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The early processing of metaphors and similes: Evidence from eye movements

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Abstract

This eye movement study examined how people read nominal metaphors and similes in order to investigate how the surface form, or wording, of these expressions affected early processing. Participants silently read metaphors (*knowledge is a river*) and similes (*knowledge is like a river*). The identical words were used in the topic–vehicle pair (*knowledge–river*) in both conditions. Experiments 1 and 2 demonstrated longer reading times and a higher proportion of regressions in metaphors than in similes. Familiarity modulated later metaphor effects in Experiment 1, but not in Experiment 2. Reading ability did not modulate the metaphor effects in Experiment 2. Results indicate that readers revised their initial interpretation of metaphors before moving on to read new text. This suggests that readers did not initially hold figurative interpretations of apt nominal metaphors that are somewhat familiar. Metaphor interpretation may be fast, but it is not easy.

Keywords

Eye movements; Metaphor; Reading

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How do readers process metaphors and similes online during silent reading? Let's consider, for example, *knowledge is a river* and *knowledge is like a river.* Nominal metaphors express a relationship between a topic (*knowledge*) and a vehicle (*river)* using the linguistic frame *X is Y.* Simile expressions relate the topic and vehicle words by including the word *like*, as in *X is like Y*. Both types of expressions convey a relationship between *knowledge* and *river* that goes beyond the literal meaning. Intuitively, both phrases ultimately evoke similar interpretations. Yet, the two phrases exemplify two categories of linguistic expressions: metaphor and simile. The distinction is marked by one key difference in surface form. The addition of *like* in the simile allows readers to initially process it as an acceptable comparison statement, given that any noun can be *like* another noun in some way. In contrast, the surface form of a metaphor is the form of a categorical statement, which asserts that X *is* Y. The literal sense of this phrase is that the second noun (Y) is a superordinate category of the first (X), as in *gummy bears are candy.* In a metaphor, however, the literal categorical interpretation is anomalous once readers identify the vehicle (Y). The present study examines whether people read phrases differently when the surface form offers a meaning that is literally possible (as it is in a simile) than when the surface form offers a meaning that is not literally possible (as it is in a metaphor).

Interest in figurative language processing dates back to Aristotle (trans. 1926). Early theories claimed that language is initially interpreted literally (Davidson, 1978; Grice, 1975; Searle, 1979). Searle (1979) proposed a serial account of figurative language processing, in which the failure of a literal interpretation triggers a search for a figurative meaning once the literal meaning is deemed "defective" (Searle, 1979, p. 114). This perspective is now known in the metaphor literature as the standard pragmatic view. According to Gibbs and Colston (2012), the pragmatic view claims that readers do not reject the literal meaning

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until the statement is fully processed. This suggests that Searle's view took into account only the full interpretation of an expression, as the reader became aware of it. Thus, the original standard pragmatic view did not seem to consider figurative interpretations that unfold quickly over the course of milliseconds during silent reading.

The present study examines the early, automatic processes involved in reading metaphors and similes. By monitoring eye movements during silent reading, we investigate a fundamental issue in the metaphor-processing literature. Do readers initially access figurative and literal interpretations in parallel or do they hold one, initial interpretation of the *X is Y* expression? On the one hand, some metaphor theories hold that the reader initially prefers one interpretation. For example, theories such as graded salience (Giora, 2003) claim that a reader maintains the most salient meaning first. Graded salience proposes a mechanism that weights properties of a particular metaphor (such as familiarity) to facilitate one interpretation more quickly than the rest, even though several interpretations are initially available (Giora, 1997; Giora & Fein, 1999). Other metaphor theories, such as categorization theory (Glucksberg, 2003, 2008; Glucksberg & Keysar, 1990) and the direct access view (Gibbs, 1994) claim that the dual reference of metaphor vehicles to both literal and figurative interpretations allows readers to process metaphors as easily as literal statements. According to this view, the vehicle in the metaphor form (*X is Y*) allows readers to access a figurative meaning directly without requiring any special processes beyond those used for understanding literal language (Gibbs & Colston, 2012).

