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Processing (Non)Compositional Expressions: Mistakes and Recovery

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Current models of idiom representation and processing differ with respect to the role of literal processing during the interpretation of idiomatic expressions. Word-like models (Bobrow & Bell, 1973; Swinney & Cutler, 1979) propose that idiomatic meaning can be accessed directly, whereas structural models (Cacciari & Tabossi, 1988; Cutting & Bock, 1997; Sprenger, Levelt, & Kempen, 2006) propose that literal processing is crucial in the access of idiomatic meaning. We used a self-paced reading task to examine how contextual expectations influence real-time processing of phrasal verbs that are ambiguous between a literal and idiomatic sense (e.g., *look up*, *turn in*) and how comprehenders recover from expectations that are revealed to be incorrect. Our results suggest that when comprehenders expect a literal interpretation in a situation where the sentence turns out to be idiomatic, real-time processing is disrupted more than if comprehenders are expecting an idiomatic interpretation and the sentence turns out to be literal. We interpret our results in favor of models of idiom processing that propose obligatory literal processing (e.g., Cacciari & Tabossi, 1988; Cutting & Bock, 1997; Sprenger et al., 2006).

Keywords: idioms, ambiguity, sentence processing, psycholinguistics, compositionality

To understand a sentence, the comprehender must infer and interpret the sentence's structure from an incremental signal that is often rife with ambiguity. Ambiguity in language is pervasive and occurs at multiple levels of linguistic representation. The literature investigating ambiguity resolution is extensive and includes examinations of ambiguity at the level of phonology (e.g., Frost, Feldman, & Katz, 1990), syntax (e.g., Ferreira & Clifton, 1986; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995), and word recognition (e.g., Frazier & Rayner, 1987; MacDonald, 1993; Swinney, 1979; Swinney & Hakes, 1976; Tabossi, 1988). The primary focus of these investigations has been on how individuals navigate the ambiguous signal to recover the correct linguistic structure.

Ambiguity in language occurs because in many domains there is no one-to-one mapping between form and meaning. In cases of lexical ambiguity, such as the word "bank," the ambiguity hinges upon the fact that there are two unrelated lexical entries for the word "bank" in English (for more information on the processing of lexical ambiguity, see, e.g., Foss, 1970; Onifer & Swinney, 1981; Rayner & Duffy, 1986; Swinney, 1979; Tanenhaus, Leiman, & Seidenberg, 1979). In cases of syntactic ambiguity (e.g., "John saw the man with the telescope"), the existence of two possible underlying syntactic structures gives rise to two possible interpretations (John uses the telescope to see the man, or John sees a man who is using a telescope; Frazier & Rayner, 1982). Existing work on syntactic ambiguity resolution has led to important insights regarding the nature of the human sentence processing system (e.g., Altmann & Steedman, 1988; Carreiras & Clifton, 1993; Ferreira & Clifton, 1986; Frazier & Rayner, 1987; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; MacDonald, 1993; Trueswell & Tanenhaus, 1991).

Our focus in this article is on idiom-related ambiguity, such as "John kicked the bucket yesterday." Similar to lexical and syntactic ambiguity, idiom-related ambiguities are also associated with the possibility of more than one representation—in this case, one representation is compositional (e.g., *John hit the bucket with his foot yesterday*), and the other representation is idiomatic (e.g., *John died yesterday*). However, unlike syntactic and lexical ambiguities, these sorts of idiom/literal ambiguities are not easily classified as being either syntactic or lexical. The literal interpretation requires that the words "kick" and "bucket" be interpreted literally as components of a verb phrase. It is less clear how comprehenders arrive at the idiomatic interpretation. One possibility is that some degree of literal processing is necessary to arrive at the idiomatic interpretation. Thus during processing, the comprehender first processes the string literally and later retrieves the idiomatic interpretation if given sufficient reason to do so. Another possibility is that literal processing and idiom access are independent. According to this view, the processing proceeds down either a literal or idiomatic route (or both). However, this raises the question of how and when the comprehension system decides upon one of these routes. Exploring this question requires that we have an understanding of (a) the relationship between literal and idiomatic processing and (b) the role of contextual effects on processing these sorts of expressions. However, as we see in the next section, models of idiom processing differ greatly on these dimensions.

Models of Idiom Processing

Models of idiom processing differ in the role of literal processing during idiom recognition. For our purposes, these models can be grouped into two categories: those that claim that idiom inter-

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pretation is independent of literal processing, and those that claim that literal processing is crucial for idiom interpretation. *Lexical models* generally interpret idioms as "big words," with literal computation playing no direct role in the processing of idiomatic expressions (Bobrow & Bell, 1973; Swinney & Cutler, 1979). Along similar lines, *Direct Access models* propose that idiomatic meaning is accessed directly prior to literal computation (Gibbs, 1980, 1985). Crucially, both of these accounts claim that literal processing plays no role in the access of idiomatic meaning. In contrast, the *Configuration Hypothesis* (Cacciari & Tabossi, 1988) and the *Hybrid Representation Hypothesis* (Cutting & Bock, 1997; Sprenger et al., 2006) both propose that literal computation has priority over access to idiomatic meaning. In the rest of this section, we briefly review the key properties of each of these models.

Lexical models of idiomatic representation treat idioms essentially as large words (Katz & Postal, 1963; Weinreich, 1969). Early research in the lexical model tradition argued that idioms are word-like (i.e., occupy the same level of representation as words) and are directly associated with semantic information without a need for compositional interpretation. For example, Bobrow and Bell (1973) argued that idioms are stored in a separate system accessed via a special non-compositional processing mode. Evidence for this claim comes from experiments showing "literalness priming" effects: Participants are more likely to interpret an ambiguous string as idiomatic if they have recently been exposed to several idiomatic strings and as literal when preceded by literal strings.

Further evidence for the word-like nature of idioms was provided by Swinney and Cutler's (1979) finding of an "idiom speed advantage." They found that idiomatic expressions are recognized as meaningful expressions faster than literal phrases (see also Gibbs, 1980, 1986; Gibbs & Gonzales, 1985; Gibbs & Nayak, 1989; McGlone, Glucksberg, & Cacciari, 1994). Swinney and Cutler argued that, during processing, (a) access to the idiom representation and (b) computation of the literal meaning proceed in parallel, with the apparent speed advantage of idioms emerging because they can be accessed directly in the mental lexicon without need for additional computational steps. Swinney and Cutler termed this model the *Lexical Representation Hypothesis*.

A different approach is suggested by the *Direct Access Hypothesis*, which argues that access to the idiomatic interpretation of a string can occur directly, bypassing literal meaning computation altogether. Evidence for this view comes from Gibbs (1980), who found that participants are faster and less error-prone when judging whether a paraphrase accurately describes the meaning of the conventional, idiomatic usage of a potentially idiomatic string than the less conventional literal usage. Additionally, he showed that memory recall for literal usage could be facilitated by both literal and idiomatic prompts (e.g., "cat" or "reveal secret," respectively, for "let the cat out of the bag") given sufficient context (see also Gibbs, 1985). Gibbs has argued that comprehenders automatically access idiomatic meaning and compute literal meaning only if there is sufficient contextual reason to do so.

