetric early processing of metaphors using a deadline procedure. Participants were required to judge whether or not a sentence was "comprehensible", with variations in the deadline imposed. When the deadline was short (600 ms), forward and reversed metaphors yielded no reliable difference in the proportion of sentences judged to be comprehensible, but both types were more likely to judged comprehensible that control sentences with scrambled terms.

Overall, this line of research appears to support two empirical conclusions. First, the relative benefit of priming a metaphor by source versus target is moderated by the ambiguity/constraint associated with the individual terms (Glucksberg et al., 1997). Second, the very early stages of metaphor comprehension at least sometimes involve symmetrical processing of the source and target (Wolff & Gentner, 2000, 2011). However, the implications of these empirical phenomena for evaluating the analogy and categorization positions remain unclear. Although symmetrical early processing is consistent with the alignment stage of the SME model of analogy, it might instead reflect some more holistic process of evaluating the global similarity of the source and target words (cf. Goldstone & Medin, 1994). On the categorization side, it is striking that the best-specified computational model (that of Kintsch, 2000) has been ignored in this debate. We described that model in terms of three steps, the first two being identifying associates of the source and then comparing these to associates of the target. Although this process could be implemented as a serial, asymmetrical algorithm, the underlying claim is simply that people find the intersection of source and target associates. An intersection search could be accomplished by spreading activation, a symmetrical process initiated from both target and source (indeed, merging the first two steps of the model as an intersection search would appear to be a neurally plausible implementation). The final step in Kintsch's (2000) model—updating the target vector based on those of the source and the shared associates—introduces a clear asymmetry in metaphor interpretation, in accord with the bulk of empirical findings.

In sum, we conclude that research on directionality of processing, though empirically fruitful, has not decided the debate between the analogy and categorization positions.

Are Similes Processed in the Same Way as Metaphors?

Another issue that has sometimes been related to alternative views of metaphor involves the relationship between similes and metaphors. As is typical in the literature on metaphor processing (e.g., Gentner, Bowdle, et al., 2001), we have been using the term "metaphor" to refer either to the linguistic form of a metaphor or to the more general conceptual linkage of disparate source and target domains. In the latter sense, an alternative form of metaphor is the simile (e.g., "My job is like a jail"), which introduces an explicit linguistic cue to comparison, whereas the standard metaphor form does not. Proponents of the categorization view have sometimes argued that similes and metaphors are both processed as category statements (Glucksberg & Keysar, 1993). On the other hand, it has also been argued that similes are *not* equivalent to their corresponding metaphors, and that this fact speaks against the analogy position (Glucksberg & Haught, 2006b). In some cases the simile form is less impacted by reversal of the terms than is the corresponding metaphor (e.g., Chiappe et al., 2003a; Glucksberg et al., 1997). Bowdle and Gentner (2005) found that people tend to prefer the simile form for novel metaphorical comparisons, but the metaphor form for more conventional metaphorical expressions. This finding was used to support the career-of-metaphor hypothesis—the interpretation being that a simile evokes an analogical comparison, which is necessary for novel metaphorical expressions, whereas the metaphor form (in agreement with the categorization position) evokes categorization, which is easier for familiar or conventionalized metaphorical expressions. We will discuss

this line of work more thoroughly below when we consider the career-of-metaphor hypothesis directly.

In general, however, it does not seem justified to tightly link the simile form to analogy and the metaphor form to categorization. By its nature, a simile explicitly cues comparison whereas a metaphor does not. The presence or absence of an explicit cue might well have an impact on how an analogical alignment (or other type of comparison) proceeds, thereby altering the time course of processing and/or the interpretation that is achieved. Thus, the mere fact that similes and metaphors differ psychologically does not preclude the possibility that analogy is involved in both, nor does it compel the interpretation that analogy and categorization are each involved but for different types of metaphors.

What Sort of Career Does Metaphor Take?

In various ways, the back-and-forth debate between the analogy and categorization advocates encouraged the development of a kind of compromise: the career-of-metaphor hypothesis. Although proposed most explicitly by Bowdle and Gentner (2005), elements of the idea trace back at least to Wolff and Gentner (1992). In essence, this compromise position posits that analogy is used to grasp novel metaphors, whereas categorization is applied to more familiar conventional metaphors. As noted above, Bowdle and Gentner (2005) supported this hypothesis with evidence that similes are preferred for novel metaphorical statements, whereas the metaphor form is preferred for more conventional metaphors.

However (in another example of the difficulties encountered in developing metaphor materials that cleanly vary in one specific way), further research led to a reinterpretation of Bowdle and Gentner's (2005) findings. A number of studies found that *aptness* of a metaphor—a measure of how well the source characterizes the target—is a better predictor of various performance measures than is conventionality (Chiappe, Kennedy, & Chiappe, 2003b; Jones & Estes, 2005, 2006). Indeed, Bowdle and Gentner (2005) themselves found that the metaphors they had classified as "novel" were rated as reliably less apt than those classified as "conventional." This confounding raised the possibility that the career of metaphor does not actually run from novel ones (for which similes are preferred) to conventional ones (for which the metaphor form is preferred). Rather, perhaps the metaphor form is preferred for apt metaphors—and metaphors generally get to be conventional only if they are apt. Novel metaphors—often constructed for experimental purposes—may generally be less apt, and hence may benefit from the explicit comparison cue provided by the simile form. Jones and Estes (2006) manipulated aptness and conventionality independently for a set of metaphors. Across three experiments, aptness rather than conventionality predicted the preference for metaphors over similes, the speed and ease of metaphor comprehension, and judgments that the target is a member of the source category.

In summary, the findings from this line of investigation call the career-of-metaphor hypothesis into serious question. It is certainly probable that novel and conventional metaphors are processed differently in various ways, but there seems to be no compelling evidence that such differences involve a shift from analogy to categorization. It should be emphasized that even proponents of the categorization view have cautioned that not all metaphors can be comprehended on the basis of categorization (Glucksberg & Haught, 2006b). But for the simple nominal metaphors generally used in the experiments we have reviewed, it remains possible that categorization is used to understand even novel ones (unless those "metaphors" are simply bad).

Individual Differences in Analogical Reasoning and Working Memory

A relatively small number of studies have investigated individual differences in cognitive factors that the analogy and categorization positions predict should impact processing of metaphors. As noted earlier, Trick and Katz (1986) found positive correlations between people's scores on a test of analogical reasoning and ratings of the comprehensibility of metaphors, especially when the source and target were drawn from dissimilar categories. Similarly, Nippold and Sullivan (1987) reported that within a sample of children, perceptual analogical reasoning was related to verbal analogical reasoning, as well as to comprehension of proportional metaphors.

Other studies, generally supportive of the categorization position, have focused on individual differences in working memory. Kazmerski, Blasko, and Dessalegn (2003) had their participants complete IQ and working memory tests, and rate and interpret a set of metaphors. They found that low-IQ participants produced poorer-quality interpretations relative to high-IQ individuals, but similar ratings. In a study by Chiappe and Chiappe (2007), individuals who scored high on a working memory test generated better interpretations of metaphors more quickly. In addition (i.e., statistically separable from the impact of the working memory measure), measures of inhibitory control (based on Stroop interference and intrusion errors on a memory test) also predicted metaphor processing (also see Pierce & Chiappe, 2008).

These findings were generally interpreted as support for Kintsch's (2000) predication theory, which relies on working memory in searching for associates of the source and target, and on inhibitory control to suppress strong associates of each that do not belong to their intersection set. However, as we discuss below, computational models of analogy also place great (probably greater) demands on working memory and inhibitory control. Moreover, measures of individual differences in analogy ability are highly correlated with measures of fluid intelligence and of executive functioning (which includes both working memory and inhibitory control; e.g., Snow, Kyllonen, & Marshalek, 1984). Thus, while studies of individual differences in metaphor processing have yielded a consistent and sensible pattern of results, these findings do not provide a strong basis for discriminating between the analogy and categorization positions.