The question of whether readers form figurative interpretations as easily as literal interpretations has yet to be resolved in the literature. Studies that measure decision time about an expression (e.g., *is it literally true?*) tend to find comparable processing times for figurative and literal expressions (Gibbs, 1992; see Gibbs & Colston, 2012, for a thorough review). For example, McElree and Nordlie (1999) examined how readers process free-standing figurative expressions using a speed–accuracy trade-off (SAT) paradigm. Participants made literalness and meaningfulness judgments to figurative, literal, and nonsense statements (e.g., *Some hearts/ temples/ clouds are stone*). Composite measures of processing speed were similar for the figurative and literal sentences, and this was interpreted to indicate that readers access figurative and literal meanings with comparable ease. However, self-paced reading studies tend to find that it takes longer to read metaphors than similes (e.g., Brisard, Frisson, & Sandra, 2001; Janus & Bever, 1985).

The literature does offer fairly consistent evidence that readers process *certain* metaphors more easily than others. Familiarity and aptness seem to facilitate metaphor processing. Readers process familiar metaphors more easily than those that are less familiar (Blasko & Connine, 1993; Columbus et al., 2015; Jones & Estes, 2005). Aptness refers to how easily readers can apply the properties of a metaphor's vehicle to its topic. Apt metaphors can be processed as easily as literal statements (Bowdle & Gentner, 2005; Jones & Estes, 2005, 2006; Roncero, de Almeida, Martin, & de Caro, 2016). Whereas much of the evidence indicates that readers interpret certain metaphors as quickly as literal statements, it does not address the question of whether readers access figurative interpretations in general as quickly as literal interpretations.

In addition, there are reasons to interpret the findings from some previous metaphor studies cautiously. First, metaphor studies often manipulate expression type by changing the topic. When statements in the figurative and literal conditions shared the same vehicle (Y) but had different topics (X), it is possible that differences in the semantic relatedness of these topic–vehicle pairs contributed additional noise that masked differences between conditions. To address this, the present study used simile and metaphor expressions that contained the same topic–vehicle word pairs. A second reason for caution is that data collected off-line do not necessarily illuminate how metaphors are initially processed. Given that decision time and SAT data are collected after reading an expression, these data might reflect a reader's full interpretation of the metaphor better than the initial processing of the expression (Janus & Bever, 1985). Therefore, we monitored eye movements in order to better understand the cognitive processes involved in processing metaphors.

Brain electrical potentials and eye movement data reflect processing as it occurs and, therefore, may be particularly informative for understanding early figurative language processes. For example, Lai, Curran, and Menn (2009) measured event-related potentials (ERPs) as participants read predicates with conventional metaphorical meaning and literal meaning. N400 amplitudes were larger when the target appeared in the figurative context (*Every point in my argument was attacked*) than in the literal context (*Every soldier in the frontline was attacked*), indicating more effortful processing in the figurative than in the literal conditions. Other ERP studies also suggest that readers have more difficulty processing figurative than literal meanings (e.g., Coulson & Van Petten, 2002; Lai et al., 2009; Tartter, Gomes, Dubrovsky, Molholm, & Stewart, 2002).

Eye movement studies offer a more natural reading experience than is usually available in ERP studies, as eye movement studies allow participants to read sentences at their own pace and re-read text as desired. In the first eye movement study of metaphor processing, Inhoff, Lima, and Carroll (1984) followed up Ortony, Schallert, Reynolds, and Antos (1978) in order to examine how prior context affects metaphor processing. Participants read long related, short related, and unrelated contexts before figurative and literal statements. Metaphor sentences were read as quickly as literal statements when preceded by long related contexts. However, short contexts led to longer reading times for metaphors than for literals. Blasko and Briihl (1997) also found that related contexts facilitated metaphor processing. More recently, Olkoniemi, Ranta, and Kaakinen (2016) examined how readers process metaphoric, sarcastic, and literal expressions in story contexts. The target sentences were identical across conditions, and the prior sentence biased the target's interpretation. Olkoniemi et al. (2016) found longer first-pass reading times for metaphorical than for literal sentences, which indicates that figurative language processing is difficult even in a supporting context.

The present study contributes to this literature by investigating how skilled readers process metaphors and similes. In particular, we examine how the surface form, or wording, affects the millisecond-by-millisecond processing of these two expressions. Participants read the same topic and vehicle pairs in each condition (across subjects) in order to control for word frequency and the semantic distance between topic–vehicle pairs. With this design, the primary difference in the conditions was the interpretation of the topic–vehicle relationship yielded by the presence or absence of the word *like*. Thus, we test whether readers process metaphors as easily as similes and how the difference in surface form affects early reading processes.