In sum, the two models discussed so far, Lexical Access and Direct Access, both claim that *literal computation plays no role in the access of idiomatic meaning*. Both approaches agree that idiomatic and literal processes occur *independently* of each other. They differ slightly with respect to the timing of these processes: According to the Lexical Access Model, idiomatic and literal processes may occur in parallel, but according to the Direct Access Model, idiomatic processing may even precede literal computation.

A different view of the relation between idiomatic and literal processing is represented by the *Configuration Hypothesis.* According to this approach, *literal processing precedes access to idiomatic meaning.* For example, Cacciari and Tabossi (1988) argued that comprehenders proceed with the normal process of literal interpretation until they are faced with sufficient cues to trigger recognition of a string as being idiomatic. If this occurs, the idiomatic meaning is retrieved and enters into the comprehension process. Support for this view comes from cross-modal lexical decision experiments that probed whether idiomatic and literal interpretations were activated during the processing of Italian idioms such as *in seventh heaven*. For prompt words related to the idiomatic meaning (e.g., HAPPY), they found early priming effects with more predictable idioms than with less predictable idioms. For prompt words related to the literal meaning (e.g., STARS), they found a strong and lasting priming effect for unpredictable idioms but not for predictable idioms.

These results go against the claims put forward by the proponents of the Lexical Access and Direct Access Models that literal and idiomatic processes are independent of each other, and support the Configuration Hypothesis's view that literal processing is the default mode. The Configuration Hypothesis's claims about the importance of literal processing also fit well with findings indicating that even idioms have internal structure (Gibbs & Gonzales, 1985; Konopka & Bock, 2009; Peterson, Burgess, Dell, & Eberhard, 2001).

Additionally, Cacciari and Tabossi's (1988) findings suggest that literal processing has priority over idiomatic processing, contrary to what is claimed by the Direct Access Model. In light of these findings, Cacciari and Tabossi proposed the *Configuration Hypothesis*, in which idioms have a distributed lexical representation. According to the Configuration Hypothesis, literal processing proceeds automatically and continues until the parser accumulates enough evidence that the string it is considering is idiomatic (see also Titone & Connie, 1999). If that happens, the idiomatic meaning is retrieved (see also Tabossi & Zardon, 1993).

In sum, the Configuration Hypothesis—unlike the Lexical Access and Direct Access Models—regards literal processing as something that automatically occurs before idiomatic processing. In a similar vein, the *Hybrid Representation Hypothesis* also argues for a distributed representation and a primacy of literal processing. On the basis of speech error data, Cutting and Bock (1997) suggested that the production of idioms is sensitive not only to the idiomatic meaning of the phrase in question but also to its syntactic structure and its literal meaning. They presented participants with pairs of idioms which overlapped in structure and/or meaning. Participants were asked to produce one of the idioms in the pair from memory as quickly as possible. Cutting and Bock found that structurally-overlapping idiom pairs resulted in higher error rates, and that meaning overlap produced as many errors with idiom/idiom pairs as it did with idiom/literal pairs.

Based on these findings, Cutting and Bock (1997) argued for a *Hybrid Representation Hypothesis*. In this model, idiomatic expressions are represented as phrasal frames in a lexical-conceptual layer of the lexicon. Like words, idioms are associated directly

with conceptual content. Like structures, access is mediated via the literal components of the expression, and the lexical-conceptual representation is associated directly with a structural representation. In an extension of Cutting and Bock's work, Sprenger et al. (2006) proposed a revised Hybrid model in which idiomatic representations are instantiated as *super-lemmas*, which serve as a representation of the syntactic properties of the idiom. The introduction of these *super-lemmas* allows idiomatic representations to compete with other lemmas during production. For example, *kick the bucket* could compete with *die* at the same level of lexical representation during production (see also Kuiper, van Egmond, Kempen, & Sprenger, 2007).

The Hybrid Representation Hypothesis predicts a tight integration between the idiomatic representation of an ambiguous string and the literal meaning of its components. Activation of an expression such as *kick the bucket*, for example, should result in activation of literal *bucket* which should in turn result in activation of semantically and phonologically related lemmas (e.g., *pail* and *buck*). Indeed, recent work by Sprenger et al. (2006) showed this to be the case: They found that sentence completion of an incomplete idiomatic string was facilitated by priming words related phonologically or semantically to the target word.

In sum, existing models of idiom processing make conflicting predictions regarding the relationship between literal processing and idiomatic processing. While the Lexical Access and Direct Access Models regard the two processes as independent, the Configuration Hypothesis and the Hybrid Representation Hypothesis claim that idiomatic processing is preceded by some amount of literal processing.

Contextual Effects

It is well-known that the human language system is capable of making use of many sources of information (e.g., Burgess, Tanenhaus, & Seidenberg, 1989; MacDonald, Pearlmutter, & Seidenberg, 1994; Spivey & Tanenhaus, 1998; Spivey, Tanenhaus, Eberhard, & Sedivy, 2002; Tanenhaus, Carlson, & Trueswell, 1989; Trueswell & Tanenhaus, 1991). Broadly speaking, research has shown that prior linguistic context influences ambiguity resolution in the domain of lexical ambiguity (Rayner, Pacht, & Duffy, 1994; Swinney, 1979; Tabossi, Colombo, & Job, 1987; Tanenhaus et al., 1979), syntactic ambiguity (Altman, van Nice, Garnham, & Henstra, 1998; Trueswell, Tanenhaus, & Garnsey, 1994; see also MacDonald, 1993), and metaphorical processing (Inhoff, Lima, & Carroll, 1984; Ortony, Schallert, Reynolds, & Antos, 1978).

Work on idioms has also found that prior context influences how comprehenders process idiomatic strings (Bobrow & Bell, 1973; Cacciari, Padovani, & Corradini, 2007). However, real-time studies of the time-course of idiom interpretation are rare (though see Colombo, 1993; Titone & Connie, 1999; Vespignani, Canal, Molinaro, Fonda, & Cacciari, 2010). Additionally, existing models of idiom processing make divergent predictions regarding the effects of prior context on processing. Hybrid models (Cutting & Bock, 1997; Sprenger et al., 2006) and the Configuration Hypothesis (Cacciari & Tabossi, 1988) both predict a certain priority for literal processing. In the former, access to idiomatic meaning is dependent upon activation of the literal meanings of the idiom's component lemmas. In the latter, the proposal is that sentence processing proceeds literally until the idiom is recognized. While these models differ significantly in both representation and process (see Tabossi, Fanari, & Wolf, 2009; Tabossi, Wolf, & Koterle, 2009), both suggest that some degree of literal processing occurs before idiomatic meaning is retrieved. With respect to the idiomatic interpretation, however, these models both indicate that contextual influences could prevent or postpone retrieval of idiomatic meaning during processing.

