"A Cruel King" Is Not the Same as "A King Who Is Cruel": Modifier Position Affects How Words Are Encoded and Retrieved From Memory

Article *in* Journal of Experimental Psychology Learning Memory and Cognition · March 2019

DOI: 10.1037/xlm0000694

CITATIONS
0

READS
63

3 authors, including:

Hossein Karimi
University of California, Davis
9 PUBLICATIONS **118** CITATIONS

SEE PROFILE

Journal of Experimental Psychology: Learning, Memory, and Cognition

“A Cruel King” Is Not the Same as “A King Who Is Cruel”: Modifier Position Affects How Words Are Encoded and Retrieved From Memory

Hossein Karimi, Michele Diaz, and Fernanda Ferreira

Online First Publication, March 18, 2019. http://dx.doi.org/10.1037/xlm0000694

American Psychological Association

Journal of Experimental Psychology:
Learning, Memory, and Cognition

0278-7393/19/$12.00

http://dx.doi.org/10.1037/xlm0000694

"A Cruel King" Is Not the Same as "A King Who Is Cruel": Modifier Position Affects How Words Are Encoded and Retrieved From Memory

Hossein Karimi and Michele Diaz
Pennsylvania State University

Fernanda Ferreira
University of California, Davis

We examined whether the position of modifiers in English influences how words are encoded and subsequently retrieved from memory. Compared with premodifiers, postmodifiers might confer more perceptual significance to the associated head nouns, are more consistent with the "given-before-new" information structure, and might also be easier to integrate because the head noun is available before the modifications are encountered. In 4 experiments, we investigated whether premodified (*the cruel and merciless king*), and postmodified (*the king who was cruel and merciless*) noun phrases (henceforth, NPs) could induce variations in ease of subsequent retrieval. In Experiments 1, 2, and 3, participants used more pronouns (*he*), as opposed to full descriptions (*the king*) to refer to postmodified NPs than to unmodified competitors, but pronominal reference to premodified NPs and unmodified competitors did not differ, suggesting that postmodified NPs are more accessible in memory. When the data from all 3 experiments were combined, we also observed significantly more pronominal reference to post- than to premodified NPs, as well as a greater increase in pronominal reference rates between postmodified NPs and unmodified competitors than between premodified NPs and unmodified competitors. In Experiment 4, words following critical pronouns were read faster when the pronouns referred to modified than to unmodified NPs, and also when the pronouns referred to post- rather than premodified NPs. Taken together, our results show enhanced retrieval facilitation for postmodified NPs compared with premodified NPs. These results are the first to demonstrate that the linear position of modifications results in measurable processing cost at a subsequent point. The results have important implications for memory-based theories of language processing, and also for theories assigning a central role for discourse status and information structure during sentence processing.

Keywords: semantic richness, modifier position, encoding, retrieval, referential processing

Language processing involves encoding words, maintaining them in memory, and retrieving them at subsequent points when necessary. For instance, when processing *The man drank the juice because he was thirsty*, memory representations for *the man*, *juice* and other words are created and maintained in memory, and when a retrieval trigger such as *he* is encountered, the associated representation (i.e., the man) is retrieved from memory to support successful formation of the referential dependency between the pronoun (*he*) and its "referent" (i.e., *the man,* Cook, 2014; Dell, McKoon, & Ratcliff, 1983; Gernsbacher, 1989; Gerrig & McKoon, 1998; Lucas, Tanenhaus, & Carlson, 1990; MacDonald & MacWhinney, 1990; Sanford & Garrod, 1989, 2005). A property of most pronouns is that they do not contain much semantic content and therefore the retrieval of the associated representation helps create a coherent discourse representation via the anaphoric link. It is important to clarify that while we talk about pronouns as referring to preceding associated NPs for the sake of simplicity, the reader should bear in mind that an NP itself is a referring expression in the sense that it necessarily refers to a real-world entity or an entity in the interlocutor's mental model. In this sense, pronouns do not actually refer to the surface NP they are associated with, but rather to the entity that the NP refers to.