Neural Substrate of Metaphor Processing

Though our review focuses on behavioral studies of metaphor comprehension, the analogy and categorization positions also lead to different predictions about the likely neural substrate. Accordingly, we will consider some evidence from neural studies of metaphor processing that bears on the two positions. We will not undertake a full review, but rather rely largely on findings from recent meta-analyses of neural studies concerning metaphor processing (Bohrn et al., 2012; Rapp et al., 2012; Vartanian, 2012) and analogical reasoning (Hobeika, Diard-Detoeuf, Garcin, Levy, & Volle, 2016; Vartanian, 2012).

By way of background, we will first consider what is known about the neural substrate of analogical reasoning, and how neural evidence constrains computational models of analogy. In work on the psychology of metaphor, by far the most prominent computational model has been SME (Falkenhainer et al., 1989). However, numerous other computational models of analogy have been developed over this review period, including Analogical Constraint Mapping Engine (ACME; Holyoak & Thagard, 1989), Incremental Analogy Machine (IAM; Keane, Ledgeway, & Duff, 1994), Structured Tensor Analogical Reasoning (STAR; Halford, Wilson, & Phillips, 1998), Learning and Inference with Schemas and Analogies (LISA; Hummel & Holyoak, 1997, 2003), and Discovery Of Relations by Analogy (DORA; Doumas, Hummel, & Sandhofer, 2008). Although these computational proposals differ in many important ways, they generally share key assumptions relevant to potential applications to metaphor comprehension. In particular, most assume structured representations that encode variable bindings—information about "who did what to whom." Analogy is a prime example of higher-order relational reasoning (Penn et al., 2008), as its full power depends on explicit relational representations (Doumas & Hummel, 2012). Such representations distinguish relational roles from the entities that fill those roles, while coding the bindings of entities to their specific roles.

In those computational models of analogy that aim to make contact with the neural basis for reasoning (e.g., STAR, LISA, and DORA), variable binding and the alignment process that depends on such bindings place extensive demands on working memory and processing capacity. Neuropsychological (e.g., Morrison et al., 2004; Waltz et al., 1999) and neuroimaging studies (e.g., Bunge, Helskog, & Wendelken, 2009; Cho, Holyoak, & Cannon, 2007) have established that complex analogical reasoning involves broad regions of the frontal and parietal cortices that form a frontoparietal network (Duncan, 2010). In particular, numerous studies (e.g., Bunge et al., 2009) have shown that complex analogical reasoning (including reasoning about verbal analogies that cross semantic domains, as metaphor does; Green, Kraemer, Fugelsang, Gray, & Dunbar, 2010, 2012) is almost invariably accompanied by activation of the left rostrolateral prefrontal cortex (RLPFC; for an overview of research on its functions, see Burgess & Wu, 2013). The meta-analyses of neuroimaging studies reported by Vartanian (2012) and by Hobeika et al. (2016) support this conclusion. Accordingly, activation in this area can be used as a neural marker that should be observed during metaphor comprehension when and if analogy (based on complex relational processing) provides the underlying mechanism.

The next step is to examine whether neural studies of conceptual combination (the most likely mechanism that could underlie the categorization position) and of metaphor understanding also reveal reliable neural activity in this region. In the case of conceptual combination—at least for simple, literal compounds like "young man"—the RLPFC does not appear to be activated. The region most typically involved in conceptual combination is the anterior temporal cortex (often considered the semantic hub of the brain; e.g., Baron, Thompson-Schill, Weber, & Osherson, 2010; Lambon Ralph, Sage, Jones, & Mayberry, 2010).

In the case of metaphor, findings from over 60 neural studies have been summarized in recent meta-analyses (Bohrn et al., 2012; Rapp et al., 2012; Vartanian, 2012). In interpreting these results, we need to keep in mind that all of these studies used simple metaphors, usually in the nominal form (though sometimes in predicate form). Surveying the available studies, a number of brain areas tend to be activated to a greater degree when processing metaphors as compared with literal language. Notable areas that support metaphor include broad regions of the temporal cortex, the inferior frontal gyrus (often linked to semantic selection; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997), and sometimes the dorsolateral prefrontal cortex (a major substrate of working memory). Activation is typically bilateral, but sometimes more pronounced in the right hemisphere for relatively novel metaphors. What is most striking in the context of our evaluation of the analogy position as an account of metaphor is that *none* of the many neural studies of metaphor have yielded clear activation of the RLPFC, the region that has emerged as a neural marker of complex analogical reasoning. The neural evidence, then, does not provide support for the view that analogy is the dominant process involved in comprehending simple metaphors. As Kintsch and Bowles (2002) noted, in cases where metaphor comprehension appears to be relatively easy, complex analogical reasoning is not a viable mechanism.

What about the career-of-metaphor hypothesis, according to which analogy is used to process novel metaphors, then is gradually replaced by categorization as the metaphor becomes more conventional? A recent neuroimaging study (Cardillo, Watson, Schmidt, Kranjec, & Chatterjee, 2012) tested this hypothesis by using metaphors that were initially novel, and having people read them repeatedly so that the expressions became increasingly familiar. This study found that the RLPFC was not selectively engaged by metaphor processing at *any* stage in the process of conventionalization. Interestingly, broad areas of the right hemisphere were somewhat more active when the metaphors were novel. In general, overall neural load decreased with repeated exposure to the metaphors, but there was no compelling evidence of a qualitative shift in processing strategy.

In sum, the available neural evidence (in accord with the behavioral findings reviewed earlier) does not favor the view that simple metaphors (even novel ones) generally require explicit analogical reasoning. However, we need to be careful not to overstate this negative conclusion. It remains possible that metaphors are interpreted using some analogical mechanism that is computationally less demanding than those assumed in current models of explicit analogical reasoning. In our final section we will revisit our interim conclusion and consider alternative interpretations.

What is the Status of Conceptual Mappings as a Psychological Theory?

Over the past four decades the analogy and categorization positions have engaged in very direct debates as to which provides the best account of metaphor comprehension, and whether they should be somehow integrated. In contrast, the interchanges between adherents of the first two positions and the third—conceptual mapping—have generally been more oblique. Perhaps because the third position is rooted more in linguistics than in psychology, it has sometimes been unclear precisely what psychological claims it makes.

At the most general level, the conceptual mapping position posits that meaning is based on broad conceptual metaphors. In

particular, many concepts appear to be derived from our naïve understanding of physical space, which has been characterized as a "universal donor" to metaphor (Gentner, Bowdle, et al., 2001, p. 242). For example, a simple sentence like "She gave me a good idea," arguably draws on the conceptual metaphors IDEAS ARE OBJECTS and MENTAL TRANSFER IS PHYSICAL TRANSFER. Human conceptual structure (and hence the semantic structure of human languages) is viewed as ultimately grounded in perception and action. This view (which predates the conceptual mapping position; see Miller & Johnson-Laird, 1976) is attractive in many ways, potentially helping to understand the origins of abstract concepts.

However, the core *psychological* issues about metaphor comprehension involve the mental and neural processes underlying online processing. In normal usage, a sentence such as "She gave me a good idea" may not be processed as a metaphor at all, but simply as a literal expression. In general, the conceptual mapping position tends to blur the distinction between metaphorical and literal language (for defenses of the distinction see Kittay, 1987, especially pp. 19–22; and Stern, 2000, pp. 176–187). Lakoff and Johnson (1980) claimed that a word like "depressed" is understood in terms of a conceptual mapping summarized by the slogan SAD IS DOWN (p. 15). On a historical scale, conceptual mapping might provide an account of what has been dubbed "cognitive archeology" (Gentner, Bowdle, et al., 2001)—the etymology of individual word meanings. But although our conceptual and semantic structure may well be largely metaphorical in origin (Barfield, 1928/1964; Embler, 1966; Evans & Green, 2006; Goatly, 1997; Lakoff & Johnson, 1980, 1999), it is far from obvious that people access deep conceptual mappings each time they encounter any expression that might be somehow traced to a proposed conceptual metaphor.