This is in contrast to the Direct Access Hypothesis (Gibbs, 1980) and the Lexical Representation Hypothesis (Swinney & Cutler, 1979). Proponents of the Direct Access Hypothesis suggest that idiomatic interpretation can be made available without any priority of literal processing, and claim that this is the normal route. Proponents of the Lexical Representation Hypothesis claim that both meanings are processed in parallel; however, the model does not rule out in principle that sufficient contextual information could restrict consideration to one or the other interpretations. However, these models are similar in suggesting that sufficient contextual bias should not *reduce consideration of the idiomatic meaning.*

To test the validity of these different predictions for real-time processing, we examined the explored the consequences of recovery when contextual bias is incongruent with the correct interpretation in globally unambiguous sentences.

Aims of the Present Study

We conducted a self-paced reading experiment to explore how sequences that are ambiguous between literal and idiomatic interpretations are influenced by literal-biasing and idiom-biasing contexts. In particular, we compare situations where the contextually-induced bias turns out to be correct and situations where the contextually-induced bias is incorrect/misleading. If someone is expecting an idiomatic interpretation but the sentence turns out to be literal, does this incur a processing cost? Conversely, if someone is expecting a literal interpretation and the sentence turns out to be idiomatic, does this incur a processing cost? How do these two situations compare to each other?

If literal processing is default and/or mediates access to the idiomatic interpretation, as claimed by the Configuration Hypothesis and Hybrid Representation views (Cacciari & Tabossi, 1988; Cutting & Bock, 1997; Sprenger et al., 2006), we predict that a violated expectation is more costly when the reader is expecting a literal interpretation than when she is expecting an idiomatic interpretation. In other words, *correcting one's expectations toward an unexpected literal interpretation is easier than correcting one's expectations toward an unexpected idiomatic interpretation*.

This prediction is derived from the claim that literal processing is primary and occurs before the idiomatic meaning is retrieved: If the comprehender mistakenly attempts to interpret a literal structure as idiomatic and must then revise her interpretation toward the literal interpretation, she may be able to make use of the (perhaps partial) literal processing that she has already accomplished, thereby recovering from such mistakes relatively quickly. If literal meaning is not primary, as proposed by the Lexical Representation and Direct Access Hypotheses (Gibbs, 1980; Swinney & Cutler, 1979), we predict a different outcome. If the Direct Access Hypothesis is correct, we predict that comprehenders will *not* have trouble processing the idiomatic meaning, regardless of context.

However, they should exhibit difficulty in literally resolving trials when context suggests an idiomatic interpretation. This is essentially the opposite of what the Configuration Hypothesis and Hybrid Representation models predict.

The Lexical Representation Hypothesis predicts two potential outcomes. First, since both the literal and idiomatic interpretations are processed in parallel, we may see no asymmetry in processing between literally resolving and idiomatically resolving trials. Alternatively, in light of earlier work showing that idiomatic access is faster than literal computation, the Lexical Representation Hypothesis is also compatible with a finding where idiom-resolving trials are processed faster than literal-resolving, regardless of bias, simply due to the speed advantage of idiom retrieval. This pattern is also predicted by the Direct Access Hypothesis.

In sum, if literal processing is obligatory and can be relied upon regardless of expectations, we predict that for *literal strings*, processing will be less perturbed, regardless of whether the bias is literal or idiomatic. In contrast, for *idiomatic strings*, we expect that processing will be more perturbed if the preceding bias lead participants to expect a literal string.

Self-Paced Reading Experiment

To explore these questions we conducted a self-paced reading study that examines what happens when the comprehender is required to change their expected interpretation of an ambiguous string. We used phrasal verbs that are ambiguous between literal and idiomatic interpretations (e.g., *rush into* [a decision vs. a building]) and embedded them in sentences that bias either a literal or idiomatic interpretation (e.g., literal bias: *The daring fireman rushed into . . .* vs. idiomatic bias: *The foolish entrepreneur rushed into . . .*). In addition to manipulating the contextual expectations, we also manipulated whether the sentence was resolved in favor of the idiomatic or the literal interpretation (e.g., *rushed into the decision* [idiomatic] vs. *rushed into the building* [literal]). This allows us to examine the differences between idiom and literal processing during smooth comprehension and also during recovery from misplaced expectations. Examination of this recovery process can help shed light on whether literal processing is (a) privileged/automatic (Cacciari & Tabossi, 1988; Cutting & Bock, 1997; Sprenger et al., 2006) or (b) unrelated to idiomatic access (Gibbs, 1980; Swinney & Cutler, 1979).

Method

Participants. Thirty-two adult native speakers of American English from the University of Southern California community participated in this study.

Materials. This experiment consisted of 16 targets and 32 fillers (see the Appendix). Each target contained a verb + preposition string (e.g., *rush into*, *look up*, *dwell on*) that was ambiguous between a literal and an idiomatic interpretation. We manipulated (a) the bias induced by the sentential subject (*Idiom Bias* vs. *Literal Bias*) and (b) the disambiguating resolution signaled by the noun after the verb + preposition sequence (*Idiom Resolution* vs. *Literal Resolution*). As a result, two conditions are *congruent*, in that the resolution matches the bias. Two conditions are *incongruent*, because the resolution does not match the expectations created by the bias. An example is shown in Table 1, for the ambiguous verb + preposition sequence "dig into." We refer to the congruent conditions as [IdiomBias|IdiomRes] (line (a) in Table 1) and [LiteralBias|LiteralRes] (line (d) in Table 1), and we refer to the incongruent conditions as [IdiomBias|LiteralRes] (line (b) in Table 1) and [LiteralBias|IdiomRes] (line (c) in Table 1).

Targets were designed such that they consisted of a *Biasing Subject* and *Post Subject* relative clause followed by the critical *Verb + Preposition* and then continued with a *Resolution* which clearly signaled whether the *Verb + Preposition* sequence was idiomatic or literal. Sentences also included a spillover region at the end. Within a particular target, sentences differed only in the *Bias* and *Resolution.* Items were designed such that (a) the *Biasing Subject* biased participants toward either a literal interpretation (lines c,d in Table 1) or an idiomatic interpretation (lines a,b) of the verb + preposition sequence, and (b) the *Resolution* resolved the sentence toward either a literal interpretation (lines b,d) or an idiomatic interpretation (lines a,c).

Table 1 also includes our three regions of interest. We were primarily interested in reading times around the critical verb and at the disambiguating noun. To account for potential spillover we opted to use three word analysis regions. The *verb region* included the critical verb, preposition and the word immediately following the preposition (typically a determiner). The *disambiguation region* included the disambiguating noun and the following two words. We also analyzed the three word region preceding the critical verb to serve as a baseline.

Fifteen comprehension questions were interspersed among the target and filler items. Five of the questions probed basic information from the beginning of the immediately preceding sentence, five from the middle, and five from the end. This was done to encourage participants to attend to all parts of the sentence.

