Verb Metaphors are Processed as Analogies

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Abstract

We propose a novel process account for how verb metaphors (e.g., *The boat waddled*) are understood: they are processed as analogical comparisons between the event denoted by the verb and an event schema activated by the noun. We first review evidence that this account is consistent with findings in analogical reasoning and both literal and metaphoric sentence comprehension. Next, we report the results of an online study of verb metaphor comprehension that supports our claims. We conclude with a discussion of the implications of our findings for theories of metaphor processing and language change over time.

Keywords: metaphor; verb metaphor; metaphor processing; sentence comprehension; analogy

Introduction

Metaphor is a pervasive phenomenon in language and cognition. Psycholinguistic work has made great advances in our understanding of metaphor (Blank, 1988; Bowdle & Gentner, 2005; Chiappe, Kennedy, & Smykowski, 2003; Gentner & Wolff, 1997, 2000; Gibbs, 1992; Giora, 1997; Glucksberg & Keysar, 1990; Glucksberg, McGlone, & Manfredi, 1997; Katz, 1989; Keysar et al., 2000; Ortony, 1979; Thibodeau & Durgin, 2011; Trick & Katz, 1986; Tourangeau & Rips, 1991; Wolff & Gentner, 2000, 2011), but this work has focused almost exclusively on noun metaphor—that is, on metaphors (and similes) of the form *X is (like) a Y*—e.g., *That surgeon is a butcher*. Yet there is evidence that verb metaphors are more common than noun metaphors (Jamrozik et al., 2013; Krennmayr, 2011). Relatively little work has examined how verb metaphors are processed (but see Ronderos et al., 2021).

In this paper, we propose and test a novel processing account for verb metaphor. We propose that verb metaphors are comprehended as analogies are: as comparisons processed via structure-mapping (Forbus et al., 2017; Gentner, 1989; Markman & Gentner, 1993). We first lay out the theory and review supporting evidence. Specifically, we aim to show that predictions drawn from research on analogical processing apply well to the phenomena of verb metaphor. We then describe a study that tests a further prediction of our account. We conclude with a discussion of larger implications for theories of metaphor processing and language evolution.

Verb metaphor processing

Verb metaphors range from novel (e.g., *The boat pranced over the waves*) to conventional (e.g., *The years flew by*). Conventional verb metaphors have standard interpretations that are widely understood. Indeed, their metaphoric interpretations can be found in dictionaries. For example, Merriam-Webster Online lists as the third sense of *flew* the meaning "to move, pass, or spread quickly." In terms of processing, a plausible account is that conventional verb metaphors are understood by accessing potential meanings from memory (i.e, sense-selection). But there remains the question of how *novel* verb metaphors like *The boat pranced* or *The wagon limped* are understood.

We propose that novel verb metaphors are understood via analogical processing. Of course, this proposal runs into an immediate objection. In an analogy like *Mitochondria are the power plants of the cell*, it is clear that a comparison is to be drawn between the two concepts *mitochondria* (the target) and *power plants* (the base). But in *The wagon limped,* it would be nonsensical to compare the event denoted by verb *limp* with the entity denoted by the noun *wagon*. So how does an analogical account apply here?

Our proposal is that the verb is compared not with the entity that the noun refers to, but rather with an event schema that is activated by the noun. As we review in the next section, there is evidence that comprehending a noun like *wagon* calls forth not only the entity it denotes, but also an event schema that captures our knowledge of what wagons typically do (the events they typically participate in)—e.g., moving on wheels across the ground, or *rolling*. Thus, our claim is that comprehending a verb metaphor like *The wagon limped* is a matter of comparing two event schemas: *limping* and *rolling*.