What, then, does the conceptual mapping position imply about how people comprehend metaphors? In surveying the work related to conceptual metaphor as a psychological theory, three broad controversies are salient. We will consider each in turn.

What is the Role of Conceptual Mapping in Online Comprehension?

One line of empirical work (primarily involving proponents of the categorization position) has challenged the claim that conceptual mappings are necessarily engaged when people comprehend everyday language. For example, Glucksberg and McGlone (1999) asked college students to interpret metaphors for love to assess whether they make use of the alleged conceptual mapping LOVE IS A JOURNEY (see Figure 3). They found that "journey" was almost never mentioned by participants. This was true even for the metaphor, "Our love is a journey to the bottom of the sea," which includes the word "journey." Instead, participants generated paraphrases such as "Our love is mysterious and dangerous."

A useful paradigm for investigating online use of conceptual mappings makes use of metaphorical targets that can be described using multiple sources. Nayak and Gibbs (1990) gave people passages that were intended to set the stage for an idiomatic expression that was based either on the conceptual mapping ANGER IS HEAT ("she blew her top") or else ANGER IS A BEAST ("she bit his head off"). Participants rated the idiom as a more appropriate completion if it was consistent with the terms that preceded it in the passage (e.g., "hotter" cues anger, vs. "savage" cues animal). However, Glucksberg, Brown, and McGlone (1993) noted that this result could have been due to either simple lexical priming or to postcomprehension evaluation of stylistic consistency. They replicated Nayak and Gibbs' (1990) study using a control for lexical overlap, and with reading time as the dependent measure (because reading time more clearly measures online comprehension). Contrary to the prediction of the conceptual mapping position, consistency of mapping had no impact on reading time. Other studies confirmed the absence of a mapping-consistency effect for conventional expressions (Boronat, 1990; Gentner, Bowdle, et al., 2001; Keysar, Shen, Glucksberg, & Horton, 2000). However, these studies did obtain consistency effects for more novel metaphorical expressions.

A particularly interesting domain in which a consistency effect is found involves conceptual metaphors for time (Gentner & Imai, 1992; Gentner, Imai, & Boroditsky, 2002). Time is generally understood in terms of space, but admits of two alternative mappings. In the ego-moving system, a person is conceptualized as moving along a time line. The "front" is assigned to the future, and "back" to the past. This system yields expressions such as "The Thanksgiving holiday is behind us." In the time-moving system, time is conceptualized as being in motion (like a conveyor belt on which we are standing), with the future moving toward the past ("Christmas is coming"). Hence the "front" is assigned to the past, yielding expressions such as "Thanksgiving is before Christmas." People make use of perspective information when they encounter these two types of temporal configurations in discourse (McGlone & Harding, 1998). Gentner et al. (2002) found that online processing of time expressions was slowed if successive expressions shifted from one mapping system to the other.

In summary, evidence from studies of metaphor comprehension does not support the extreme view that comprehension of expressions ordinarily considered literal, such as "I'm depressed," necessarily requires access to a conceptual mapping such as SAD IS DOWN (Keysar et al., 2000). In general, conventional metaphors or idioms seem to be understood without evoking a conceptual mapping, as evidenced by the lack of a mapping-consistency effect on reading time. The consistency effects observed for time terms (Gentner et al., 2002) constitute an interesting exception. However, the alternative systems for coding time (ego-moving vs. time-moving), although presumably both derived from a mapping to space, may now function psychologically as autonomous conceptual systems for coding time. Thus, the fact that shifting from one to another causes interference confirms that time expressions involve a systematic ambiguity, but need not imply that time is necessarily mapped to space during online comprehension.

There is, however, good evidence that inconsistent mappings impair online processing for *novel* metaphorical expressions (Boronat, 1990; Keysar et al., 2000). Although such findings provide some support for the conceptual mapping position, they would also be predicted by the analogy position (Gentner, Bowdle, et al., 2001; Wolff & Gentner, 2011).

Is Conceptual Mapping Just Analogical Mapping?

The limited empirical support for the conceptual mapping position highlights a second issue that warrants critical assessment: Perhaps the conceptual mapping position is actually just a special

case of the analogy position. Proponents of conceptual mapping may have made a descriptive contribution by identifying a variety of source-target pairings that underlie many literal and figurative word meanings, and that people continue to commonly use to generate and comprehend novel metaphors. However, perhaps they have failed to provide a distinct new psychological theory of metaphor comprehension.

Indeed, proponents of the conceptual mapping view have had little to say about the computational process that might operate in applying such mappings. Lakoff and Turner (1989) proposed the "invariance hypothesis," later renamed the "invariance principle" (Lakoff, 1993; Turner, 1993). According to Lakoff's (1993) statement of the principle, "Metaphorical mappings preserve the cognitive topology (that is, the image-schema) of the source domain, in a way consistent with the inherent structure of the target domain" (p. 215). But from a psychological and computational perspective, what the invariance hypothesis means remains unclear (Murphy, 1996). Because the standard conceptual-mapping slogans, like LOVE IS A JOURNEY, explicitly relate one source to one target, the hypothesis would seem to imply that a fixed isomorphism exists between the two domains. However, this interpretation of the hypothesis would preclude multiple mappings for the same target (LOVE IS A JOURNEY, LOVE IS A FIRE), as well as multiple targets for a single source (LOVE IS A FIRE, KNOWLEDGE IS A FIRE).

If source and target domains are free to take on multiple metaphorical "partners," the invariance hypothesis would appear to simply be a new name for the isomorphism principle incorporated in most computational models of analogical reasoning. And indeed, Gentner, Bowdle, et al. (2001; also Gentner & Bowdle, 2008) have argued that conceptual mappings can be explained by the SME model of analogy. However, as we discussed earlier, computational models that assume an explicit alignment process are inherently demanding on working memory and related resources. This fact does not mesh with Lakoff's (1993) claim that "The system of conventional conceptual metaphor is mostly unconscious, automatic, and is used with no noticeable effort, just like our linguistic system and the rest of our conceptual system" (pp. 227–228). As the example shown in Figure 3 suggests, the conceptual mapping view posits that mappings between individual components of the source and target are prestored and fixed (e.g., for LOVE IS A JOURNEY, "travelers" maps to "lovers" and "obstacles" to "problems"). Thus, Lakoff (1993) apparently predicts that conceptual mappings, in the sense he intends, do not require a cognitively demanding online process of alignment. As we saw earlier, the computational models of metaphor inspired by Lakoff's (1993) theory (Barnden, 2008) have taken the form of analogy models based solely on prestored (and hand-coded) conceptual mappings. Although these models have not been clearly linked to human working memory limits, prestored mappings could plausibly reduce the cognitive load imposed by full-blown analogical reasoning.

The most compelling resolution of this theoretical dilemma is the same as the apparent conclusion supported by empirical studies. Highly conventional metaphors do not appear to require online access to conceptual mappings (i.e., such mappings are even easier than "automatic"—they are not performed at all). Novel metaphors, by contrast, require the kind of information-processing mechanisms proposed by the analogy and/or categorization positions. It is possible that some conventional metaphors are understood using a constrained analogy mechanism, which reduces cognitive load.

Are Conceptual Mappings Embodied?