Norming. Before conducting the main experiment, it was essential for us to evaluate our items to ensure that they behaved as expected. In particular, for our results to be valid, we needed to (a) ensure that our biases do indeed bias individuals to interpret the ambiguous string literally/idiomatically, (b) make sure that our biases are sufficiently balanced within and

Table 1
Example Stimuli

Biasing subject	Post subject		Verb	Disambiguation		Spillover	
a. The hungry waitress	who had been	working all day	dug into	the	sandwich	just after	noon on Sunday.
b. The hungry waitress	who had been	working all day	dug into	the	tomb	just after	noon on Sunday.
c. The daring archaeologist	who had been	working all day	dug into	the	sandwich	just after	noon on Sunday.
d. The daring archaeologist	who had been	working all day	dug into	the	tomb	just after	noon on Sunday.
		Pre-verb region	**Verb region**		**Disambiguation region**		

across items, and (c) examine the effect that the addition of our resolutions has on the overall plausibility/acceptability of our target sentences. Points (a) and (b) are essential to our analyses, as our experiment hinges upon the fact that our biases influence participants to interpret the ambiguous phrasal verb literally or idiomatically. Likewise, point (c) is important for our conclusions, as we must be careful to ensure that any effects that we see are not simply due to differences in the plausibility/acceptability of our stimuli. To explore these issues we conducted two web-based norming studies.

Norming Study 1: Strength of the biasing context. To address points (a) and (b), we conducted a sentence completion study over the Internet. Participants ($n = 24$) were given a set of 36 target sentences consisting of the *Biasing Subject*, *Post Subject* relative clause and *Verb + Preposition* (e.g., *The hungry waitress, who had been working all day, dug into . . .*), followed by a text box, and were asked to provide a natural-sounding completion for the sentence (e.g., *. . . the tuna sandwich*). Continuations were coded for whether the critical verb + preposition string was interpreted literally or idiomatically. Cases where the interpretation was unclear were coded as ambiguous (4.95% of responses) and were excluded from further analyses. We computed the proportion of congruent continuations for each of these items and selected the 16 most symmetrical for use in the main experiment. Further analysis and discussion will focus upon these 16 items. Table 2 displays the proportion of congruent continuations (i.e., literal continuations under literal bias, idiomatic continuations under idiomatic bias) for each of our target verb + preposition sequences. To assess these data statistically, we fit the data using a mixed-effects model (Baayen, Davidson, & Bates, 2008; Jaeger, 2008), examining the effects of Bias (Literal Bias vs. Idiom Bias) on completion type (e.g., literal or idiomatic completion), and adding random effects of Subject and Item. The analyses reveal a main effect of condition ($\beta = .64$, $t = -11.19$, $p < .001$), confirming that the biases are indeed having the intended effect. However, removing the random effect of Items results in a significant deterioration in the model fit, $\chi^2(1) = 7.36$, $p < .01$, suggesting that there are still potentially interesting differences in bias strength among our items. To help address these differences in our main experiment, we computed a Normed Bias Strength score for each item by subtracting the proportion of congruent idiom-biased trials from the proportion of congruent literal-bias trials. Thus, a positive score indicates that the given item leans toward a literal interpretation, and a negative score indicates that it leans toward an idiomatic interpretation. These values are also reported in Table 2.

In sum, the results of the first norming study verify that our biases do indeed bias participants as expected. Furthermore, we see that while our biases are reasonably balanced, there are some by-item differences in bias strength, as shown by the Normed Bias Strength scores in Table 2. In the analysis of the self-paced reading time results, we include Normed Bias Strength as a predictor in our regression models, which allows us to capture potential effects of this item-based variation.

Norming Study 2: Plausibility. As mentioned above, another potential concern is that our items may contain a confound such that target sentences in certain conditions are simply less plausible/acceptable than other conditions. To address this issue, we conducted another Internet-based norming study in which participants ($n = 17$) rated our 16 chosen target sentences (as well as 32 filler sentences) on a 5-point scale (1 = *not plausible*, 5 = *very plausible*). Participants were instructed to rate a sentence as more plausible if the situation that it describes is plausible/reasonable and to rate a sentence as less plausible if it describes an impossible or unlikely situation. We evaluated the results of this study statistically using a linear mixed-effects model. Our results show no evidence of any meaningful differences in participants' plausibility ratings across our conditions with no significant effect of Bias, Resolution, or their interaction on participants ratings (all $ps > .4$). These findings indicate that there is no consistent plausibility difference between our conditions.

Procedure for self-paced reading experiment. Participants completed four practice trials before the main experiment. We used a standard one-word moving-window self-paced reading task, where the words are initially masked with hyphens (-). Participants pressed a key to unmask the first word of the sentence, and when they were ready, pressed the key again

Table 2
Percentage of Sentence Continuations Congruent With the Expected Bias, and the Calculated Normed Bias Strength

Verb + preposition	Idiom congruent	Literal congruent	Normed bias strength
Fit in	40.00%	100.00%	0.600
Rushed into	55.56%	100.00%	0.444
Cut in	57.14%	100.00%	0.429
Dove into	71.43%	100.00%	0.286
Came into	83.33%	100.00%	0.167
Stood by	60.00%	71.43%	0.114
Drifted off	100.00%	100.00%	0.000
Flipped through	100.00%	85.71%	−0.143
Turned in	100.00%	33.33%	−0.667
Jumped on	100.00%	83.33%	−0.167
Dug into	87.50%	66.67%	−0.208
Waited on	100.00%	75.00%	−0.250
Backed down	85.71%	50.00%	−0.357
Dwelt on	100.00%	57.14%	−0.429
Ran up	100.00%	50.00%	−0.500
Eased off	100.00%	42.86%	−0.571

which re-masked the first word and unmasked the second word, and so on. Occasionally, participants were presented with a yes/no comprehension question based upon the content of the sentence in the previous trial. The experiment was implemented with E-Prime (Psychology Software Tools). Responses were recorded using a button-box.

Results

To prepare the data for analysis, we calculated the overall mean and standard deviation of the participants reaction times (using both targets and fillers) and trimmed reaction times which were more than 2 standard deviations from the overall mean. This affected 3.26% of our target data. The resulting data set was log-transformed, and all subsequent analyses were performed on the log-transformed values. Analyses were performed over three regions: the pre-verbal region, verb + preposition region, and disambiguation region (see Table 1). For each region, we performed both (a) whole-region analyses and (b) analyses for each individual word in the region. This was done because of the well-known spillover effect for self-paced reading: Effects may show up a word or two after the critical word.

Except where noted, all analyses were conducted using linear-mixed effects models. We included Bias and the metric of Normed Bias Strength from our first norming study as fixed effects. Subjects and items were included as random effects. For analyses of reading times in the disambiguation region, we also included fixed effects of Resolution, Word Length, and the interaction between Bias and Resolution. (Sentences did not differ in resolution, and our regions were almost entirely lexically identical by items before the disambiguation region, so we collapsed them for analyses of the pre-verb region and the verb region.) In all cases, we also modeled random slopes by subject for our main predictors (i.e., Bias, for the pre-verb and verb region, and both Bias and Resolution in the disambiguation region).