We use structure-mapping theory (Gentner, 1983, 1989; Markman & Gentner, 1993; Wolff & Gentner, 2011) as our framework for this account. In a verb metaphor such as *The wagon limped*, the target of the analogy is the noun's typical event schema, and the base is the event denoted by the verb. As in any analogical comparison, verb metaphor comprehension involves aligning two relational structures (the event schemas), identifying their common structure, and drawing inferences about the target event (the event activated by the noun) by projecting knowledge from the base event denoted by the verb. Thus, just as analogies serve to both highlight commonalities between concepts and generate inferences, so too do verb metaphors. In the example of *The*

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wagon limped, rolling and limping are readily aligned (both are forms of physical movement). Since *limping* denotes physical movement that occurs in an awkward or impaired manner, this information is projected to the noun event, so we infer that the wagon is rolling in an impaired manner.

In King and Gentner (2022a), we had participants paraphrase intransitive verb metaphors like *The wagon limped* without repeating the original noun and verb. Example paraphrases are shown in Table 1 below.

Table 1

	Original sentence	Paraphrase
(1)	The wagon limped	*The cart bumped and rolled awkwardly along the street*
(2)	The violin stammered	*The instrument played quick, repeated notes*
(3)	The rumor paced	*The gossip went back and forth*

These paraphrases illustrate the role of noun event schemas in comprehending verb metaphors. Participants clearly draw on their knowledge of what the noun subjects typically *do*—that is, the events that the nouns typically participate in—during comprehension. Wagons roll, often down a street, violins play music, and rumors spread among people. While none of these noun-related events are explicitly mentioned in the initial sentence, they consistently surface in the participants' paraphrases, suggesting they are an important component of generating a meaningful interpretation of the metaphor.

These paraphrases also illustrate the role of the verb (the base) in projecting information that elaborates the noun event (the target). For example, in (1), we infer that the rolling event associated with wagons occurs in an impaired manner, just as *limping* denotes a walking event occurring in an impaired manner. In (2), the playing event associated with violins is specified to occur in an interrupted manner, just as *stammering* denotes speaking in an interrupted manner. In (3), the spreading event associated with rumors is specified to be a back-and-forth spreading, just as *pacing* denotes a back-and-forth walking event.

In sum, our claim is that understanding a verb metaphor involves carrying out an analogical comparison between two event schemas. That is, it is a two-stage process in which structural alignment identifies common structure between the verb event and the noun event, and further inferences are projected from the verb to the noun event—for example, inferences that specify the manner in which it unfolds.

This account relies on a prior claim that must be empirically supported: that many or most nouns have event schemas that are activated during sentence processing. We briefly review evidence for this claim before further describing our account.

Noun event schemas in literal sentence processing

There is an extensive literature demonstrating that noun representations often include the events that the noun is a frequent participant in. This event knowledge appears to be a critical aspect of literal sentence comprehension (for reviews, see Elman, 2011 and Altmann & Mirković, 2009).

There is evidence that these noun event schemas are activated automatically, even when the nouns are presented in isolation. For example, nouns prime verbs that denote the events that they frequently participate in (e.g., Ferretti et al., 2001; McRae et al., 2005; McRae & Matsuki, 2009).

There is also substantial evidence that noun event knowledge is quickly integrated with the verb (e.g., Altmann, 1999; Altmann & Mirković, 2009; Altmann & Kamide, 1999; Bicknell et al. 2010; Kamide, Altmann, & Haywood, 2003; Matsuki, et al., 2011; McRae, Ferretti, and Amyote, 1997; Zarcone et al., 2014). For example, Kamide et al. (2003) used an eye-tracking paradigm in which participants listened to sentences while looking at a visual array of pictures of various objects—e.g., a man, a girl, a motorcycle, a carousel, a beer, and candy. Kamide et al. found that when participants heard *The man will ride*, they made anticipatory looks to the motorcycle, but when they heard *The girl will ride*, they made anticipatory looks to the carousel. Alternatively, when they heard *The man will taste*, they looked to the image of the beer, but when they heard *The girl will taste*, they looked to the image of the candy. Thus, participants rapidly accessed event knowledge associated with the agent nouns (man, girl) and integrated it with the verb such that it immediately constrained their predictions about the likely patient. These predictions depended on the noun and the verb jointly—i.e., people only looked to the motorcycle when the noun was *man* and the verb was *ride*; similarly, they only looked at the beer when the noun was *man* and the verb was *taste*.