The central theoretical tenet of the conceptual metaphor view has not been any specific computational proposal, but rather the general claim that metaphors (at least the conventional ones on which the position focuses) are intimately connected to the sensorimotor system, or "embodied" (Gibbs, 2006; Lakoff & Johnson, 1999). The extent to which cognition is embodied is the focus of an ongoing debate that is much broader than the field of metaphor. There is considerable evidence that semantic representations are shaped in part by representations tied to perception and action (e.g., Andrews, Vigliocco, & Vinson, 2009). Based on neural evidence, the dominant current view is that although sensorimotor information provides major input that shapes semantic representations, a supramodal layer of representation is also needed (Binder, 2016; Patterson, Nestor, & Rogers, 2007; Simmons & Barsalou, 2003). However, proponents of the conceptual mapping account of metaphor (e.g., Gallese & Lakoff, 2005) have advocated an extreme version of embodied cognition, arguing that there is little or no distinction between the processes involved in direct sensorimotor experience and those involved in representing knowledge acquired from such experiences. This claim is reminiscent of the similarly blurred distinction between the literal and the metaphorical.

Some empirical support for the embodied nature of metaphor comprehension has been provided by demonstrations that sensorimotor input can influence metaphor comprehension (Ackerman, Nocera, & Bargh, 2010; Gibbs et al., 2006; Gibbs & Matlock, 2008; Lee, Kim, & Schwarz, 2015; Richardson, Spivey, Barsalou, & McRae, 2003; Wilson & Gibbs, 2007; Zhong & Leonardelli, 2008; Zwaan & Taylor, 2006). For example, Wilson and Gibbs (2007) found that people read a metaphorical phrase such as "push the argument" more quickly immediately after they had made an appropriate body movement (pushing) rather than one that was inappropriate (chewing). A similar priming effect occurred when participants simply imagined the action, rather than actually performing it.

As another example, Ackerman et al. (2010) had participants read a passage describing a social interaction designed to be ambiguous (adversarial or friendly), and then report their impressions of it. Immediately prior to this task, the participants completed a puzzle that involved pieces that were either uncovered ("smooth" condition) or covered with sandpaper ("rough" condition). Participants who completed the "rough" puzzle rated the social interaction as less coordinated (more difficult and harsh) than did those who completed the smooth puzzle. The interpretation was that the physical sensation (rough) activated its metaphorical counterpart (a "rough" social interaction), thereby altering the participants' interpretation of the ambiguous social input.

Such findings are intriguing, but fall far short of conclusive evidence that metaphor is inherently "embodied." It is certainly the case that metaphors quite typically employ sources derived from sensorimotor experience, presumably because such experience underlies core domains of knowledge that humans share.

Moreover, many words are polysemous, with both a physical and a more abstract meaning (e.g., the Merriam-Webster dictionary lists multiple senses of "rough," including both its tactile sense and the more abstract "characterized by violence"). People are doubtless aware, in many cases, that different senses of a word are semantically linked. Thus, findings such as that of Ackerman et al. (2010) can be interpreted as evidence that evoking the physical sense of a word may also activate a related sense that once was metaphorical, but is now likely to be processed as literal.

A number of neuroimaging studies have provided evidence concerning possible linkage between metaphor comprehension and sensorimotor processing. For metaphors drawn from specific domains related to sensation and action, a number of studies have provided support for such connections. Boulenger, Hauk, and Pulvermüller (2009) found that both literal and figurative action sentences involving verbs related to the leg and arm elicited somatotopic activation. For metaphorical meanings linked to tactile sensation (e.g., "She has a rough day"), Lacey, Stilla, and Sathian (2012) found that comprehension of metaphors (as compared with matched literal sentences) activated somatosensory cortex in the parietal operculum.

Desai, Binder, Conant, Mano, and Seidenberg (2011) compared neural responses with closely matched literal ("The daughter grasped the flowers") and metaphoric ("The jury grasped the concept") action sentences, as well as matched abstract sentences ("The jury understood the concept"). The familiarity of sentences was also assessed. Consistent with the prediction of the conceptual mapping view, sentences using literal and metaphorical verbs both activated the left anterior inferior parietal lobule (aIPL, a secondary sensorimotor area involved in action planning). Relative to literal sentences, metaphorical sentences also activated the *right* aIPL, consistent with evidence reviewed earlier indicating that the right hemisphere plays a greater role in metaphor comprehension. In addition, metaphorical but not literal sentences activated left middle superior temporal sulcus, as did the abstract sentences. This area has been considered to be a semantic hub, and is particularly associated with abstract meanings. Thus Desai et al.'s (2011) findings indicate that although metaphors based on action verbs activate secondary sensorimotor areas, they also activate areas involved in processing abstract word meanings. An important additional finding in Desai et al.'s (2011) study was that activation in primary motor and biological motion perception regions was inversely correlated with familiarity, both for metaphoric and literal sentences. Their study, like that of Cardillo et al. (2012), found no support for the career-of-metaphor hypothesis (Bowdle & Gentner, 2005). However, Desai et al. (2011) suggest that both literal and metaphorical meanings of action verbs undergo a different kind of shift—*away* from activation of sensorimotor areas as the linguistic expressions become more familiar (see also Desai, Conant, Binder, Park, & Seidenberg, 2013; Schaller, Weiss, & Müller, 2017). A similar conclusion is supported by a study that used ERP methods to assess whether metaphorical expressions are processed like physical or like abstract expressions (Forgács, Bardolph, Amsel, DeLong, & Kutas, 2015). These investigators found evidence that conceptual concreteness is separable from lexical concreteness, and that processing of metaphorical expressions is not strictly driven by either form of concreteness.

In summary, the conceptual mapping view has contributed to the understanding of metaphor by emphasizing the linkage between action-oriented metaphorical meanings and brain areas associated with action planning. But contrary to more extreme versions of the embodied cognition account, metaphorical (and literal) meanings become less dependent on sensorimotor areas as they become more familiar. Moreover, metaphorical meanings also activate brain areas that support comprehension of abstract meanings. Consistent with a weak version of the embodiment hypothesis, metaphors may serve as conduits that link sensorimotor experience with abstract concepts.

Conclusions and Future Directions

What Has Been Learned About Metaphor Over the Past Four Decades?

The wide-ranging work on the comprehension of metaphor, with its myriad measures, tasks, and instruments, with its overlapping theoretical positions each represented by multiple variants, may certainly seem confusing. But our review has identified a number of key points that appear to be quite firmly established. It is the nature of active research areas that controversies garner greater attention than convergence. But in fact, several important conclusions draw support from our review.

Over roughly the first decade of our review period, the field converged on the conclusion that metaphor comprehension is based on extensions of the same processes that underlie thinking and language comprehension in general. The earlier "literal first" theory was definitively rejected, and there is no sign of its resurrection. The processes of analogical reasoning and conceptual combination (the latter underlying the categorization position) clearly operate in understanding literal language (and in the case of analogy at least, nonverbal reasoning as well). In some form, these processes also guide the comprehension of metaphor. There is no "priority of the literal" (Glucksberg, 2003).

But which is it—analogy, conceptual combination, or both? Here our review has led us to conclusions that are perhaps surprising, or even seemingly paradoxical. In the running debate between the analogy and categorization positions, we find a clear advantage for the latter. For simple nominal metaphors like "My job is a jail," people readily interpret the focal word (the source term) as shifting to a more abstract categorical meaning (Glucksberg & Keysar, 1990). Kintsch's (2000) predication model provides a well-specified computational account (based on semantic vectors for individual words) of how such a meaning shift is possible in a "one-shot" process applicable on first encounter with a novel metaphor. More recent developments in artificial intelligence lend additional support to the possibility that comprehension of simple metaphors can be modeled in terms of operations on semantic vectors (Gagliano et al., 2016).

The analogy position bears the burden of showing that a full-blown process of mapping multiple elements and relations across source and target domains is in fact required to comprehend simple metaphors. Our review did not uncover any compelling evidence of this sort. Evidence of symmetric early processing does not

appear to be theoretically discriminating. Observed patterns of preference for the simile versus metaphor forms (originally cited as evidence for the career-of-metaphor hypothesis; Bowdle & Gentner, 2005) are better explained by variations in aptness. Perhaps most telling, the neural marker of complex analogical reasoning—activation of the left rostrolateral prefrontal cortex—has not been observed in neuroimaging studies of metaphor comprehension. This absence of RLPFC activation holds even for novel metaphors, thus failing to support the career-of-metaphor hypothesis.