Reading times in the pre-verb region. Reading times for the pre-verb region—the three words immediately before the critical verb + preposition sequence, from the "Pre-Verb" chunk shown in Table 3—are shown in Figure 1. As this is before the Disambiguation region, we collapsed the Literal resolution and Idiomatic resolution conditions. Figure 1 suggests a slight speed advantage for the non-literal biasing sentences even before the onset of the verb. Table 3 shows the statistical analyses for the whole region and each of the three words (V−3, V−2, and V−1) and reveals that this is not a reliable effect. Additionally, we found no evidence of an effect of our metric of Normed Bias Strength in this region.

Reading times in the verb region. Figure 2 shows the reading times for the verb region, which is the three-word region that includes the critical verb, preposition, and the word immediately following the preposition (typically the definite determiner). As this is still before the Disambiguation region, we collapsed the Literal resolution and Idiomatic resolution conditions.

Reading times in the literally-biased condition are longer than reading times in the idiomatically-biased condition, that is, participants read the verb region faster when they are expecting an idiomatic interpretation than when they are expecting a literal interpretation. This observation is confirmed by statistical analyses: An analysis that collapses across the three words shows that the Idiomatically Biased condition is indeed read marginally faster than the Literally Biased condition (marginal effect of bias; see Table 4).

Table 3
Effects of Bias Over the Pre-Verbal Region and Over Each Word in That Region Reporting the Intercept, t Values, and p Values

Analysis region	β	*t*	*p*
Region	−.030	−1.29	.196
V−3	−.040	−1.45	.147
V−2	−.026	−0.90	.370
V−1	−.050	−1.43	.153

Note. V = verb.

Analyses of the individual words in this region fail to reveal any significant effects on either the verb (V) or the preposition (V+1) but show a marginal effect on the word following the preposition (V+2), where $p = .069$. We attribute the lack of clear effects on individual words to the fact that the phrasal verbs are very short (4.9 letters on average for the verb and 3.0 letters for the preposition), which can exacerbate spill-over effects. In any case, the finding that idiomatically biased trials are faster is already well-attested in prior work (e.g., Gibbs, 1980, 1986; Gibbs & Gonzales, 1985; Swinney & Cutler 1979) and is not crucial for the main claims we are making in this article. As with the pre-verb region, we found no evidence of an effect of our metric of Normed Bias Strength in this region.

Reading times in the disambiguation region. Figure 3 shows the word-by-word reading times for the disambiguating region, which consisted of the three-word region immediately following the verb region and signaled whether the ambiguous verb + preposition sequence was idiomatic or literal. Figure 4 shows the reading times computed for the whole disambiguation region (averaged across all three words).

The whole-region reading times (RTs; see Figure 4) show a striking asymmetry: RTs on *literally-resolving trials* (bars on the right) do not differ for [LiteralBias] versus [IdiomBias] trials—both have roughly equal RTs. However, *idiomatically-resolving trials* show a slowdown on [LiteralBias] trials relative to [IdiomBias] trials. This asymmetry can also be seen in the word-by-word reading times (see Figure 3).

The statistical results are reported in Table 5. When averaging over the full region, we find significant main effects of both bias and congruence but no bias-by-resolution interaction. Thus, idiomatically biased conditions are read faster than literally biased conditions, and congruent conditions are read faster than incongruent conditions. Analyses of the individual words reveal a significant facilitatory effect of congruence for the first and final word. We also see a marginal effect of bias on the first word and a significant effect of bias on the final word, with idiomatically-biased conditions being faster than literally-biased conditions.

With regards to the control factors in our model, we also see some effect of our Normed Bias Strength metric in the whole-

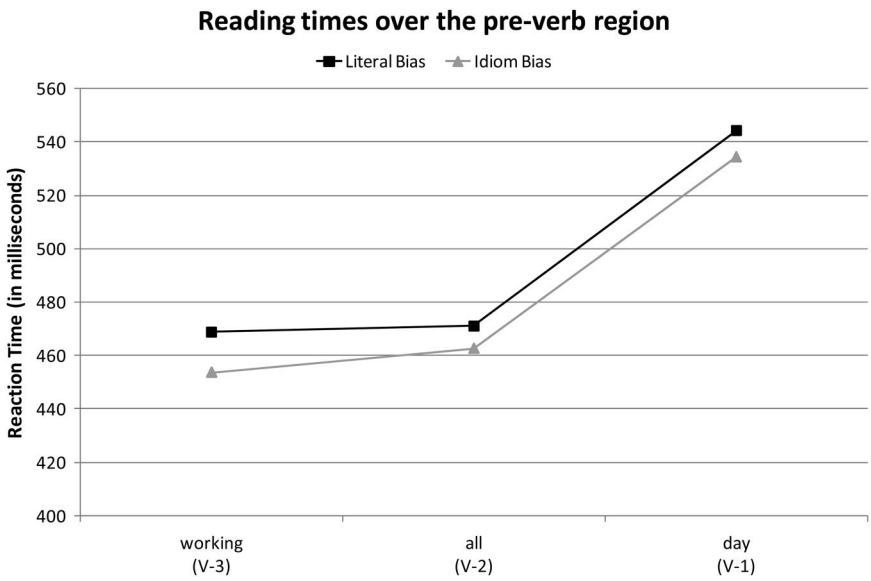

Figure 1. Reading times for literally and idiomatically biased conditions over the three-word region preceding the verb (V). Reading times for literally biased trials are represented by the dark line, whereas reading times for idiomatically biased trials are represented by the light line.

region analysis and on the final word in this region. Additionally, we found a significant or marginal effect of Word Length throughout this region (V+3: $\beta = .024$, $t = 2.92$, $p < .01$; V+4: $\beta = .017$, $t = 1.75$, $p = .08$; V+5: $\beta = .020$, $t = 2.50$, $p < .05$). Generally, these effects suggest that longer words, and target sets where the biases are asymmetric in favor of a literal interpretation, have slightly longer reaction times. While neither of these effects is crucial to our conclusions, they do justify the inclusion of Normed Bias Strength and Word Length in our model and add further support to the claim that our observed effects are due to our manipulation, rather than these factors.