The present study brings eye movement data to bear on a fundamental issue that differentiates two perspectives in the metaphor-processing literature. Metaphor-processing theories that claim that readers hold figurative and literal interpretations in parallel make different predictions for our data than theories that claim that readers hold primarily one interpretation. If readers access figurative and literal interpretations of a phrase in parallel, then they should easily access a figurative meaning that satisfies the phrase *X is Y.* This would predict comparable reading and rereading times for similes and metaphors. Alternatively, readers initially might hold one primary interpretation that is not necessarily figurative. The simile surface form is plausible with either a literal or a figurative interpretation, but a literal interpretation of the metaphor surface form yields a categorical statement that is not plausible (e.g., knowledge is not a type of river). In this case, readers would reject their first interpretation in order to retrieve another. Longer reading times and more frequent regressions for metaphors could reflect the processing cost of switching to another, less available meaning in order to satisfy the non-literal *X* is *Y* expression.

Experiment 1

This study investigates how skilled readers process metaphors and similes when they are reading at their own pace for comprehension and can re-read as desired. Each participant saw half of the topic–vehicle pairs in the simile

1 2 3

(a) Frank thinks that knowledge is a| river| because| it keeps changing its course.

(b) Frank thinks that knowledge is like a| river| because| it keeps changing its course.

Figure 1. The analysis regions for metaphors (a) and similes (b) in Experiments 1 and 2.

condition and half in the metaphor condition. As seen in Figure 1, the regions of interest are the vehicle (1) and the spillover region (2). For completeness we also report data from the explanation region (3). The vehicle (e.g., *river*) is the first point at which readers can detect that the phrase is a nominal metaphor rather than a literal categorical statement. In order to understand the early aspects of figurative language processing that begin with word recognition and the subsequent processes that are reflected in rereading times, we report initial reading time (gaze duration), all the time spent reading in a region before moving on to read new text (go-past time), and the proportion of regressions out of a region.

Method

Participants. Fifty native English speakers with normal or corrected-to-normal (via contact lenses) vision participated for course credit or payment of $7 US at the University of Massachusetts.

Apparatus. An Eyelink 1000 eye tracker monitored the movement of the right eye, as participants viewed sentences binocularly. Viewing distance was 60 cm, and 3–4 characters equalled approximately 1° of visual angle. Eye position data were sampled at 1000 Hz.

Materials. Sixty-two nominal metaphor and simile pairs of the form *X is/is like Y* (*Roads are/are like snakes*) were selected from Internet searches and materials used in previous research (e.g., Chiappe, Kennedy, & Smykowski, 2003). In order to confirm aptness, 20 students rated the metaphor phrases for aptness from 1(*not at all apt*) to 10 (*very apt*; $M = 6.3$, $SE = 0.18$, $SD = 1.4$). Items in the simile and metaphor conditions were identical, except that the word *like* appeared in the simile condition. In the eye movement study, the target phrase was followed by an explanation of the metaphor or simile (. . . *because they twist and turn*), so that the vehicle would not appear in a sentence-final position.

Design. We manipulated expression type (metaphor or simile) within items; the identical topic–vehicle pairs appeared in simile and metaphor phrases. Each participant read half of the topic–vehicle pairs presented as similes and the other half presented as metaphors in a counterbalanced design. Post hoc analyses included familiarity as a continuous variable. Another group of 20 students, who also did not participate in the eye movement experiment, rated the familiarity of the metaphor phrases (1–*not at all familiar* to 7–*very familiar*; M=3.8, SE=0.17, SD=1.3). The experimental items were randomly interleaved with 92 filler items from unrelated experiments, so that fewer than half of the 154 items seen by each participant appeared in the metaphor and simile conditions. Participants answered a yes/no comprehension question after 25% of the sentences (mean accuracy=89%).

Data cleaning and analyses. Software developed at the University of Massachusetts (Clifton, Stracuzi, & Kinsey, 2006) was used to delete trials with blinks (Eyedoctor Version 0.6.3 g) and to obtain subject and item averages for each condition (Eyedry Version 1/25/2013). Predetermined cut-offs were used to trim the data (Rayner, 1998). Fixations shorter than 80 ms and longer than 800 ms were eliminated (2% of fixations). Trials in which there was a blink or track loss during reading were removed prior to analysis (7% of trials).

Analyses of first-pass fixation times included only trials without regressions in order to avoid the potential confound of regressions and faster reading times (Altman, 1994; Rayner & Sereno, 1994). Data were analysed using linear mixed effects modelling (LMM) in an R environment. Random factors were subjects and items (intercepts and condition slopes; Baayen, Davidson, & Bates, 2008). Fixed effects were condition (metaphor vs. simile) and centered familiarity ratings. Separate models were created for each measure in each region. The maximal model failed to converge for gaze duration in the spillover region and regressions-out in the vehicle region. In these cases, random slopes and intercepts were used for the subjects variable, but only random intercepts for items. Regressions from the explanation region were not analysed. Proportions of regressions-out were analysed using logistic regression (Jaeger, 2008). Fixed effects were considered significant if t or z>1.96.