Previous research has demonstrated that semantically enriching an NP by adding modifying information to it facilitates the subsequent retrieval of that NP from memory. Specifically, prior research has shown that a word is processed more easily if it triggers the retrieval of a modified NP compared with when it requires the retrieval of an unmodified NP. Interestingly, English allows NPs to be both pre- and postmodified and previous studies have employed both modification types to investigate the effect of semantic richness on subsequent retrieval. For instance, using premodifiers, Hofmeister (2011) showed that semantically richer NPs such as *an alleged Venezuelan communist* result in faster reading times relative to unmodified NPs such as *a communist*, when a subsequent verb (e.g., *banned* in . . . *who the members of the club banned*) triggers the retrieval of the memory representation of the target noun (i.e., *communist*, also see Hofmeister & Vasishth, 2014). Similarly, using postmodifiers, Karimi and Ferreira (2016b) demonstrated that ambiguous pronouns tend to be

Hossein Karimi and Michele Diaz, Department of Psychology, Pennsylvania State University; Fernanda Ferreira, Department of Psychology, University of California, Davis.

Correspondence concerning this article should be addressed to Hossein Karimi, Department of Psychology, Pennsylvania State University, 140 Moore Building, University Park, PA. E-mail: karimi@psu.edu

interpreted as referring to semantically richer NPs such as *the actor who was frustrated and upset* compared to unmodified NPs (i.e., *the actor*). These results have been interpreted as reflecting higher memory activation (i.e., higher accessibility[1]) for the memory representation associated with richer NPs (e.g., Ariel, 1990; Fletcher, 1984; Gernsbacher & Hargreaves, 1988; Givón, 1983; Gundel, Hedberg, & Zacharski, 1993; Lewis & Vasishth, 2005; Lewis, Vasishth, & Van Dyke, 2006). In other words, semantically richer words seem to result in more robust encoding, which then leads to easier retrieval later in the discourse. Interestingly, the effect of modification is not restricted to language comprehension: Karimi, Fukumura, Ferreira, and Pickering (2014) showed that compared with unmodified NPs, postmodified NPs are more likely to be subsequently referred to with pronouns (*he*) than with repeated nouns (*the actor*), which is in line with previous research showing that pronouns (and attenuated referring expressions, in general) reflect higher accessibility for the associated memory representation (Arnold, 2001; Brennan, 1995; Fukumura & Van Gompel, 2010, 2011; Stevenson, Crawley, & Kleinman, 1994). Thus, semantic richness has been shown to lead to easier subsequent retrieval during both language production and language comprehension.

An important question that remains unanswered regarding the semantic richness effect is whether the position of modifiers affects how modified NPs are encoded and later retrieved from memory. Languages sometimes provide their speakers with choices as to how to encode a message. For example, a message could be delivered through an active syntactic form (*The man drank the juice*) or a passive form (*The juice was drunk by the man*); a previously mentioned noun phrase such as *the man* could subsequently be referred to with a pronoun (*he*) or with a repeated noun (*the man*); a complementizer such as *that* could be mentioned (*I think that the man is thirsty*), or be left out from a sentence (*I think the man is thirsty*), and so on and so forth. Importantly, most, if not all, of these alternative forms result in measurable variations in processing cost, and numerous psycholinguistic studies have investigated the processing costs of these alternative forms. For instance, passive sentences have been shown to be more difficult to process than active sentences (e.g., Bock & Warren, 1985; Ferreira, 2003; see Chomsky, 1986, 1993, 1995); repeated referring expressions result in more processing difficulty than a pronoun when they refer to highly activated NPs (e.g., Almor, 1999; Gordon, Grosz, & Gilliom, 1993), and not realizing the optional complementizer *that* for less predictable predicates has been shown to lead to processing difficulty (e.g., Ferreira, & Henderson, 1990; Trueswell, Tanenhaus, & Kello, 1993; also see Jaeger, 2010). To the best of our knowledge, the potential processing consequences of the choice between premodified and postmodified NPs (e.g., *the red car* vs. *the car that's red*) have not been investigated. As mentioned above, English allows both types of modifications and thus provides an opportunity to investigate this question within the same language.