To directly compare the effects of congruence on literally-biased and idiomatically-biased conditions, we computed difference scores for each resolution type by subtracting the raw reaction times for idiomatically-biased trials from the raw reaction times for literally-biased trials (averaged over the disambiguation region, computed both by subjects and by items). If the difference score is 0, this means that idiomatically-biased

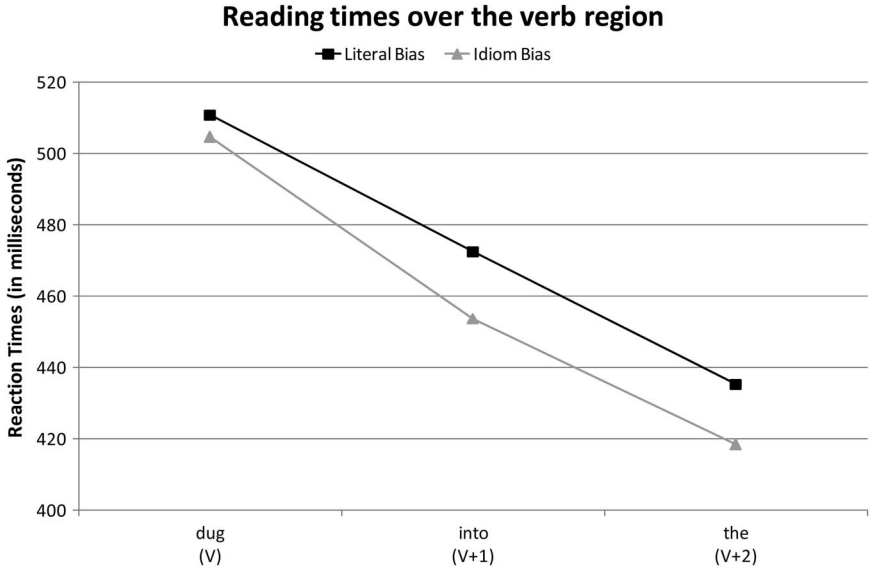

Figure 2. Reading times for literally and idiomatically biased conditions over the three-word region starting with the verb (V). Reading times for literally biased trials are represented by the dark line, whereas reading times for idiomatically biased trials are represented by the light line.

Table 4
Effects of Bias Over the Verb Region and Over Each Word in That Region

Analysis region	β	*t*	*p*
Region	−.037	−1.73	.083†
V	−.039	−1.23	.219
V+1	−.039	−1.36	.173
V+2	−.047	−1.83	.069†

Note. V = verb.
† $p < .10$.

and literally-biased trials do not differ. If the difference score is positive, this means idiomatically-biased trials are read faster than literally-biased trials. We used one-sample *t* tests to test whether the scores differ from 0. For literally-resolving trials, the difference scores do not differ from 0: Subjects, $t_1(31) = 0.625$, $p = .54$; Items, $t_2(15) = -0.01$, $p = .99$. As can be seen in Figure 4, on literally-resolving trials, the reading times for idiom-biased and literally-biased conditions are comparable. However, on idiomatically-resolving trials, the difference score is significantly above 0: Subjects, $t_1(31) = 3.87$, $p < .001$; Items, $t_2(15) = 3.03$, $p < .01$. In other words, on idiom-resolving trials, idiomatically-biased trials are read faster than literally-biased trials.

In sum, we find that when the ambiguous verb + preposition string (e.g., *dig into*) turns out to be used literally, RTs are the same regardless of whether participants were expecting a literal or an idiomatic interpretation. For idiomatically-resolving trials, however, expectations created by the biasing subject (*daring archeologist* or *hungry waitress*) do matter: When the ambiguous verb + preposition string turns out to be idiomatic, participants who were expecting a literal interpretation (literally-biased conditions) were significantly slower at the disambiguation region than participants expecting an idiomatic interpretation.

Discussion and Conclusions

The results of our self-paced reading study shows that when faced with the task of interpreting an ambiguous verb + preposition sequence (e.g., *dig into, rush into*) as literal (literally-resolving conditions), participants perform equally well regardless of whether prior contextual bias led them to expect a literal or idiomatic interpretation. However, when participants have to interpret the verb + preposition sequence idiomatically (idiom-resolving conditions), they experience reading time slowdowns when prior contextual bias had led them to expect a literal interpretation. These results suggest that contextual bias does not play a strong role in determining whether participants consider the *literal* meaning of these phrases. Regardless of bias, individuals seem readily capable of interpreting these phrases literally. Contextual bias does, however, influence whether participants consider the idiomatic interpretation, as we find that participants are much more capable of interpreting these phrases idiomatically when prior context leads them to expect an idiomatic interpretation. These findings support the hypothesis that literal interpretation is computed prior to idiom retrieval as proposed by the Hybrid Representation and Configuration Hypotheses (Cacciari & Tabossi, 1988; Cutting & Bock, 1997; Sprenger et al., 2006) and go against claims arguing that both idiomatic and literal interpretations are processed in parallel as proposed by the Lexical Representation Hypothesis (Swinney & Cutler, 1979) or that idiomatic meaning

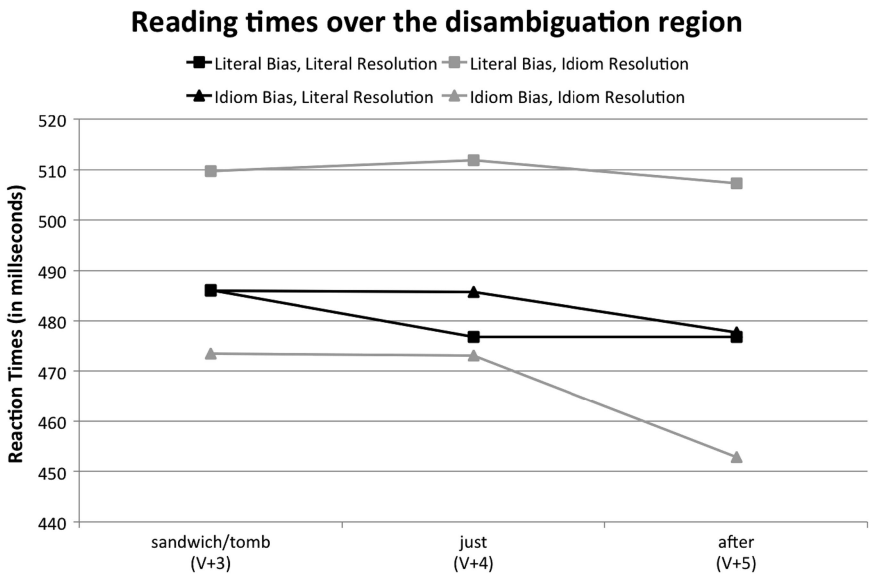

Figure 3. Reading times for literally and idiomatically biased conditions over the three-word disambiguation region. Reading times for literally biased trials are represented with squares, and reading times for idiomatically biased trials are represented with triangles. Literally resolving trials are represented with dark lines, and idiomatically resolving trials are represented with light lines. V = verb.