In sum, there is ample evidence from research on literal sentence processing that noun representations often include event schemas, and that these are fluently integrated with the verb during comprehension. Our contention is that this integration also occurs when processing verb metaphors.

Structure-mapping in verb metaphor comprehension

Our claim is that verb metaphors are processed by structure-mapping between the event denoted by the verb and the event activated by the noun. Conceiving of verb metaphor as a species of analogy leads to four empirical predictions. Predictions (1) to (3) below are consistent with recent findings on verb metaphor. Prediction (4) is tested in the experiment presented below.

Prediction 1: The verb mutability effect In analogies, comparison results in the abstraction of the base of the analogy, while the target remains fixed as the literal referent of the comparison. For example, a typical interpretation of the analogy *Misinformation is like a virus* is "misinformation spreads rapidly among people and causes harm." Here the target (misinformation) remains literally construed (that is, we assume that we are actually talking about

misinformation). But the base (virus) is abstracted in the interpretation; its effect is to convey the relational information "spreads rapidly and causes harm". Thus, as the literal referent, *misinformation* retains its domain-specific features, while domain-specific features of *virus* (e.g., biological details about viruses) are discarded. There is evidence that carrying out such comparisons can lead, over time, to the metaphoric abstraction becoming a new conventional meaning of the base word (Bowdle & Gentner, 2005; Cardillo et al., 2012; Zharikoff & Gentner, 2002).

If verb metaphors are comprehended in the same way as analogies, then we might expect that the noun event (the target) would remain stable, while the verb (the base) would be abstracted as a result of comparison with the noun event. Consistent with this prediction, a number of studies have found evidence for a *verb mutability effect* in sentence processing (Gentner & France, 1988; King & Gentner, 2022a, 2022b). People strongly prefer to interpret nonliteral sentences like *The wagon limped* by abstracting the meaning of the verb while preserving the meaning of the noun (as shown in Table 1 above). King and Gentner (2022b) found that these meaning changes were predominantly analogical (metaphorical) extensions in which the verb's literal meaning was adapted to fit the noun. Interestingly, this pattern holds even when the verb is highly incompatible with the event suggested by the noun (e.g., participants interpret *The violin marched* as being about steady, rhythmic sound production, rather than physical movement; King & Gentner, 2022a, 2022b).

Prediction 2: The more dissimilar the noun event and verb event are, the greater the degree of verb change

In analogy, the similarity between two concepts is defined as the degree of shared structure between their representations. The more dissimilar the two concepts, the smaller the common structure that will be identified by the structure-mapping process (Forbus et al., 2017; Gentner et al., 2009), and therefore the greater the degree of change/abstraction the base will undergo as a result of comparison. For example, compare the degree of abstraction of *bridge* necessary to understand *An isthmus is like a bridge* vs. *An education is like a bridge*. In the former, an isthmus and a bridge share both concrete, domain-specific commonalities (e.g., they are both physical structures that span a physical gap of some sort) and domain-general relational commonalities (they allow objects to cross a physical space that would otherwise be impassable). In the latter, education and bridge share only highly abstract, domain-general relational commonalities (e.g., they provide a means to attain a goal that might otherwise be out of reach). Thus, the base *bridge* becomes abstracted further as a result of its comparison with *education* than with *isthmus* (though both *isthmus* and *education* remain stable as the literal referent of the comparison).