Motivation and Predictions

We expected modifier position to affect subsequent retrieval based on previous research showing that syntactic information (such as subjecthood, c-command, etc.) can restrict the search space for retrieval candidates, thereby reducing interference (e.g., Arnett & Wagers, 2017; Dillon, 2011; Dillon et al., 2014; Kush, 2013; Parker, Shvartsman, & Van Dyke, 2017; Van Dyke & McElree, 2011). Moreover, previous research has demonstrated that the production of pre- and postmodified NPs may depend on how efficiently the modifying information can constrain the potential referent on a visual display ((Rubio-Fernández, 2016). If syntactic constraints can influence retrieval, and if the choice between pre- and postmodifying information can influence communication efficiency, it is conceivable that the syntactic choice between pre- and postmodifiers might also influence how NPs are encoded and subsequently retrieved.

There are three possible outcomes: (a) premodified NPs are more robustly encoded in memory than postmodified NPs, (b) postmodified NPs are more robustly encoded than premodified NPs, and (c) pre- and postmodified NPs do not differ in encoding efficiency. Interestingly, all three possibilities receive support from the current psycholinguistic literature.

Premodified NPs might be encoded more efficiently than postmodified NPs because the head of a premodified NP is relatively less susceptible to time-based decay. Memory representations are assumed to decay over time, and their susceptibility to decay increases with the temporal distance between when they are encoded, and when they are retrieved (Baddeley, 2000; Chomsky, 1965; Gibson, 1998; Lewis & Vasishth, 2005; Lewis et al., 2006; Van Dyke & Lewis, 2003). Because postmodifiers, but not premodifiers, necessarily add more temporal distance between the head noun and the subsequent retrieval site, the memory representation of the head noun is more likely to decay (i.e., lose activation strength) when it is postmodified than when it is premodified.

Another reason why premodified NPs could be encoded more strongly in memory than postmodified NPs is because premodifiers might narrow down the number of possible upcoming head nouns (i.e., reduce the entropy or uncertainty about the head noun), thereby rendering the head noun more predictable (Hale, 2001, 2006; Levy, 2008; note that even if the lexical identity of the upcoming head noun is not predictable, the head of a premodified NP is still relatively more predictable than the head of a postmodified NP). This predictability might lead to preactivation of the features of the upcoming head noun and also to an active maintenance of those features in memory, which might in turn facilitate encoding (of the head noun itself as well as the integration of modifying information) when the head noun is eventually encountered. Because the head noun is revealed before the modifying information in the case of postmodified NPs, such preactivation and/or active maintenance is unavailable for postmodified NPs, potentially rendering them more vulnerable to decay. In fact, predictability of upcoming information plays a central role in one of the main explanations proposed to account for the observation that semantically rich NPs facilitate subsequent retrieval. Under this account, known as *head-reactivation*, predictable information is preactivated and then becomes reactivated as the modifying words are being encoded into memory (Hofmeister, 2011; Lewis & Vasishth, 2005; Lewis et al., 2006). This reactivation has been argued to facilitate the incorporation of the extra semantic content

[1] In this study, we use the terms "accessibility" and "retrieval ease" interchangeably, and both terms refer to how easily a previously encoded representation could be re-accessed or retrieved from memory.

with the head noun, and also to prevent the decay of the head noun's memory representation due to passage of time (Lewis & Vasishth, 2005; Lewis et al., 2006). For example, based on the head-reactivation account, premodifiers result in higher activation for the head noun because the syntactic category of the head (i.e., "noun") is preactivated when the modifying words are encountered and becomes reactivated with each premodifying word,[2] giving the memory representation of the syntactic category multiple activation boosts, and leading to higher ultimate activation of the head noun compared to unmodified NPs. For instance, when encoding a premodified NP such as *the frustrated and visibly upset actor*, the syntactic category "noun" is preactivated as soon as *the frustrated* is encountered, because a "noun" syntactic category is highly predictable given *the frustrated* (note that other features such as "+human" etc. could also be predicted and preactivated). Importantly, the memory representation associated with the syntactic "noun" category becomes reactivated with each modifying word, preventing it from decay and facilitating the integration of the modifying words with the head noun. As a result, when the head noun is finally revealed, it enjoys a higher level of activation than it would have if the noun were not premodified. Also, note that because preactivation of the head facilitates the incorporation of dependent semantic content (i.e., the modifying information), this mechanism may boost semantic richness as well.