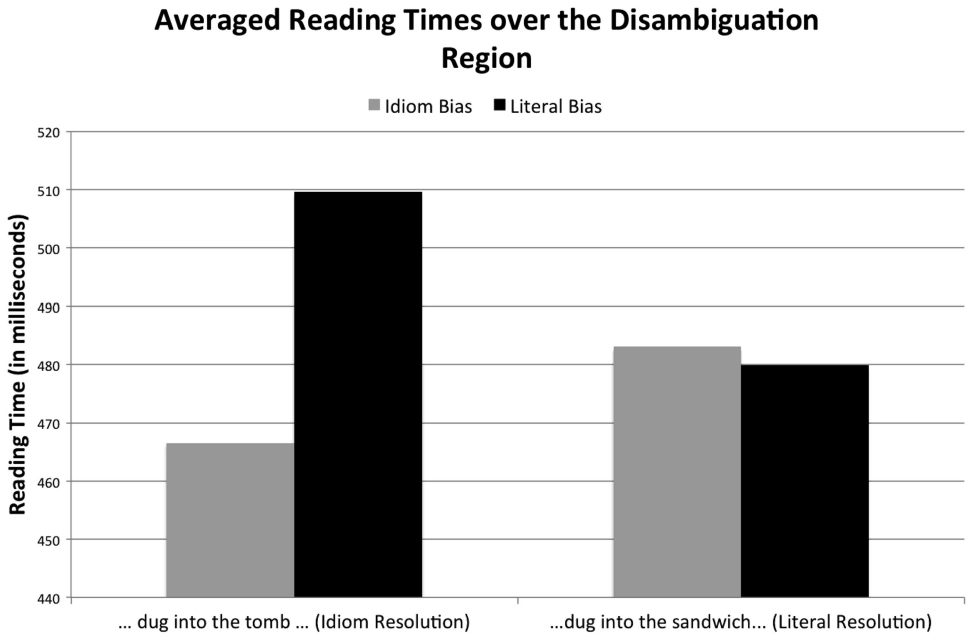

Figure 4. Reading times for the whole disambiguation region.

has priority as proposed by the Direct Access Hypothesis (Gibbs, 1980).

When assessing the meaning of this finding, it is worth keeping in mind that prior work has claimed that idiomatic strings are easier/faster to process that literal strings (e.g., Swinney & Cutler, 1979). Our findings show that the picture is actually more complex: Idiomatic retrieval suffers if not accompanied by the right kind of contextual support (see also Cacciari & Tabossi, 1988; Fanari, Cacciari, & Tabossi, 2010) and corroborates similar findings using full idioms (e.g., *kick the bucket*) in the visual world eye-tracking paradigm (Holsinger & Kaiser, 2010, 2012). In essence, it would be an oversimplification to claim that idiomatic expressions are consistently easier to process than literal expressions.

Table 5
Effects of Bias, Congruency, and Their Interaction, and Our Norming Metric of Bias Strength Over the Disambiguation Region and Over Each Word in That Region

Analysis region	β	*t*	*p*
Region			
Bias	−.066	−2.83	.005**
Congruence	.063	2.69	.007**
Bias × Congruence	−.028	−0.61	.543
Normed strength	.084	1.81	.070†
V+3			
Bias	−.067	−2.28	.023*
Congruence	.062	1.80	.072†
Bias × Congruence	.019	0.31	.756
Normed strength	−.009	−0.16	.876
V+4			
Bias	−.031	−1.05	.293
Congruence	.061	2.17	.030*
Bias × Congruence	−.016	−0.03	.766
Normed strength	.051	0.96	.336
V+5			
Bias	−.066	−2.09	.037*
Congruence	.065	2.29	.023*
Bias × Congruence	−.040	−0.72	.472
Normed strength	.135	2.37	.018*

Note. V = verb.
† $p < .10$. * $p < .05$. ** $p < .01$.

The asymmetrical cost of revising one's expectations can be explained by assuming that the literal representation of ambiguous strings like "dig into" is either automatically active or quickly recoverable. This behavior is predicted under both the *Configuration Hypothesis* (Cacciari & Tabossi, 1988) and the *Hybrid Representation Hypothesis* (Cutting & Bock, 1997; Sprenger et al., 2006) of idiom representation. For the Configuration Hypothesis, some processing of literal meaning occurs prior to idiom recognition. For the Hybrid Representation Hypothesis, access to the idiomatic expression is dependent upon activation of the literal lemmas and, by spreading activation, their literal representation.

While both the Configuration Hypothesis and the Hybrid Representation Hypothesis claim that literal activation is at least partially obligatory, neither claim that idiomatic access is obligatory. Thus, given sufficient contextual bias, it is possible that the comprehension system simply fails to activate the necessary idiomatic interpretation. If this idiomatic meaning then turns out to be necessary to construct a valid sentential interpretation, then it must be retrieved after the fact, and this contributes to the slowdown that we observed. Crucially, these results are not predicted by either the Direct Access hypothesis (Gibbs, 1980, 1985) or by parallel processing accounts such as the Lexical Representation Hypothesis (Swinney & Cutler, 1979).

These findings draw an interesting parallel to lexical constraint-based models of sentence comprehension (see

MacDonald et al., 1994; Trueswell et al., 1994). In these models, purely lexical information, such as the frequency of participial use of a verb, interacts with contextual information in the process of syntactic ambiguity resolution. Experiments examining this interaction observe a reduction or elimination of metrics of processing difficulty (such as reading time) when contextual and lexical factors point in the same direction, but no such reduction when they are incongruent (see, e.g., Trueswell, 1996). On the surface, this behavior is very similar to the asymmetrical behavior observed in this study. We observed that contextual congruence was not relevant when the verb + preposition target was literal but had a large impact when the verb + preposition was idiomatic.

Whether these results can be explained by this framework remains to be seen, however. To explain our results in this framework, we would expect literal usage to be more frequent than idiomatic usage for our items. This seems unlikely, particularly as care was taken in norming to select phrasal verbs which were equibiased between a literal and idiomatic interpretation. It is possible, however, that the frequency that individual words are used in idiomatic phrasal verbs may play a role. The items used in this study, however, are not optimal for testing this hypothesis, so we leave this question to further work.

Thus, these results support the views of idiom representation and processing proposed by the Hybrid Representation Hypothesis and the Configuration Hypothesis. The current data, however, do not allow us to easily decide between these two distinct models. We could possibly interpret these effects as arising due to the asymmetrical extent of network activation involved in the activation and comprehension of the literal interpretation (e.g., literal lemmas; their grammatical, conceptual, and structural properties) which is necessarily more distributed than the activation necessary for the idiomatic expression (the super-lemma and its conceptual meaning). If this view is correct, then the asymmetrical results obtained here and in the literature could possibly be attributed to this representational asymmetry, with idioms being faster to activate but also easier to suppress/inhibit as a result of their smaller activation footprint.

Under the Configuration Hypothesis, we could explain these data by proposing that the literal/idiomatic asymmetry arises because (a) participants obligatorily do some amount of work toward the literal interpretation and (b) the speed of idiomatic meaning retrieval is highly sensitive to contextual influences. Point (a) explains why we do not see significant differences in literally resolving sentences, as participants have some amount of literal processing to fall back on. Likewise, point (b) would explain the disruption we see in idiomatically resolving sentences, as we know that contextual support and other expectation-based factors (see, e.g., Fanari et al., 2010) play a strong role in the speed of idiom retrieval. However, as mentioned earlier, these data do not allow us to clearly distinguish between these models, and we leave this for future work.