Procedure. Each participant sat in front of the eye tracker and used chin and forehead rests to minimize head movements. A three-point calibration screen was used. Participants were told to read normally for comprehension, and that a question would appear after some sentences. The experiment session lasted 30–45 min.

Results and discussion

Mean reading times and mean proportion of regressions appear in Table 1. The LMM analyses appear in Table 2. Analyses of the vehicle region returned a main effect of expression type in all three measures; we observed longer gaze durations and re-reading times as well as a higher proportion of regressions for metaphors than for similes. This pattern indicates *a metaphor effect*; readers had greater difficulty processing metaphors than similes.

Table 1. Experiment 1: Eye movements in the region.

Measure	Vehicle	Spillover	Explanation
Gaze duration (ms)			
Simile	272 (3)	225 (2)	719 (13)
Metaphor	282 (4)	233 (2)	727 (13)
Go-past time (ms)			
Simile	275 (3)	230 (2)	772 (14)
Metaphor	297 (4)	246 (2)	780 (14)
Regressions out (proportion)			
Simile	.07 (.007)	.04 (.005)	.03 (.005)
Metaphor	.14 (.009)	.07 (.007)	.03 (.005)

Note: Standard errors are in parentheses.

Inspection of an Expression × Familiarity interaction for go-past time in the vehicle region indicates that the metaphor effect appeared primarily in the unfamiliar items. In the spillover region, analyses returned a main effect of expression type in the three measures as well. Also, a main effect of familiarity appeared in gaze duration and go-past time in this region; participants read *because* faster in the familiar items than for the unfamiliar items. Inspection of the marginal Expression × Familiarity interaction in go-past time for the spillover region indicates that the metaphor effect was somewhat larger for unfamiliar than for familiar items. Inspection of the Expression × Familiarity interaction in regressions-out indicates that a metaphor effect appeared for all but the most familiar items.

Experiment 1 offers evidence that readers begin processing metaphors before the eyes leave the vehicle. Metaphoricity affected reading time and re-reading patterns, indicating that readers had more difficulty processing metaphors than similes. Difficulty processing the less familiar metaphors appeared in re-reading times on the vehicle and regressions from the spillover region.

Experiment 2

We conducted Experiment 2 in order to replicate the pattern of results in Experiment 1 and to examine how reading ability affects metaphor and simile processing. Previous eye movement studies indicate that reading ability affects word recognition (e.g., Ashby, Rayner, & Clifton, 2005; Veldre & Andrews, 2014) but the eye movement literature has yet to examine how reading skill affects the processing of metaphor vehicles.

According to verbal efficiency theory (Perfetti, 1985), readers with more efficient word recognition processes have more resources available for comprehension. Better readers also have read more by the time they reach college than have poor readers, and, therefore, better readers should be more familiar with the metaphors used in this study. For these reasons, we expected to find a larger metaphor effect for poor college readers than for good college readers.

Table 2. Experiment 1: Analyses of the eye movement data.

Measure	Vehicle			Spillover			Explanation		
	b	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*
Gaze duration									
Expression	12.71	6.07	**2.09**	11.68	3.60	**3.24**	10.46	13.03	0.80
Familiarity	−6.50	5.23	−1.24	−4.87	1.97	**−2.45**	28.26	36.35	0.78
Express × Famil	−5.44	3.43	−1.58	−1.82	2.39	−0.76	−8.15	8.52	−0.95
Go-past time									
Expression	20.55	5.20	**3.95**	17.08	4.15	**4.11**	10.92	11.71	0.93
Familiarity	−5.50	5.21	−1.05	−4.29	2.09	**−2.05**	31.59	40.48	0.78
Express × Famil	−10.14	3.53	**−2.86**	−5.95	3.05	−1.94	−14.89	8.57	−1.73
Regressions out									
Expression	0.83	0.18	**4.65**	0.53	0.27	**1.97**			
Familiarity	−0.05	0.08	−0.60	−0.05	0.12	−0.46			
Express × Famil	−0.17	0.10	−1.60	−0.32	0.15	**−2.08**			

Note: Significant effects appear in bold. Express = expression; Famil = familiarity.