Of course, it could be objected that our negative conclusion about the role of analogy in grasping nominal metaphors is itself based largely on null findings. But in the absence of compelling positive evidence that the more complex analogy process is operating, parsimony favors the less complex categorization position (which is bolstered by the undisputed observation that people easily interpret nominal metaphors as category statements).

What makes our negative conclusion about the analogy position seem slightly paradoxical is that as soon as we step back from the realm of simple nominal metaphors, that position is once again alive and flourishing. In fact, there is near-unanimity among theorists that *both* analogy and categorization play a role, somehow, in metaphor comprehension. The career-of-metaphor hypothesis, which argued that analogy only operates for novel metaphors, was of course a major concession—the hypothesis assumes that for more familiar metaphors, categorization is operating. But from the other side of the debate, proponents of the categorization view (and of conceptual combination as the underlying process) have acknowledged that a wide range of metaphors require some more complex process, most likely analogy (e.g., Keysar et al., 2000; Kintsch, 2000).

Indeed, the strongest empirical evidence favoring the analogy position emerged in our critical analysis of the conceptual mapping position. The evidence that inconsistent mapping impairs comprehension of novel metaphors (Boronat, 1990; Keysar et al., 2000) seems best explained by the use of analogy. Critically, the metaphors investigated in relation to the conceptual mapping position have tended to be more varied and structurally complex than nominal metaphors (e.g., "His skill left his opponent far behind him at the finish line;" Gentner, Bowdle, et al., 2001). Without analogy, it is possible to go a considerable distance toward understanding metaphor, but that road ends well short of the intended destination.

Future Directions for Studies of the Psychology of Metaphor

We conclude with a few thoughts about future directions that deserve the attention of researchers investigating metaphor as it relates to a broad range of psychological phenomena.

Toward a More General Theory

Despite their often-divergent views, the major theorists of the past four decades have concurred that no theory so far proposed is able to account for people's comprehension of the full range of metaphors, including the many forms in which they appear in poetry and other literary sources (for examples see Brooke-Rose, 1958; Sommer & Weiss, 1996). A few empirical studies have suggested that analogy and categorization both have limitations as potential processing mechanisms (e.g., Becker, 1993; Damerall & Kellogg, 2016; Tourangeau & Rips, 1991). A more general theory will likely require an integration of the processes of analogy and conceptual combination, introducing refinements of each.

With respect to analogy, we have focused on models such as SME and others that perform an explicit alignment process to identify mappings between source and target. As we have emphasized, this process imposes a heavy cognitive load. There is evidence, however, that some analogical processing can proceed in a more implicit fashion, without requiring an elaborate mapping process, or even awareness that a source is being used (e.g., Schunn & Dunbar, 1996). This kind of implicit analogical transfer may involve some form of relational priming (Day & Gentner, 2007; Estes & Jones, 2006, 2009; Mather, Jones, & Estes, 2014; Popov & Hristova, 2015; Popov, Hristova, & Anders, 2017; Spellman, Holyoak, & Morrison, 2001). Reading and understanding one instantiation of a relation may put that relation into a state of readiness, which helps to process a subsequent instantiation of the same relation. Such relational priming very likely plays a role in understanding metaphors. In addition, some conventional mappings may be prestored for easy reuse, as assumed by computational models inspired by the conceptual mapping position.

It is noteworthy that literary critics have often suggested that some (though certainly not all) literary metaphors can be understood with apparent ease. For example, the poet William Butler Yeats (1903) claimed that ". . . symbolism said things which could not be said so perfectly in any other way, and *needed but a right instinct for its understanding* . . ." (p. 227; emphasis added). In the language of current cognitive psychology, his idea was that symbols (those for which the reader is properly prepared) evoke their intended meanings with little cognitive effort. This possibility is in keeping with Lakoff's (1993) claim that the system of conventional conceptual metaphor operates in a relatively automatic fashion. Thus, understanding metaphor may in part depend on developing a better understanding of implicit relational processing.

Another promising theoretical direction is to consider ways in which analogy and conceptual combination might be integrated. The career-of-metaphor hypothesis was an attempt to relate these two processes in a serial fashion based on conventionalization: analogy on first encounter, categorization on subsequent encounters. A more promising approach, in our view, is to consider the ways in which the two processes could interact within a single act of metaphor comprehension. In essence, conceptual combination operates on featural representations of a pair of individual words, merging them in a constrained fashion to create a new representation. As Kintsch (2000, 2001) noted, metaphor comprehension in his model can be viewed as an extension of contextual shading—the online generation of a specific meaning tailored to the context.

Suppose, then, that a complex metaphor is understood by a process of analogical alignment. The output would be a set of mappings—paired concepts (often corresponding to lexicalized word meanings) drawn from the source and target. Each individual mapping establishes what has more generally been termed a *coupling* between words (Levin, 1962)—links based on extrasyntactic cues (which can also include phonological cues such as alliteration or rhyme). These mapped elements could then be fed through a process of conceptual combination (perhaps using a process sim-

ilar to that described by Kintsch, 2000), which would create a context-specific semantic representation.

This kind of integrated psychological process, and the meanings that emerge from it, might be termed *analogical resonance*. The term "resonance" (and such similar terms as "reverberation" and "synergy") has often been used to characterize metaphor comprehension (e.g., Apter, 1982; Beardsley, 1958, p. 147; Black, 1979, p. 26; El Refaie, 2015; Ricœur, 1977, p. 215). The basic idea is that analogy, supported by linguistic cues, creates couplings between words and their associated concepts. These couplings invite comparisons, which in essence cause meanings to "resonate" and modify each other. Such resonance may highlight both similarities and differences between concepts, and create new, context-dependent meanings that coexist with the more literal word meanings used in the interpretive process. Analogical resonance could underlie poetic effects such as personification (e.g., "Death knocked on his door" hints that death has a human quality). This type of subtle meaning adjustment fits well with the longstanding intuition that metaphor involves the "interanimation of words" (Richards, 1936).

A Wider Range of Metaphors

Perhaps the most obvious limitation of much of the work on metaphor over this review period is its unbalanced focus on nominal metaphors (and occasionally predicate metaphors) rather than more complex forms. It could be argued that this imbalance in choice of stimuli has been to the detriment of the analogy position. If we apply the conceptual mapping ARGUMENT IS WAR, then the battleground of nominal metaphors allowed the categorization position to control the high ground. We therefore call for research that tackles the comprehension of a wide variety of types of metaphors. As an aid in that undertaking, Appendix B provides a list of sources for examples of metaphors.

Besides advocating investigation of a broader range of metaphors, we would also call attention to the need to broaden the range of languages and cultures in which metaphors are investigated. There have been a few studies of metaphor in languages other than English, including Japanese, Italian, Hebrew, and Dutch (e.g., Aisenman, 1999; Boot & Pecher, 2010; Cacciari & Glucksberg, 1995; Utsumi, 2007). Broader exploration of the use of metaphors in different languages and cultures could illuminate possible differences between culture-specific and more universal metaphors. For example, in Chinese and other Asian cultures the human face seems to provide the source for the conceptual mapping DIGNITY IS FACE; this metaphor seems less salient in western cultures (Yu, 2008). Investigations of such cultural differences may shed light on the mechanisms by which cultures support the conventionalization of some metaphors.