In the verb metaphor case, this predicts that the degree of verb abstraction will also depend on the degree to which the noun event and verb event are similar. Several studies have found exactly this pattern (Gentner & France, 1988; King & Gentner, 2022a, 2022b). For example, consider the below set of paraphrases of verb metaphors involving the verb *limped* from King and Gentner (2022a):

Table 2

	Original sentence	Paraphrase
(1)	The woman limped	*The girl walked favoring one leg*
(2)	The wagon limped	*The cart bumped and rolled awkwardly along the street*
(3)	The rumor limped	*The gossip did not spread easily*

The paraphrases show that as the degree of similarity between *limped* and the target noun event decreases from (1) to (3), the concrete aspects of *limped* become increasingly inapplicable, with the result that the verb sheds progressively more domain-specific features while preserving abstract relational ones. In (1), the sentence is literal and *limped* retains its typical literal meaning. In (2) *limped* abstracts such that it still refers to physical motion, though that motion occurs via wheels rather than legs; in (3) *limped* is abstracted further to characterize the non-physical, metaphorical motion of a rumor spreading. Consistent with structure-mapping, in each paraphrase, the noun event remains relatively fixed, while the degree of verb abstraction resulting from the comparison is a function of the degree of shared structure between the noun and verb events.

Prediction 3: The verb event generates inferences about the nature of the noun event A hallmark of analogies is that they can lead to the spontaneous generation of inferences about the target based on connected relational structure in the base. The analogy *Misinformation is like a virus* highlights that both misinformation and viruses can spread exponentially among people, inviting the inference that, as is the case with viruses, it may be possible to "inoculate" against misinformation.

In the verb metaphor case, this predicts that comprehension should result in inferences about the nature of the noun event (the target) based on the structure of the verb event (the base). Table 1 and Table 2 above both demonstrate this pattern, with the verb acting to further specify the noun event in each paraphrase (e.g., in *The wagon limped* → *The cart bumped and rolled awkwardly along the street*, the *roll* event activated by cart is specified to unfold in a manner consistent with how a *limped* event unfolds—that is, in an impaired manner).

Prediction 4: Structure-mapping activates structure relevant to the mapping During analogical comparison, structure-mapping results in greater activation of common conceptual structure (i.e., the shared structure between the base and target representations that constitutes the meaning of the analogy) than unmapped structure. In the case of verb metaphor, this predicts that comprehension will result in the activation of *event* structure shared between the noun event and verb event—that is, event structure relevant to the

interpretation of the metaphor—to a greater extent than event structure that it is irrelevant to the interpretation of the metaphor. We test this prediction in the experiment reported below.

Summary In sum, past work has shown that the behavior of verb metaphors matches Predictions (1) to (3) of the analogy framework. All of these findings, however, were offline investigations that examined the outcome of processing (the paraphrases), rather than processing itself. In this paper, we seek to provide direct, online evidence of structure-mapping as the underlying process. Thus, here we test Prediction (4) using an online methodology that assessed how prior activation of mapped vs. unmapped conceptual structure affected the interpretation speed of verb metaphors.

Experiment

We used a primed interpretation paradigm to examine whether verb metaphor comprehension resulted in greater activation of mapped structure compared to unmapped structure. If this is the case, then prior activation of part of that mapped structure should facilitate processing. Each verb metaphor was therefore preceded by one of two primes (between subject): (1) a *relevant prime* that was intended to activate conceptual structure involved in the ultimate mapping (and therefore interpretation) of the subsequent metaphor, or (2) an *irrelevant prime* unrelated to the metaphor's interpretation that should not activate conceptual structure relevant to the final mapping. RTs for interpretation times served as the dependent measure. The key prediction under structure-mapping is that items should be faster to interpret when preceded by a relevant prime compared to an irrelevant prime.

Method

Participants 49 undergraduates who reported speaking English since birth completed the experiment in person in the lab. Participants received credit in an introductory psychology course for their participation

Materials & Design 14 intransitive novel verb metaphors (e.g., *The boat burped*) were constructed by pairing verbs that expected human or animal subjects with incompatible nouns (see Gentner & France, 1988; King & Gentner, 2022b). Items were designed to suggest a single, clear interpretation. For each metaphor, relevant and irrelevant primes were selected such that both primes were physical components of the subject noun (e.g., for *The boat burped*, they were *smokestack* and *anchor*, respectively), but only the relevant prime (e.g., *smokestack*) was expected to activate the to-be-mapped conceptual structure and thus facilitate comprehension speed for the subsequent verb metaphor. The metaphors and primes are listed in Table 3 below.