However, some other findings predict a more robust encoding, and therefore an easier subsequent retrieval, for post- than premodified NPs. For instance, Dillon, Clifton, Sloggett, and Frazier (2017) demonstrated that "at-issue" linguistic content causes more interference during the retrieval of a target item than "not-at-issue" content, suggesting that at-issue information is encoded more robustly in memory. Specifically, Dillon et al. (2017) showed that restrictive relative clauses embedded in a main clause (e.g., *The butcher asked who the lady who bought Italian ham was cooking dinner for*) produce more interference during the subsequent retrieval of the displaced target NP (i.e., "butcher") than do nonrestrictive clauses containing the same information (*The butcher asked who the lady, who bought Italian ham, was cooking dinner for*). Dillon et al.'s (2017) results are particularly interesting because they show that comprehenders' perception of the same information might differ based on the discourse status of that information, and that such perceptual variation can influence memory encoding (also see Dillon, Clifton, & Frazier, 2014).

Based on these results, we hypothesize that there might be greater perceptual significance associated with post- than with premodified NPs. We argue that this is because, in English, the contents of postmodifying relative clauses tend to be generally more complex than those of premodifying adjectives. For example, the more information contained in a modification, the more likely it is to be conveyed with a postmodifying relative clause than with premodifying adjectives ("The very thirsty, terribly hungry, and deeply agitated man" vs. "The man who was very thirsty, terribly hungry, and deeply agitated"). Similarly, postmodifying relative clauses are more variable in content: They might include active clauses ("The man who is wearing glasses"), passive clauses ("The man who was shot"), clauses containing another NP ("The man who kissed the woman"), and so forth. Moreover, postmodifying relative clauses are more likely to carry more specific information. For instance, although "The thirsty man" and "The man who was thirsty" form acceptable NPs, "The man who was thirsty since morning" forms a grammatical noun phrase, but "The thirsty since morning man" does not. As such, language users might have implicitly learned (through repeated exposure) that postmodifying information is more strongly associated with more complex information, and might therefore allocate more attentional and/or memory resources to them during encoding. As such, just like restrictive clauses, postmodifying relative clauses might be *perceived* as conveying relatively more important (i.e., "at-issue") information than premodifying adjectives, even though they might not *actually* carry information that is more important to the current discourse. Nonetheless, this perceived importance might lead to more robust encoding and therefore easier subsequent retrieval of post- than premodified NPs. Yet another reason why postmodified NPs might enjoy a greater perceptual salience in memory might be that they already contain a relative pronoun (i.e., who) which might boost the perceptual topicality of the head noun (see Hemforth, Konieczny, & Scheepers, 2000).

A second source of support for the expectation of more efficient encoding of postmodifiers relative to premodifiers comes from the information structure of the two modification types. Specifically, some theories and findings suggest that language processing is easier when "given" (i.e., presupposed) information precedes "new" (i.e., focused) information (e.g., Ariel, 1990, 1991, 1996; Benatar & Clifton, 2014; Chafe, 1976; Clark & Clark, 1978; Gundel, 1978, 1988; Halliday, 1967; Haviland & Clark, 1974). Note that there two type of "givenness" in the literature and it is important to clarify the distinction between them. *Referential* givenness involves reference to an entity in the real world (or in the discourse model) via a linguistic expression (such as "the man"). *Relational* givenness, on the other hand, involves how information is partitioned into what a sentence/phrase is about, namely the *topic*, and what is predicated about the topic, namely the *predicate*. The topic is "given" in relation to predicate in the sense that it is independent, and outside the scope of the predicate, and the predicate is "new" in relation to the topic in the sense that it is new information that is asserted, questioned, and so forth about the topic (see Gundel, 1988; Gundel & Fretheim, 2004). Note also that *relational* givenness corresponds to the distinctions between *presupposition* and *focus* (e.g., Chomsky, 1971; Jackendoff, 1972), *topic* and *comment* (e.g., Gundel, 1978), and *theme* and *rheme* (e.g., Vallduví & Vilkuna, 1998).