Generally, our results support a priority of literal computation during the processing of idioms and demonstrate that simple contextual cues, in our case the meaning of the sentential subject, are sufficient to bias individuals real-time processing of expressions which are ambiguous between a literal and an idiomatic sense. We argue that during comprehension, individuals compute literal interpretations by default, but access to idiomatic interpretations are heavily driven by contextual factors. Future work will further explore the factors influencing access to idiomatic interpretations and will more closely examine the compatibility and differences in predictions between the lexical representations proposed by the Hybrid Representation Hypothesis and the comprehension processes proposed by the Configuration Hypothesis.

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Appendix A

Target Stimuli for Experiment 2

The sentences shown in (a) and (b) are the Idiomatically Biased conditions, and the sentences shown in (c) and (d) are the Literally Biased conditions. The sentences in (a) and (d) are Idiomatically Resolving, and the sentences in (b) and (c) are Literally Resolving.

(1a) The awkward geek, who was very thin, fit in at the society without any difficulties.

(1b) The awkward geek, who was very thin, fit in the hole without any difficulties.

(1c) The tiny contortionist, who was very thin, fit in the hole without any difficulties.

(1d) The tiny contortionist, who was very thin, fit in at the society without any difficulties.

(2a) The foolish entrepreneur, who liked living on the edge, rushed into the decision without a second thought.

(2b) The foolish entrepreneur, who liked living on the edge, rushed into the building without a second thought.

(2c) The brave fireman, who liked living on the edge, rushed into the building without a second thought.

(2d) The brave fireman, who liked living on the edge, rushed into the decision without a second thought.

(3a) The jealous boyfriend, who had stayed up very late, cut in halfway through the dance after getting a drink from the soda machine.

(3b) The jealous boyfriend, who had stayed up very late, cut in the cutting room after getting a drink from the soda machine.

(3c) The talented seamstress, who had stayed up very late, cut in the cutting room after getting a drink from the soda machine.

(3d) The talented seamstress, who had stayed up very late, cut in halfway through the dance after getting a drink from the soda machine.

(4a) The bored intellectual, who had won many contests, dove into the crossword almost immediately.

(4b) The bored intellectual, who had won many contests, dove into the pool almost immediately.

(4c) The muscular swimmer, who had won many contests, dove into the pool almost immediately.

(4d) The muscular swimmer, who had won many contests, dove into the crossword almost immediately.

(5a) The spoiled heir, who was very worried, came into a fortune late last Thursday.

(5b) The spoiled heir, who was very worried, came into a room late last Thursday.

(5c) The late employee, who was very worried, came into a room late last Thursday.

(5d) The late employee, who was very worried, came into a fortune late last Thursday.

(6a) The stubborn father, who was a strict vegetarian, stood by his decision despite other suggestions.

(6b) The stubborn father, who was a strict vegetarian, stood by the tree despite other suggestions.

(6c) The attractive model, who was a strict vegetarian, stood by the tree despite other suggestions.

(6d) The attractive model, who was a strict vegetarian, stood by his decision despite other suggestions.

(7a) The bored student, who hadn't slept properly the night before, drifted off during the lecture despite drinking a cup of coffee earlier in the day.

(7b) The bored student, who hadn't slept properly the night before, drifted off the road despite drinking a cup of coffee earlier in the day.

(7c) The tired driver, who hadn't slept properly the night before, drifted off the road despite drinking a cup of coffee earlier in the day.

(7d) The tired driver, who hadn't slept properly the night before, drifted off during the lecture despite drinking a cup of coffee earlier in the day.

(8a) The bored security guard, who was very strong for his size, flipped through the magazine to make the time go by faster on his lunch break.

(8b) The bored security guard, who was very strong for his size, flipped through the hoop to make the time go by faster on his lunch break.

(8c) The skilled acrobat, who was very strong for his size, flipped through the hoop to make the time go by faster on his lunch break.

(8d) The skilled acrobat, who was very strong for his size, flipped through the magazine to make the time go by faster on his lunch break.

(*Appendix continues*)

(9a) The clever entrepreneur, who made a lot of money, jumped on the opportunity and was rewarded with a large sum.

(9b) The clever entrepreneur, who made a lot of money, jumped on the moving train and was rewarded with a large sum.

(9c) The daring stuntman, who made a lot of money, jumped on the moving train and was rewarded with a large sum.

(9d) The daring stuntman, who made a lot of money, jumped on the opportunity and was rewarded with a large sum.

(10a) The hungry waitress, who had been working all day, dug into a sandwich just after noon on Sunday.

(10b) The hungry waitress, who had been working all day, dug into a tomb just after noon on Sunday.

(10c) The daring archaeologist, who had been working all day, dug into a tomb just after noon on Sunday.

(10d) The daring archaeologist, who had been working all day, dug into a sandwich just after noon on Sunday.

(11a) The loveable waitress, who was saving up for a car, waited on a customer on a sunny Thursday afternoon.

(11b) The loveable waitress, who was saving up for a car, waited on the bench on a sunny Thursday afternoon.

(11c) The impatient commuter, who was saving up for a car, waited on the bench on a sunny Thursday afternoon.

(11d) The impatient commuter, who was saving up for a car, waited on a customer on a sunny Thursday afternoon.

(12a) The argumentative philosopher, who was wearing a brown jacket, backed down from the argument and admitted that he had made a mistake.

(12b) The argumentative philosopher, who was wearing a brown jacket, backed down the corridor and admitted that he had made a mistake.

(12c) The frightened explorer, who was wearing a brown jacket, backed down the corridor and admitted that he had made a mistake.

(12d) The frightened explorer, who was wearing a brown jacket, backed down from the argument and admitted that he had made a mistake.

(13a) The disappointed athlete, who wanted to be left alone, dwelt on the defeat for many years.

(13b) The disappointed athlete, who wanted to be left alone, dwelt on the mountain for many years.

(13c) The old hermit, who wanted to be left alone, dwelt on the mountain for many years.

(13d) The old hermit, who wanted to be left alone, dwelt on the defeat for many years.

(14a) The spoiled bride, whose husband was in the army, ran up the bill without paying much attention.

(14b) The spoiled bride, whose husband was in the army, ran up the stairs without paying much attention.

(14c) The worried mother, whose husband was in the army, ran up the stairs without paying much attention.

(14d) The worried mother, whose husband was in the army, ran up the bill without paying much attention.

(15a) The understanding professor, who wanted to enjoy himself over spring break, eased off the workload as he didn't want to end up exhausted.

(15b) The understanding professor, who wanted to enjoy himself over spring break, eased off the ledge as he didn't want to end up exhausted.

(15c) The cautious mountain climber, who wanted to enjoy himself over spring break, eased off the ledge as he didn't want to end up exhausted.

(15d) The cautious mountain climber, who wanted to enjoy himself over spring break, eased off the workload as he didn't want to end up exhausted.

(16a) The excellent student, who worked very hard, turned in the assignment and then left the room.

(16b) The excellent student, who worked very hard, turned in the doorway and then left the room.

(16c) The graceful ballerina, who worked very hard, turned in the doorway and then left the room.

(16d) The graceful ballerina, who worked very hard, turned in the assignment and then left the room.

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