Greater Attention to Context and Pragmatics

A closely related direction that warrants greater attention concerns the role of context and pragmatic knowledge in metaphor comprehension. With important exceptions (e.g., Gentner, Bowdle, et al., 2001; Gagné, Friedman, & Faries, 1996; Gildea & Glucksberg, 1983; Ortony et al., 1978), most studies of metaphor comprehension have examined the processing of isolated phrases or sentences. But metaphors are typically embedded in a rich context, both linguistic and extralinguistic. A metaphor can initiate a complex process of comprehension, inference, and transfer of ideas and emotions that will extend far beyond the very early stages of comprehension on which our review has focused. Metaphors and analogies can be used to teach new concepts in science (Aubusson, Harrison, & Ritchie, 2006) and mathematics (Richland, Zur, & Holyoak, 2007), and can also be used to influence people's attitudes about issues of social policy (Landau et al., 2010). For example, describing a poorer city neighborhood as "infected by urban blight" strongly implies that the area needs to be contained and perhaps razed, rather than reinvigorated (Schön, 1979/1993). A small metaphor can have large consequences.

Metaphors need not always be entirely verbal. It has long been recognized that some gestures have a metaphorical interpretation (McNeill, 1992). For instance, when talking about the "head" of an institution, a speaker is more likely to use the upper part of their gesture space. In western culture, the vertical axis is used not only to indicate various hierarchies, but also to express value judgments that can be positive (up) or negative (down). The connections between gesture and metaphor have been explored in connection with conceptual mappings (see articles in Cienki & Müller, 2008). Other pragmatic contexts for metaphors involve *depictions* (Clark, 1996, 2016)—physical representations of imagined scenes that people create using their hands, arms, face, or body as a whole to augment (or sometimes substitute for) linguistic communication. We suspect that greater attention to the pragmatic context of metaphoric utterances will contribute to future theory development.

Connections to Literary Psychology

By broadening the range of metaphors considered by psychologists, it may be possible to contribute to advances in the closely related field of literary psychology (e.g., Kidd & Castano, 2013; Oatley, 2016; Semino & Steen, 2008). A number of unresolved issues might be usefully explored further in connection with literary metaphors. For example, a model based on analogical resonance might begin to grapple with the difficult problem of explaining the ways in which literary metaphors often *differ* from analogy as the latter is used for such purposes as problem solving and scientific theory development (e.g., Gentner, 1983; Gentner, Bowdle, et al., 2001; Sternberg & Nigro, 1983). As Sternberg and Nigro (1983) observed, metaphors seem to produce a kind of blending of source and target, whereas more "rigorous" analogies do not.

Scientific analogies strongly favor unambiguous one-to-one mappings, which yield "clean" and consistent inferences about the target (Gentner, 1983). In contrast, literary metaphors often seem ambiguous and open-ended (Empson, 1930). In fact, it has been argued that metaphors are often not strictly ambiguous, but rather express complex composite meanings, serving as what have been termed *plurisigns* (Wheelwright, 1968). Roughly, a standard ambiguity is a case in which an expression could mean either A or B, and it is not clear which is intended. A plurisign, by contrast, is a case in which A and B are *both* intended. The simplest examples are puns, but metaphors can create more interesting plurisigns. For example, consider the phrase "stranger music" (the title of a book of collected poems by Leonard Cohen). The phrase could mean "music for strangers," or "music by a stranger," or "music that is

stranger than other music." Or (and this seems closer to the poetic effect) it could mean all of these at once (and moreover by metonymy, "music" stands for "poetry"). Such blendings and composite meanings, which give metaphors the power of semantic compression, might reflect analogical resonance.

A number of other core properties of literary metaphors deserve closer scrutiny than they have so far received in psychological studies. In particular, such metaphors often produce an emotional impact (Sternberg & Nigro, 1983). Arguably, none of the current computational models adequately address what it even means for a metaphor to elicit an emotion. Analogy models generate new propositions, and conceptual combination generates new feature vectors, but both types of outputs reflect "cold" cognition rather than "hot" emotion. Of course, cognitive models can potentially create a semantic representation of an emotional state, but that is not the same as experiencing an emotion. Work on literary reading has shown that this activity can have an emotional impact on the reader (Miall & Kuiken, 2002; Oatley, 1994, 2016). Bohrn, Altmann, Lubrich, Menninghaus, and Jacobs (2013) examined the neural correlates of aesthetic judgments about proverbs. The study of metaphor may require deeper understanding of its relation to emotion in general, and empathy in particular (Cohen, 2008).

Finally, metaphor and analogy are closely linked with poetic symbolism, and to extended forms such as parables and allegories (Holyoak, 1982, in press). In addition to using metaphors to teach, there may be value in teaching the use of metaphor (Low, 2008). At least by middle school, systematic instruction in the generation and interpretation of poetic symbols (e.g., the mappings between the four seasons and the stages of a human life) can help students interpret and enjoy poetry (Peskin, Allen, & Wells-Jopling, 2010; Peskin & Wells-Jopling, 2012). The metaphors and symbols found in poetry may have implications for the creation and comprehension of novel metaphors and also the acquisition of relatively universal symbols.

Robert Frost (doubtless guided by the conceptual mapping LIFE IS A JOURNEY) created the most famous metaphor in 20th-century American poetry (Frost, 1916):

> Two roads diverged in a wood, and I—
> I took the one less traveled by,
> And that has made all the difference.

Notice that these lines simply describe the source, with no mention of a target. The passage makes perfect literal sense, with no incongruity. And yet, we immediately see that Frost means something much more. The notion of a conceptual mapping may lead back to the exploration of *archetypes* (Bodkin, 1934); and the psychology of metaphor may take a path that leads back to the field of literary psychology.

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Appendix A

Summaries of Behavioral Studies of Metaphor, 1976–2016

The summary information in Appendices A1–A4 (modeled on similar summaries reported in a meta-analysis by Harkin et al., 2016) include number of experiments; total sample size and (in parentheses) number of participants in each experiment; language in which metaphors were presented; dependent measures and techniques; specific model(s) supported, and alternative model(s) not supported). Most (but not all) of these publications are discussed in our review. Note that in these summaries, the interpretations of evidence in each article are those of the authors of that article. The tables use the terminology of specific models and hypotheses (generally special cases of the three major positions), following the usage of the authors. Note that the metaphors examined in these studies were almost invariably presented in English, a basic fact that warrants caution in generalizing conclusions across languages.

(*Appendices continue*)

Table A1
Studies Claiming to Provide Empirical Support for the Analogy Position

Article	Studies	Sample size	Language	Dependent measures	Techniques	Support for	Lack of evidence for
Tourangeau and Sternberg (1981)	2	97 (57, 40)	English	goodness, comprehensibility	rating, completion, ranking	comparison/interaction view	multistage view
Sternberg and Nigro (1983)	2	144 (96, 48)	English	aptness, comprehensibility	completion, choice, rating, reaction times	analogy/interaction view	—
Trick and Katz (1986)	1	138	English	paired antonym adjectives, comprehensibility, aptness, interpretability, appreciation, individual differences	rating, verbal ability (the Verbal Reasoning subtest of the DAT and the Word Meaning scale of the Iowa vocabulary test)	analogy/interaction view	—
Gentner and Clement (1988)	4	112 (20, 10, 5, 77)	English	aptness, metaphoricity, relationality, immediacy, importance to the target	priming, description, interpretation, rating	structure-mapping view	salience imbalance view
Gentner and Imai (1992); Gentner, Imai, and Boroditsky (2002)	3	224 (112, 72, 40 passers-by)	English	time-related aspects	decision tasks, question answering, reaction times	structure-mapping view, conceptual mapping view	—
Wolff and Gentner (1992)	2	64 (24, 40)	English	interpretability	interpretation, priming, reaction times	structure-mapping view, career of metaphor view	attributive categorization view
Gentner and Wolff (1997)	4	252 (60, 40, 40, 112)	English	interpretability	interpretation, priming, reaction times	career of metaphor view	attributive categorization/pure matching view
Bowdle and Gentner (1999)	1	48	English	form preference, sensibility	statement completion, rating	career of metaphor view	attributive categorization/pure matching view
Aisenman (1999)	2	43 (23, 20)	Hebrew	form preference, features	choice, description, feature listing	structure-mapping view	attributive categorization view
Wolff and Gentner (2000)	3	108 (36, 32, 40)	English	truthfulness, comprehensibility	choice, reaction times, priming	structure-mapping view	attributive categorization view
Bowdle and Gentner (2005)	3	96 (16, 32, 48)	English	form preference, comprehensibility, concreteness	choice, rating, interpretation, statement completion, response times	career of metaphor view	—
Campbell and Katz (2006)	2	190 (110, 80)	English	sensicality, comprehensibility	rating, paraphrasing, decision making, rating	structure-mapping view, constraint satisfaction view	attributive categorization view
Gokcesu (2009)	3	162 (74, 34, 54)	English	interpretability, preference, sensicality	paraphrasing, choice, rating, reaction times	career of metaphor view	—
Wolff and Gentner (2011)	4	136 (32, 48, 32, 24)	English	comprehensibility, pair-formation	time-limited decision making, judgment, reaction times	structure-mapping view, career of metaphor view	attributive categorization view, strong embodiment position
Thibodeau and Durgin (2011)	4	279 (72, 80, 62, 65)	English	aptness, conventionality, properties, comprehensibility	ratings, priming, reaction times, listing	career of metaphor view	—
Jamrozik, Sagi, Goldwater, and Gentner (2013)	2	6 (3, 3)	English	metaphoricity, novelty	rating	structure-mapping view	—