Crucially, a head noun could be argued to be *relationally* (but not referentially) "given" with respect to modifying information. This is because the head noun is what the whole NP is about and the modification predicates extra information about the head noun. Consequently, postmodified NPs could be argued to be consistent with the given-before-new principle because the head noun (i.e., the given information) precedes new information (i.e., the modification), whereas premodified NPs are not consistent with the given-before-new information structure because the head noun follows the modification. As such, postmodified NPs might be easier to process, integrate, and encode in memory, which in turn may facilitate their retrieval. It is important to mention that from a *referential* perspective, a modified NP may actually be interpreted as conveying new information regardless of modifier position, and

[2] Under some versions of the memory-based retrieval theories, a reactivation is considered a retrieval (see Anderson et al., 2004).

an unmodified NP could be taken as conveying given information. This is because the reason additional information is needed in the first place could be that the referent of a modified NP is not unique enough, hence requiring extra information for clarification. However, note that our critical focus here is between pre- and postmodified NPs and not between pre- or postmodified versus unmodified NPs. Both pre- and postmodified NPs carry extra information, rendering their referential status the same. Crucially, however, the information contained in postmodified NPs proceeds from the topical (i.e., relationally "given") head noun toward supplementary material (i.e., the predicate, or "new" information), whereas the information structure for premodifiers follows the reverse order (i.e., from predicate/supplementary to topical information).

A third reason why we might expect a more robust encoding of post- versus premodifying information pertains to the different memory demands associated with processing these two types of modifications. In the foregoing, we argued that active maintenance of the preactivated features of the head noun might give an encoding advantage to premodified NPs. However, it is also possible that such maintenance might tax memory resources and actually complicate encoding. Specifically, and as mentioned above, premodifiers need to be maintained in memory until the head noun is encountered, which delays integration. However, no such maintenance is necessary for postmodifiers because the modifying information follows the head noun, and integration can take place immediately. As such, premodified NPs might incur a "maintenance cost," which has been shown to tax memory resources (Wagers & Phillips, 2014).[3]

Finally, no difference in the encoding of pre- and postmodifiers is predicted by the *distinctiveness* account for the effect of semantic richness on subsequent retrieval. Based on this account, semantically richer NPs result in the creation of memory representations that are more distinct compared with unmodified NPs. As such, there is less interference from other items in memory during the retrieval of semantically richer NPs (Gallo, Meadow, Johnson, & Foster, 2008; Hofmeister & Vasishth, 2014; Jacoby, & Craik, 1979; Nairne, 2006). Importantly, if the modifying information is kept constant, both pre- and postmodified NPs should be equally distinct in memory, resulting in no variation in encoding efficiently and therefore later retrieval.

Thus, to contribute to the current literature on how semantically rich concepts are encoded and retrieved from memory, we investigated whether there are processing costs associated with the choice between premodifying and postmodifying a noun within an NP. Specifically, we investigated whether the subsequent retrieval ease of the memory representations associated with pre- and postmodified NPs differ from each other. Moreover, given the variety of predictions in the current literature, the results of this study also advances our understanding of the role of perceptual, information structure and memory factors during the encoding of words.

The Present Study

To answer our questions, we capitalized on the flexibility of English with regard to the position of modifiers. As mentioned above, English allows modifiers to either precede a noun (*the cruel and merciless king*), or to follow it (*the king who was cruel and merciless*). Thus, if the retrieval ease of pre- and postmodifiers differ, we can observe these effects within the same language. In this study, we conducted four experiments to investigate whether pre- and postmodified NPs differ in terms of how easily they can be retrieved from memory. In Experiments 1, 2, and 3, we measured the potential effect of modifier position on the retrieval ease of associated NPs during language production. In Experiments 4, we investigated this same question during language comprehension.