Method

Participants. Forty-eight native English speakers with normal or corrected-to-normal vision participated for course credit at Central Michigan University.

Apparatus. The apparatus was the same as that in Experiment 1.

Materials. Sentences were the same as those in Experiment 1. Participants also completed the Nelson–Denny Reading Test in a separate session. The Nelson–Denny is a standardized reading comprehension test that is normed for college students. Participants earned a mean standard score of 219 ($SD = 16$), which is roughly a 13.6 grade equivalent (i.e., midway through the second year of their undergraduate education).

Design. The design was similar to that of Experiment 1. In addition, reading score was included as a between-subjects variable in order to examine how reading skill affected metaphor processing.

Procedure. The procedure was the same as that in Experiment 1, with one exception. This study was conducted in two sessions one week apart. The first session involved completing the Nelson–Denny Reading Test. In the second, participants read silently as their eye movements were monitored.

Data cleaning and analyses. The eye movement data were cleaned and analysed using the same cut-offs and software as those in Experiment 1. Six percent of trials were excluded for track losses and/or blinks. Reading score was computed as a composite standard score based on performance on the Vocabulary and Comprehension sections of the reading test. Reading score and familiarity were centred and were included as continuous variables in the LMMs. The maximal model failed to converge for regressions-out in the vehicle region.

Table 3. Experiment 2: Eye movements in the region.

Measure	Vehicle	Spillover	Explanation
Gaze duration (ms)			
Simile	300 (4)	253 (3)	780 (14)
Metaphor	329 (5)	258 (3)	781 (15)
Go-past time (ms)			
Simile	311 (5)	267 (5)	861 (17)
Metaphor	345 (5)	285 (3)	863 (16)
Regressions out (proportion)			
Simile	.09 (.008)	.05 (.006)	.07 (.007)
Metaphor	.18 (.010)	.13 (.009)	.07 (.007)

Note: Standard errors are in parentheses.

Results and discussion

Mean reading times and proportion of regressions appear in Table 3, and the LMM analyses appear in Table 4. In the vehicle region, a main effect of expression appeared in all three measures, indicating that readers found metaphors more difficult to process than similes from the time they fixated the vehicle. Regressions from the vehicle region were more likely for unfamiliar items than for familiar items. In the spillover region, metaphor effects appeared in go-past time and regressions. Also, a main effect of familiarity appeared in gaze duration and go-past time in this region; participants read the word *because* faster in the familiar items than in the unfamiliar items. In the explanation region, analyses returned an Expression × Familiarity interaction; participants spent longer reading

Table 4. Experiment 2: Analyses of the eye movement data.

Measure	Vehicle			Spillover			Explanation		
	b	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*
Gaze duration									
Expression	27.56	5.73	**4.80**	6.78	4.57	1.48	10.16	12.97	0.78
Familiarity	−6.84	6.74	−1.01	−6.56	2.53	**−2.60**	23.45	37.78	0.62
Reading score	−1.62	0.45	**−3.58**	−1.27	0.28	**−4.41**	−3.24	1.21	**−2.68**
E×F	−1.80	4.29	−0.42	0.41	3.21	0.13	4.47	9.74	1.48
E×R	−0.19	0.31	−0.62	0.20	0.26	0.77	−0.66	.76	−0.86
F×R	−0.12	0.16	−0.80	−0.01	0.12	−0.09	−0.27	0.40	−0.68
E×F×R	0.35	0.23	1.49	0.07	0.18	0.43	−0.12	.57	−0.21
Go-past time									
Expression	31.22	6.89	**4.53**	19.09	7.05	**2.71**	7.20	14.88	0.48
Familiarity	−11.18	7.18	−1.55	−11.31	4.34	**−2.61**	12.26	44.07	0.27
Reading score	−1.83	0.56	**−3.22**	−1.67	0.43	**−3.86**	−4.75	1.57	**−3.02**
E×F	−1.55	5.20	−0.29	−1.69	4.84	−0.35	26.63	11.16	**2.38**
E×R	−0.22	0.40	−0.53	0.10	0.41	0.24	−0.06	0.90	−0.68
F×R	−0.13	0.21	−0.60	0.05	0.20	0.25	−0.00	0.48	−0.01
E×F×R	0.36	0.30	1.19	0.10	0.28	0.37	−0.46	0.68	−0.67
Regressions out									
Expression	8.34	1.25	**6.65**	1.32	0.25	**5.08**			
Familiarity	−1.72	7.75	**−2.22**	−0.25	0.14	−1.80			
Reading score	−6.70	9.71	−0.68	−0.03	0.01	**−2.55**			
E×F	4.09	9.65	0.42	−0.05	0.14	−0.39			
E×R	−2.23	7.91	−0.28	0.01	0.01	1.34			
F×R	7.57	4.85	0.01	−0.00	0.00	−0.25			
E×F×R	2.34	6.07	0.38	0.00	0.00	0.02			

Note: Significant effects appear in bold. E = expression; F = familiarity; R = reading.

the explanations after familiar metaphors than explanations in the other three conditions.