To ensure that any observed effect was due to interactions with the mapping process and not to a difference in the strength of *a priori* relatedness between the primes and target nouns and verbs, across all items both primes were matched in terms of relatedness to each stimulus noun and verb (all *p*s > .05). To calculate relatedness, we used word2vec (Mikolov et al., 2013), a widely-used vector space word embedding model that represents word meanings as high dimensional vectors, allowing the relatedness of two words to be calculated by taking the cosine of the angle between their vectors.[1]

Two between-subject assignment factors were created such that if an item was preceded by a relevant prime in one assignment factor, it was preceded by an irrelevant prime in the other. Every participant saw the same 14 verb metaphors, with half of those items preceded by an irrelevant prime and half preceded by a relevant prime.

24 literal intransitive sentences were also included as filler items in order to disguise the objective of the experiment and to avoid giving participants too many "odd" sentences in a row that might promote abnormal processing strategies. Half the fillers had animal subjects (e.g., *The dog barked, The horse galloped*) and half had inanimate subjects (e.g., *The alarm rang, The cup shattered*). As with the metaphors, fillers were divided evenly in terms of being preceded by relevant vs. irrelevant primes. Finally, four practice items (two literal, two metaphoric, of which half were preceded by relevant primes and half were preceded by irrelevant primes) were included to familiarize participants with the experimental procedure before beginning the main experiment.

Table 3: Metaphoric items and primes

Item	Relevant Prime	Irrelevant Prime
The boat burped	smokestack	anchor
The car limped	engine	windshield
The mattress shrieked	spring	tag
The truck howled	horn	wheel
The kettle drooled	spout	lid
The firetruck yelled	siren	hose
The guitar stammered	string	knob
The camera chirped	shutter	film
The plane waddled	wing	cabin
The bicycle pranced	tire	gearshift
The blender attacked	blade	button
The rifle barked	barrel	trigger
The typewriter babbled	keys	paper
The tree cried	leaf	trunk

Procedure Participants were randomly assigned to one of the two assignment factors. Each participant first read instructions informing them that they would be tasked with interpreting a number of sentences as quickly as possible. Although some of those sentences would be odd, they should do their best to provide a meaningful interpretation in each

[1] We used pretrained vectors publicly available from Google at https://code.google.com/archive/p/word2vec/.

case. The structure of each trial was explained, and then participants completed the four practice trials before moving on to the main experiment. In the main experiment, the first two trials were the same two fillers for all participants (*The flashlight shone* and *The lion roared*). The remaining filler and target items were presented in randomized order for each participant.

The structure of each trial was as follows. The message *Get Ready!* was presented on screen for 1000 ms, followed by a blank screen for 1000 ms, a fixation cross for 1250 ms, a blank screen for 100 ms, a priming mask for 500 ms, the prime for 1500 ms, a blank screen for 1250 ms, and finally the item, for unlimited duration. As soon as the participant had thought of a meaningful interpretation, they pressed the spacebar, at which point the item disappeared and they typed their interpretation. When finished typing, the participant pressed the enter key, and the next trial began.

Analysis & Results

Each of the 49 participants paraphrased all 14 target items, resulting in a total of 686 target paraphrases included in the analysis. Example paraphrases are shown in Table 4 below:

Table 4: Sample paraphrases from the experiment

Original item	Paraphrase
The boat burped	*The boat sputtered and let out a cloud of smoke*
The blender attacked	*The appliance quickly crushed its contents*
The rifle barked	*The firearm let out a single loud shot in a quiet environment*
The tree cried	*The tree leaves fell and its branches sagged*
The car limped	*The car struggled to move forward*
The kettle drooled	*Water dribbled from the opening of the kettle*
The plane waddled	*The plane wobbled in the air as it hit turbulence*

The key prediction from structure-mapping is that priming to-be-mapped conceptual structure (structure relevant to the meaning of the metaphor) should facilitate processing more than priming unmapped/irrelevant structure.