(*Appendices continue*)

Table A2
Studies Claiming to Provide Empirical Support for the Categorization Position

Article	Studies	Sample size	Language	Dependent measures	Techniques	Supporting	Lack of evidence for
Harris (1976)	3	100 (28, 44, 28)	English	metaphoricity, comprehensibility, interpretability	rating, paraphrase, reaction times	direct processing	multistage view
Glucksberg, Gildea, and Bookin (1982)	3	129 (20, 85, 24)	English	truthfulness, goodness, familiarity	judgment, reaction times, classification, rating	direct processing	multistage view
Camac and Glucksberg (1984)	1	10	English	validity	lexical decision, reaction times	attributive categorization view	stored metaphorical meanings
Pollio, Fabrizi, Sills, and Smith (1984)	1	120	English	analyticity, syntheticity, contradiction, anomaly, metaphoricity, and comprehensibility	classification, reaction times	direct processing	multistage view
Keysar (1989)	2	133 (77, 56)	English	truthfulness, comprehensibility	judgment, rating, reaction times	direct processing	multistage view
Biava (1991)	1	124	English (non-native)	comprehensibility, memorability	choice, completion, recall	direct processing	multistage view
Blasko and Connine (1993)	5	293 (89, 41, 43, 80, 40)	English	validity	judgment, lexical decision, priming	direct processing	—
Glucksberg, Brown, and McGlone (1993)	3	88 (24, 32, 32)	English	appropriateness, comprehensibility	judgment/choice, reading times, priming	attributive categorization view	conceptual mapping view of idioms
Cacciari and Glucksberg (1995)	3	355 (199, 96, 60)	Italian	semantic transparency, familiarity, imagery, comprehensibility	rating, imagery production and recall	attributive categorization view	conceptual mapping view of idioms
McGlone (1994, 1996)	4	132 (32, 32, 30, 38)	English	comprehensibility, similarity, memorability	rating, paraphrase, reaction times, completion, recall	attributive categorization view	conceptual mapping view
Gagné, Friedman, and Faries (1996)	3	350 (85, 225, 40)	English	comprehensibility, contextual influence	feature generation, comprehension, priming, reading times	schema-based approach/ predication/conceptual combination	—
Glucksberg, McGlone, and Manfredi (1997)	2	57 (40, 17)	English	reversibility, sensicality, comprehensibility	paraphrase, rating, decision task, priming, response times	attributive categorization view	salience imbalance view, structure-mapping view
Goldvarg and Glucksberg (1998)	2	38 (18, 20)	English	difficulty, comprehensibility, similarity	rating, interpretation	attributive categorization view	comparison view
Chiappe and Kennedy (1999)	2	76 (30, 46)	English	form preference, comprehensibility, memorability, aptness	choice, rating, recall	attributive categorization view	structure-mapping view
McElree and Nordlie (1999	1	13	English	meaningfulness, truthfulness	judgment	direct processing/attributive categorization view	multistage view
Keysar, Shen, Glucksberg, and Horton (2000)	3	124 (44, 48, 32)	English	comprehensibility, word validity	verification, reaction times, priming, lexical decision task	attributive categorization view	conceptual mapping view
Gernsbacher, Keysar, Robertson, and Werner (2001)	3	368 (112, 140, 116)	English	sensicality	decision making, reaction times, priming	attributive categorization view	—
McGlone and Manfredi (2001)	1	68	English	comprehensibility, retention	interpretation, completion, reaction times, priming	attributive categorization view	structure-mapping view
Gagné (2002)	3	106 (30, 36, 40)	English	ease of interpretation, goodness, feature truthfulness, form appropriateness, aptness, comprehensibility	rating, choice, reaction times	conceptual combination	—
Kintsch and Bowles (2002)	1	24	English	difficulty, comprehensibility	judgment, completion	Kintsch's computational model	—
Chiappe, Kennedy, and Smykowski (2003a)	2	148 (44, 104)	English	sensicality, comprehensibility, aptness, conventionality	rating	attributive categorization view	comparison view
Chiappe, Kennedy, and Chiappe (2003b)	1	34	English	aptness, comprehensibility	rating	attributive categorization view	comparison view
Kazmerski, Blasko, and Dessalegn, 2003)	2 (1 ERP)	82 (48, 34)	English	familiarity, comprehensibility, interpretation, individual differences	rating, paraphrase, IQ tests (the Kaufman Brief Intelligence Scale; the verbal IQ section of the Multidimensional Aptitude Battery, Version II), working memory tests	Kintsch's computational model	—
Jones and Estes (2005)	3	171 (51, 60, 60)	English	membership, aptness	categorization, rating, priming	attributive categorization view	structure-mapping view
Jones and Estes (2006)	3	139 (48, 60, 31)	English	form preference, comprehensibility	choice, reaction times, rating, categorization	attributive categorization view	career of metaphor view
Glucksberg and Haught (2006a)	1	16	English	comprehensibility, form preference	interpretation, reaction times, rating	attributive categorization view	career of metaphor view

(*Appendices continue*)

Table A2 (*continued*)

Article	Studies	Sample size	Language	Dependent measures	Techniques	Supporting	Lack of evidence for
Chiappe and Chiappe (2007)	3	612 (149, 276, 187)	English	comprehension, metaphor production, working memory, verbal ability	a listening span task, completion, a Stroop task, interpretation, reaction times, retrieval fluency task, metaphor generation task, PPVT-III, digit span forward, digit span reverse, magazine recognition questionnaire	Kintsch's computational model	—
Utsumi (2007)	2	392 (164, 228)	Japanese	form preferences, features, feature salience, aptness, similarity, familiarity, conventionality,	comprehensibility/choice, listing, rating	attributive categorization view	—
Pierce and Chiappe (2008)	1	275	English	metaphor production	figurative statement production task, the operation span task	attributive categorization view	career of metaphor view
Pierce, MacLaren, and Chiappe (2010)	1	144	English	word set memory, truthfulness, working memory, verbal ability	WSPAN, Metaphor Interference Effect task, PPVT-III, judgment, reaction times	attributive categorization view/Kintsch's computational model	—
Dulcinati, Mazzarella, Pouscoulous, and Rodd (2014)	4	208 (11, 49, 66, 82)	English	form preference, interpretability, conventionality, aptness	one-word paraphrase, rating	attributive categorization view	career of metaphor view

Table A3
Studies Claiming to Provide Empirical Support for the Conceptual Mapping Position