A main effect of reading score appeared in reading time measures for all regions; the good readers read faster than the poor readers. However, no analyses returned an interaction of reading ability and expression type, which suggests that adult reading ability did not modulate how metaphors are processed. Further research is needed to examine whether adult reading ability affects the interpretation of novel metaphors and whether reading ability affects how children process metaphors.

General discussion

This is the first eye movement study to examine how readers process metaphors and similes as they silently read sentences. In Experiment 1, initial reading times and re-reading times were slower for the vehicle and the word to its right when reading the metaphors than when reading the similes. Also readers were more likely to regress from these regions when reading metaphors than when reading similes. In Experiment 1, familiarity modulated metaphor effects in later reading measures (go-past and regressions out), but this pattern did not replicate in Experiment 2. Experiment 2 replicated the main metaphor effect: Participants initially read the vehicle more slowly in the metaphor than in the simile condition. Metaphor effects also appeared in re-reading time and proportion of regressions from the vehicle and the spillover region, showing that difficulty reading metaphors can affect where and when the eyes move during reading. These data indicate that metaphors are more difficult to process than similes, which is consistent with most previous online studies that compared metaphors and literal statements (Brisard et al., 2001; Coulson & Van Petten, 2002; Inhoff et al., 1984; Janus & Bever, 1985; Lai et al., 2009; Olkoniemi et al., 2016; Tartter et al., 2002). The Experiment 2 data indicate that better readers read metaphors and similes more quickly than did their less skilled peers, and found no evidence that reading skill affects metaphor processing.

Our eye movement data make several novel contributions to the existing literature. First, the data demonstrate that the difficulty with metaphors begins during the initial reading of the vehicle and the word to its right. This pattern indicates that early, automatic interpretation processes differ for metaphors and similes. Metaphor effects rarely appeared in the explanation region, which suggests that readers can access figurative interpretations relatively quickly. In other words, metaphor interpretation is relatively fast but it is not easy. Second, readers had difficulty processing apt, somewhat familiar metaphors, which indicates that the metaphor effect is not confined to novel metaphors. Third, the metaphor effect appeared when participants read the same topic–vehicle pairs embedded in different surface forms, which suggests that the surface form of the metaphor contributes to the processing difficulty (in addition to the familiarity of the topic–vehicle relationship).

Theories claiming that readers initially hold one interpretation as primary are more consistent with these data than theories that claim that readers hold several meanings in parallel. If readers initially accessed several interpretations of the *X is Y* phrase, then they should have an initial figurative interpretation available for metaphors, and reading times for metaphors would be comparable to the reading times for similes. In this study, however, participants read metaphor vehicles more slowly than the same words in simile expressions. They also were more likely to look back and re-read metaphors. These patterns are considered to reflect re-analysis and repair of an initial interpretation (Rayner, 2009). Given that the literal interpretation did not make sense in the metaphor conditions, readers searched for an alternative meaning. This switch carried a processing cost, which was reflected in slower reading of the vehicle and increased re-reading times for the metaphors as compared to the similes. Therefore, our data suggest that when apt and mostly familiar nominal metaphors appeared without prior context, readers initially held one primary interpretation.

Familiarity affected reading times. Participants read the word to the right of the vehicle faster in familiar than in unfamiliar expressions. Metaphor effects appeared in initial reading time for the vehicle whereas familiarity effects did not arise until the spillover region. Given that readers were sensitive to expression type earlier than they were sensitive to familiarity, it seems unlikely that familiarity guides the initial processing of nominal metaphors. These data are more consistent with the idea that readers search for a figurative interpretation of the nominal metaphor, and familiarity affects subsequent processing. The Familiarity × Expression interactions that appeared in re-reading and regressions-out in Experiment 1 did not replicate in Experiment 2. More extreme manipulations of familiarity may yield more robust effects in future studies.