To test this prediction, the analysis proceeded as follows. RTs were operationalized as the amount of time from stimulus onset to spacebar press (indicating the participant had thought of meaningful interpretation). Inspection of RTs indicated a heavily rightward-skewed distribution and resulted in model residuals with substantial departures from both normality and homoskedasticity; thus, a log transformation was used (Whelan, 2008), which resulted in an approximately normal distribution of RTs and ameliorated the prior violations of model assumptions. Next, a linear mixed effect model was fit, with logRT as the dependent measure, prime type (relevant vs. irrelevant) as the fixed effect, and subjects and items included as random intercepts.[2]

As predicted, the effect of prime type was significant: participants were faster to interpret items when they were preceded by a relevant prime than an irrelevant prime, b = .12, SE = .04, t = 3.33, p < .001. In this model, b represents the estimated difference in logRTs for items preceded by irrelevant primes vs. relevant primes; thus, we found that RTs were 12% slower in the irrelevant prime condition (M_{logRT} = 1.08, SE = .09) than in the relevant prime condition (M_{logRT} = .96, SE = .09). Mean logRTs by prime type are plotted in Figure 1 below.

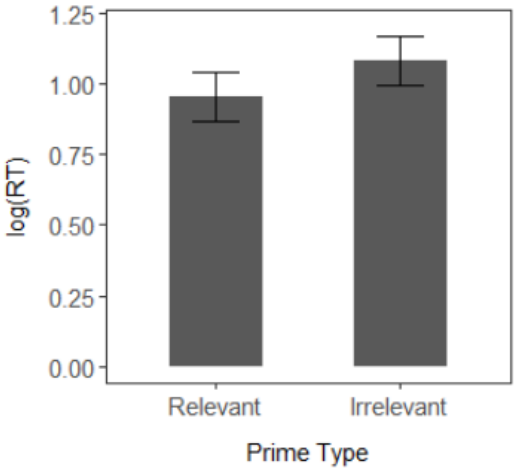

Figure 1. Mean logRTs by prime type.

Discussion

As predicted, words that primed relevant noun event structure resulted in significantly faster comprehension times for the metaphors that followed than did words that primed irrelevant noun event structure. For example, participants were faster to interpret *The boat burped* when primed with *smokestack* (evoking an exhaust-emission event), than when primed with *anchor* (evoking an anchoring event).

Moreover, the paraphrases listed in Table 2 provide additional support for the earlier predictions: comprehension resulted in abstraction of the verb (while the noun meaning remained stable), and the verb event generated inferences that further specified the noun event. For example, in *The kettle drooled* → *Water dribbled from the opening of the kettle*, the pouring event activated by kettle occurs in a manner consistent with drooling. Likewise, in *The plane waddled* → *The plane wobbled in the air as it hit turbulence*, the plane tips side to side as it flies, just as a person tips side to side when waddling.

[2] We used iterative model comparison as described by Barr et al. (2013) to identify the maximal random effect structure supported by the data. Significance testing used Satterthwaite's method for approximating degrees of freedom (see Luke, 2017).

General Discussion

In this paper, we proposed and tested a novel process account for verb metaphors: they are processed as analogical comparisons between the event schema denoted by the verb and an event schema activated by the noun. We reviewed evidence from past work on verb metaphor showing that verb metaphors behave as predicted by an analogical framework in which the verb is the base and the noun is the target in a comparison that is processed via structure-mapping. First, comprehension results in an analogical abstraction of the verb, while the noun remains stable as the referent (the verb mutability effect). Second, the degree of verb abstraction depends on the degree of shared structure between the verb event and the noun event—as the two become less similar, the verb's meaning becomes increasingly generalized. Third, the verb event generates inferences about the noun event based on identified commonalities between the two. That is, the noun event is further specified as unfolding in a manner consistent with the verb event.