Article	Studies	Sample size	Language	Dependent measures	Techniques	Supporting	Lack of evidence for
Gibbs and O'Brien (1990)	3	72 (24, 24, 24)	English	mental images	description, question answering	conceptual mapping view of idioms	—
Nayak and Gibbs (1990)	6	174 (22, 27, 28, 42, 28, 27)	English	similarity, meaningfulness, degree of emotion	judgment, rating, choice, reaction times, priming	conceptual mapping view of idioms	—
Gibbs, Bogdanovich, Sykes, and Barr (1997)	2	70 (34, 36)	English	comprehensibility, appropriateness in contexts, recognition	lexical decision, reaction times	conceptual mapping view of idioms	Attributive categorization view
Gibbs and Bogdonovich (1999)	3	60 (20, 20, 20)	English	comprehensibility, mental images, domain knowledge	description	conceptual mapping view	—
Boroditsky (2000)	3	453 (98, 302, 53)	English	metaphor schema consistency	priming, rating, question answering, decision making	conceptual mapping view	—
Meier and Robinson (2004)	3	112 (34, 28, 53)	English	word positivity or negativity, determining position	evaluation, positioning, reaction times	conceptual mapping view (embodiment)	—
Gibbs et al. (2006)	2	80 (20, 60)	English	mental images, body actions	image formation, description, question answering, priming	conceptual mapping view (embodiment)	—
Zwaan and Taylor (2006)	5	225 (32, 58, 39, 36, 60)	English	sentence comprehensibility, sensibility	visual, verbal, and motor priming, reaction times	conceptual mapping view (embodiment)	—
Wilson and Gibbs (2007)	2	96 (51, 45)	English	comprehensibility	priming, reaction times, real and imagined body movements	conceptual mapping view (embodiment)	—
Meier, Hauser, Robinson, Friesen, and Schjeldahl (2007)	6	269 (41, 47, 33, 27, 66, 55)	English	verticality, association, images	categorization, judgment, rating, reaction times	conceptual mapping view (embodiment)	—
Casasanto (2008)	3	140 (27, 33, 80)	English	similarity, closeness	rating	conceptual mapping view (embodiment)	—
Casasanto and Boroditsky (2008)	6	72 (9, 9, 9, 16, 10, 19)	English	line displacement or duration, moving dot's path	estimation, memory retrieval, comparison	conceptual mapping view (embodiment)	—
Katz and Taylor (2008)	4	645 (200, 200, 125, 120)	English	life events	time-limited listing, personality/mood questionnaires, recall	conceptual mapping view	—
Zhong and Leonardelli (2008)	2	117 (65, 52)	English	social exclusion	temperature estimation, product rating	conceptual mapping view (embodiment)	—

(*Appendices continue*)

Table A3 (*continued*)

Article	Studies	Sample size	Language	Dependent measures	Techniques	Supporting	Lack of evidence for
Thibodeau and Durgin (2008)	3	175 (36, 67, 72)	English	comprehension, conventionality, fit	verification, reaction times, priming	conceptual mapping view	Attributive categorization view
Wilkowski, Meier, Robinson, Carter, and Feltman (2009)	7	438 (111, 43, 74, 47, 58, 50, 65)	English	font suggestiveness, images, temperature estimates, facial expressions	categorization, classification, error rates, reaction times, priming	conceptual mapping view (embodiment)	—
Ackerman et al. (2010)	6	338 (54 passers-by, 43 passers-by, 64 passers-by, 42, 49 passers-by, 86)	English	object weight, public issues, social interaction	impression formation, judgment, puzzle completion, negotiation task, priming	conceptual mapping view (embodiment)	—
Boot and Pecher (2010)	4	130 (30, 40, 30, 30)	Dutch	color similarity, distance	decision making, reaction times, error rates	conceptual mapping view (embodiment)	—
Gibbs and Ferreira (2011)	1	24	English	entailments, implications	judgment, rating	conceptual mapping view	—
Thibodeau and Boroditsky (2011)	5	1,419 (485, 247, 312, 185, 190)	English	paragraph comprehension, judgment	problem solving, synonym listing	conceptual mapping view	—
Goodhew, McGaw, and Kidd (2014)	1	57	English	concept words, spatiality/verticality	identification, priming, reaction times	conceptual mapping view	—
Lee and Schwarz (2014)	3	337 (73 passers-by, 172, 92)	English	memories, relevance, shapes, similarity	framing, priming, knowledge quiz, memory test, satisfaction rating, relationship evaluation, similarity rating, matching and maze tasks	conceptual mapping view	—

Table A4
Studies Claiming to Provide Empirical Support Against One or More Positions

Article	Studies	Sample size	Language	Dependent measures	Techniques	Lack of evidence for
Verbrugge and McCarrell (1977)	4	240 (96, 60, 20, 64)	English	interpretability, resemblance	paraphrase, recall, completion	attributive categorization view
Janus and Bever (1985)	1	8+6	English	comprehensibility, predictability	reading times, rating	attributive categorization view
Blank (1988)	1	30	English	recognition, sensibility	reaction times, rating	attributive categorization view
Gregory and Mergler (1990)	1	108	English	truthfulness, possible sense, metaphoricity	verification, rating, reaction times	attributive categorization view
Tourangeau and Rips (1991)	3	112 (80, 16, 16)	English	interpretability, goodness, aptness, comprehensibility, features, feature salience, distinctiveness, relationality, relevance, adequacy	paraphrase, rating, listing, judgment	attributive categorization view, structure-mapping view
Becker (1993)	2	196 (164, 32)	English	attributes, interpretability, metaphoricity, goodness, familiarity, similarity of the target and the source	listing, paraphrase, confidence ratings	attributive categorization view, structure-mapping view
Damerall and Kellogg (2016)	3	132 (60, 43, 29)	English	comprehension	interpretation, reaction times, priming	attributive categorization view, career of metaphor view

(*Appendices continue*)

Appendix B

Sources of Metaphor Examples of Potential Use to Psychologists

Publication	Description
Brooke-Rose (1958)	A rich source of poetic metaphors in English expressed by different grammatical forms.
Cardillo, Schmidt, Kranjec, and Chatterjee (2010)	Supplemental materials contain 280 metaphorical expressions related to motion and auditory perception, given in nominal and predicate forms.
Dancygier and Sweetser (2014)	The chapters related to metaphor contain a set of examples, most of them from the conceptual mapping standpoint.
Gentner and Clement (1988)	The article includes over 40 metaphorical expressions used in the study.
Goatly (1997)	Includes a range of examples of metaphorical language taken from conversations, news reports, popular science, magazines, advertisements, and literature.
Jones and Estes (2006)	Contains a list of metaphorical experimental stimuli rated for conventionality and aptness.
Katz, Paivio, Marschark, and Clark (1988)	The appendices contain 204 literary and 260 nonliterary examples of metaphor rated by participants across 10 psychological dimensions (ratings of comprehensibility, perceived metaphoric qualities, imagery values, familiarity, and source-target relatedness).
Knowles and Moon (2006)	A wide range of examples compiled from different sources, including poetry, prose, different corpora, and other books on metaphor. The examples are mostly in English, with some examples from other languages.
Kövecses (2005)	Contains examples of metaphors as viewed from the conceptual mapping point of view. These include illustrations of conceptual metaphors from English, Chinese, Japanese, and Hungarian.
Kövecses (2010)	Provides examples that illustrate a range of conceptual metaphors.
Lakoff and Johnson (1980)	Offers examples of what the authors call orientational, ontological, and structural metaphors.
Lakoff and Turner (1989)	Contains a large body of examples from poetry, mainly used to corroborate or illustrate various aspects of the conceptual mapping view.
Sommer and Weiss (1996)	This dictionary provides the most comprehensive organized repository of literary metaphors in English, compiled from works of poetry and prose.
Turner (1987)	Offers an abundance of literary and nonliterary metaphors that generally exemplify underlying conceptual mappings.

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