Here we express several caveats to our findings. First, previous research indicates that the qualities of any particular metaphor are likely to modulate the size and timing of metaphor effects (Blasko & Connine, 1993; Bowdle & Gentner, 2005; Jones & Estes, 2005). Therefore, the effects observed here in apt, somewhat familiar metaphors may differ when reading novel metaphors. Novel metaphors require readers to form new associations between the topic and vehicle, and this could amplify metaphor effects. Second, we consider the metaphor effects that appeared in several measures and in different regions to reflect a common processing cost for metaphors. However, future studies may reveal that each of these effects reflects a particular processing cost. Third, some readers may question whether the eye movement data reflect initial metaphor and simile interpretation, given the early time course of the metaphor effects observed here. As the simile and metaphor phrases were nearly identical, meaning interpretation seems to be the most likely driver of these metaphor effects. The reader's interpretation is unlikely to complete by the time the eyes leave the vehicle. Therefore, it is possible that additional effects may arise at later times in the comprehension process that were not measured in this study. Lastly, we recognize that some readers may be tempted to attribute metaphor effects on the vehicle to differences in the word to the left of the vehicle (target – 1; *like* and *is*, respectively). It seems unlikely that a different target – 1 can completely account for the metaphor effects observed here, given that a similar pattern of effects also appeared in the spillover region, where *because* followed the vehicle. Here, the word to the left of *because* was the same word in the simile and metaphor conditions. In two experiments, eye movement data in the spillover region indicated that readers have more difficulty processing metaphors than similes. Therefore, it seems unlikely that the metaphor effects observed here are epiphenomenal.

The primary purpose of this study was to obtain eye movement data that extend our understanding of early metaphor processing. Two experiments demonstrated that participants initially read metaphor vehicles more slowly than when the identical words appeared in simile expressions. Participants also were more likely to look back after leaving the vehicle and *because* regions of the metaphors than after leaving those regions of the similes. Participants spent longer re-reading in the metaphor condition than in the simile condition. These data indicate that readers found metaphors more difficult to process than similes, which we term a *metaphor effect*. This pattern is consistent with theoretical perspectives claiming that readers initially hold one primary interpretation of an expression. Given that the surface form of nominal metaphors (*X is Y)* is the form of a literal categorical statement as well as a metaphor, this ambiguity may set the reader up for a literal interpretation that is not plausible once Y is recognized. This violation seems to prompt the reader to find a plausible interpretation of the metaphor before moving on to read new text. We suggest that the power of metaphors is enhanced by how effectively the metaphor surface form drives re-analysis and recovery of a quick figurative interpretation.

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References

Altman, G. T. M. (1994). Regression-contingent analyses of eye movements during sentence processing: Reply to Rayner and Sereno. *Memory & Cognition*, *22*, 286–290.

Aristotle. (1926). *The art of rhetoric*. New York, NY: G. P. Putnam's Sons.

Ashby, J., Rayner, K., & Clifton, C., Jr. (2005). Eye movements of highly skilled and average readers: Differential effects of frequency and predictability. *The Quarterly Journal of Experimental Psychology Section A*, *58*, 1065–1086.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*(4), 390–412.

Blasko, D. G., & Briihl, D. S. (1997). Reading and recall of metaphorical sentences: Effects of familiarity and context. *Metaphor and Symbol*, *12*, 261–285.

Blasko, D. G., & Connine, C. M. (1993). Effects of familiarity and aptness on metaphor processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*, 295–308.

Bowdle, B. F., & Gentner, D. (2005). The career of metaphor. *Psychological Review*, *112*, 193–216.

Brisard, F., Frisson, S., & Sandra, D. (2001). Processing unfamiliar metaphors in a self-paced Reading task. *Metaphor and Symbol*, *16*(1-2), 87–108.

Chiappe, D., Kennedy, J. M., & Smykowski, T. (2003). Reversibility, aptness, and the conventionality of metaphors and similes. *Metaphor and Symbol*, *18*, 85–105.

Clifton, C. E., Stracuzi, D., & Kinsey, J. (2006). EyeDoctor (Version 0.6.3 g) and EyeDry (Version 1/25/2013) [Computer Software]. Retrieved from http://www.psych.umass.edu/eyelab/software/

Columbus, G., Sheikh, N. A., Côté-Lecaldare, M., Häuser, K., Baum, S. R., & Titone, D. (2015). Individual differences in executive control relate to metaphor processing: An eye movement study of sentence Reading. *Frontiers in Human Neuroscience*, *8*, 1057.

Coulson, S., & Van Petten, C. (2002). Conceptual integration and metaphor: An event-related brain potential study. *Memory and Cognition*, *30*, 958–968.