In addition, the new empirical results reported here provide evidence for a fourth prediction: that prior activation of noun event structure that is involved in the subsequent metaphoric mapping facilitates metaphor comprehension.

Theoretical Implications

Parallels with noun metaphor By treating verb metaphors as instances of analogies, our account parallels Gentner and colleagues' theory of noun metaphor comprehension, in which they have argued that noun metaphors are also instances of analogies that are processed as comparisons via structure-mapping (e.g., Gentner et al., 2001). In this view, noun metaphors like *Jealousy is a tumor* are understood via the same two-stage process of alignment and inference projection described above. Thus, as with verb metaphors, structure-mapping explains how the metaphor serves both to highlight common relational structure (e.g., both jealousy and tumors are negative experiences that are internal to a person), while also generating new inferences based on those commonalities (e.g., since tumors can metastasize if left untreated, so too may jealousy become all-consuming if not addressed). A number of empirical studies have supported the processing predictions of structure-mapping in noun metaphor comprehension (Gentner & Wolff, 1997; Gentner et al., 2001; Wolff & Gentner, 2000, 2011).

Having a single process model for both noun and verb metaphor is appealing, in that it readily allows metaphorical processing to extend beyond single local metaphors to extended metaphorical passages. Such passages often mix metaphoric uses of nouns and verbs in a single utterance—e.g., *The rockets came like locusts, swarming and settling in blooms of rosy smoke*.[3] Structure-mappings can be updated incrementally as new information is encountered (Forbus et al., 1994), providing a natural mechanism for explaining extended metaphor processing (e.g., Gentner & Boronat, 1991; Keysar et al., 2000; Thibodeau & Durgin, 2008). Thus, positing a single mechanism for both noun and verb metaphors could provide an account of how these extended metaphors are understood, without the need for process-switching as metaphors from different word classes are encountered.

Language Evolution and the Career of Metaphor Metaphor is widely considered to be an important vehicle for language change over time (e.g., Bowdle & Gentner, 2005; Xu et al. 2017; Heine, 1997; Hopper & Traugott, 2003). There are several reasons to think that novel verb metaphors may drive the evolution of verb meanings. As mentioned above, many verbs have conventional metaphoric senses that are listed in the dictionary. Consistent with our findings here, those senses are often more domain-general abstractions of the verb's literal meaning. For example, in Merriam-Webster's online dictionary, the literal meaning of *fly* is "to move in or pass through the air with wings," while the metaphoric sense is the more general "to move, pass, or spread quickly." Bowdle and Gentner's (2005) *Career of Metaphor* proposed that the metaphoric abstractions generated by comprehending novel metaphors may over time enter common circulation and become lexicalized as a new conventional metaphoric sense of the base.

This idea—paired with our present account of verb metaphors as analogical comparisons—provides a possible mechanism for linking a number of different findings regarding verb metaphor and language change. As discussed above, verbs change meaning more than nouns in online sentence processing (the verb mutability effect) and do so predominantly through analogical/metaphoric abstractions of the verb's literal meaning (King & Gentner, 2022b). The greater mutability and metaphoricity of verbs in sentence processing provides a possible explanation for the finding that verbs change meaning more than nouns over historical time periods (Dubossarsky et al., 2016), and may also relate to findings that verbs are more polysemous than nouns, controlling for frequency (Gentner, 1981; Miller & Fellbaum, 1991) and have senses that are more metaphoric than noun senses in the dictionary (King, Gentner, & Mo, 2021). We suggest that these patterns of meaning change are driven by repeated analogical abstractions of the verb that arise during the comprehension of novel verb metaphors.

Conclusion

We have proposed that verb metaphors are processed as analogies are. The predictions generated by applying an analogy framework are consistent with recent work delineating the behavior of verb metaphoric extensions. The results of the experiment here provide further evidence for the involvement of structure-mapping processes. This theory suggests a unified framework for noun and verb metaphor processing, with implications for the processing of extended metaphors, as well as language evolution over time.

[3] From Ray Bradbury's *The Martian Chronicles*.

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