Davidson, D. (1978). What metaphors mean. *Critical Inquiry*, *5*(1), 31–47.

Gibbs, R. W. (1992). Categorization and metaphor understanding. *Psychological Review*, *99* (3), 572–577.

Gibbs, R. W., Jr. (1994). *The poetics of mind: Figurative thought, language, and understanding*. New York, NY: Cambridge University Press.

Gibbs, R. W., Jr., & Colston, H. L. (2012). *Interpreting figurative meaning*. New York, NY: Cambridge University Press.

Giora, R. (1997). Understanding figurative and literal language: The graded salience hypothesis. *Cognitive Linguistics*, *8* (1), 183–206.

Giora, R. (2003). *On our mind: Salience, context, and figurative language*. New York, NY: Oxford University Press.

Giora, R., & Fein, O. (1999). On understanding familiar and less-familiar figurative language. *Journal of Pragmatics*, *31*(12), 1601–1618.

Glucksberg, S. (2003). The psycholinguistics of metaphor. *Trends in Cognitive Sciences*, *7*, 92–96.

Glucksberg, S. (2008). *How metaphors create categories—Quickly*. New York, NY: Cambridge University Press.

Glucksberg, S., & Keysar, B. (1990). Understanding metaphorical comparisons: Beyond similarity. *Psychological Review*, *97*, 3–18.

Grice, P. (1975). Logic and conversation. In P. Cole & L. Morgan (Eds.), *Syntax and semantics* (Vol. *3*, pp. 41–58). New York, NY: Academic Press.

Inhoff, A. W., Lima, S. D., & Carroll, P. J. (1984). Contextual effects on metaphor comprehension in Reading. *Memory & Cognition*, *12*, 558–567.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language*, *59*, 434–446.

Janus, R., & Bever, T. (1985). Processing of metaphoric language: An investigation of the three stage model of metaphor comprehension. *Journal of Psycholinguistic Research*, *14*, 473–487.

Jones, L. L., & Estes, Z. (2005). Metaphor comprehension as attributive categorization★. *Journal of Memory and Language*, *53*, 110–124.

Jones, L. L., & Estes, Z. (2006). Roosters, robins, and alarm clocks: Aptness and conventionality in metaphor comprehension. *Journal of Memory and Language*, *55*, 18–32.

Lai, V. T., Curran, T., & Menn, L. (2009). Comprehending conventional and novel metaphors: An ERP study. *Brain Research*, *1284*, 145–155.

McElree, B., & Nordlie, J. (1999). Literal and figurative interpretations are computed in equal time. *Psychonomic Bulletin & Review*, *6*, 486–494.

Olkoniemi, H., Ranta, H., & Kaakinen, J. K. (2016). Individual differences in the processing of written sarcasm and metaphor: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *42*(3), 433–450.

Ortony, A., Schallert, D. L., Reynolds, R. E., & Antos, S. J. (1978). Interpreting metaphors and idioms: Some effects of context on comprehension. *Journal of Verbal Learning and Verbal Behavior*, *17*, 465–477.

Perfetti, C. A. (1985). *Reading ability*. New York, NY: Oxford University Press.

Rayner, K. (1998). Eye movements in Reading and information processing: 20 years of research. *Psychological Bulletin*, *124*, 372–422.

Rayner, K. (2009). Eye movements and attention in Reading, scene perception, and visual search. *The Quarterly Journal of Experimental Psychology*, *62*, 1457–1506.

Rayner, K., & Sereno, S. C. (1994). Regressive eye movements and sentence parsing: On the use of regression-contingent analyses. *Memory & Cognition*, *22*, 281–285.

Roncero, C., de Almeida, R. G., Martin, D. C., & de Caro, M. (2016). Aptness predicts metaphor preference in the lab and on the internet. *Metaphor and Symbol*, *31*(1), 31–46.

Searle, J. (1979). Metaphor. In A. Ortony (Ed.), *Metaphor and thought* (1st ed., pp. 92–123). New York, NY: Cambridge University Press.

Tartter, V. C., Gomes, H., Dubrovsky, B., Molholm, S., & Stewart, R. V. (2002). Novel metaphors appear anomalous at least momentarily: Evidence from N400. *Brain and Language*, *80* (3), 488–509.

Veldre, A., & Andrews, S. (2014). Lexical quality and eye movements: Individual differences in the perceptual span of skilled adult readers. *The Quarterly Journal of Experimental Psychology: Section A*, *67*(4), 703–727.