Experiment 1

In this experiment, we took advantage of the well-established finding that relatively more accessible (i.e., easily retrievable) NPs are subsequently referred to with more attenuated referring expressions such as pronouns (e.g., *he*), whereas less accessible NPs are usually subsequently referred to with less attenuated referring expressions such as repeated nouns (e.g., *the king*). For example, syntactic subjects, animate NPs, and modified (i.e., semantically richer) NPs have been shown to be more likely to be subsequently pronominalized compared with syntactic objects, inanimate NPs, and unmodified (i.e., semantically less rich) NPs, respectively (syntactic subject vs. object: Arnold, 2001; Brennan, 1995; Fletcher, 1984; Fukumura & Van Gompel, 2010, 2011; Stevenson et al., 1994; animate versus inanimate: Fukumura & Van Gompel, 2011; modified versus unmodified: Karimi et al., 2014). Because syntactic subjecthood, animacy, and semantic richness have all been shown to boost the accessibility of associated NPs (subjecthood: Brennan, 1995; Brennan, Friedman, & Pollard, 1987; Gordon et al., 1993; Grosz, Joshi, & Weinstein, 1995; animacy: Bock, 1982; Bock & Warren, 1985; Branigan, Pickering, & Tanaka, 2008; Rosenbach, 2008, semantic richness: Hofmeister, 2011; Karimi & Ferreira, 2016b; Troyer, Hofmeister, & Kutas, 2016), these results suggest that NPs that are more accessible in memory tend to be later realized with pronouns rather than repeated nouns. However, the potential effect of linear placement of the semantic modification has not yet been examined. The prediction from these findings for the present experiment is straightforward: If modifier position affects the accessibility of associated NPs, we should observe reliable variations in pronominal reference to pre- versus postmodified NPs, with the modification type that results in more accessibility, leading to more pronominal reference to the associated NP. To test this hypothesis, we created experimental stimuli such as those illustrated in Table 1 in which one of two NPs was either premodified (1b–c), postmodified (1d–e), or unmodified, which constituted the baseline condition (1a).

In all experimental sentences, one NP was always mentioned first (i.e., NP1, *king*), and the other NP was always mentioned second (i.e., NP2, *prince*). In the baseline condition (1a), the two NPs were unmodified. In the other four conditions (1b–e), either NP1 or NP2 was either pre- or postmodified. Because it is possible that semantic richness on the part of the modified NP (*king*) might

[3] It might be argued that a fourth reason why postmodifiers might facilitate subsequent retrieval is that post-modifying relative clauses result in more *syntactically* complex structures relative to premodifying adjectives (at least in English), and might therefore simply elicit greater processing effort at encoding. Although this is a logical possibility, we do not discuss it further in the present article because previous research has already shown that processing effort at encoding does not determine ease of subsequent retrieval (Hofmeister, 2011).

Table 1
Sample Experimental Stimuli (Experiment 1)

Modifier position	Order of NPs	Example
a) Baseline	Baseline	The king criticized the prince.
b) Premodified	Target-Competitor	The cruel and merciless $king_{target}$ criticized the $prince_{competitor}$.
c) Premodified	Competitor-Target	The $king_{competitor}$ criticized the cruel and merciless $prince_{target}$.
d) Postmodified	Target-Competitor	The $king_{target}$ who was cruel and merciless criticized the $prince_{competitor}$.
e) Postmodified	Competitor-Target	The $king_{competitor}$ criticized the $prince_{target}$ who was cruel and merciless.

not only increase activation of that NP but also decrease activation for the copresent unmodified NP (*prince*, see Baddeley, 1986; Jäger, Engelmann, & Vasishth, 2017; Just & Carpenter, 1992; Sanford & Garrod, 1981; cf. Foraker & McElree, 2007), we categorized the NPs in the following way: In each condition, we called the modified NP the "target" and the other NP the "competitor." Targets and competitors are explicitly indicated by subscripts in (1). With this grouping, targets and competitors could be either NP1 or NP2. This design also allowed us to collapse across targets and competitors within each of the pre- and postmodified conditions, reducing the number of NPs to compare and maximizing the power of our analyses (see below). Also, because neither NP is modified in the baseline condition, there are no targets or competitors in this condition. In the two premodified conditions, the targets were modified by preceding adjectives, and in the two postmodified conditions, the targets were modified by the same adjectives, but using a relative clause. As is clear from (1), the modifying adjectives were constant across all relevant conditions.

Method

Participants. Sixty undergraduate students from the participant pool of the University of California, Davis took part in this experiment in exchange for course credit. They were all native speakers of American English and reported no language-related disorders.

Stimuli. Forty experimental sentences such as (1) were created. NP1 (*king*) was always also the syntactic subject and NP2 (*prince*) always assumed the syntactic object role. Five versions were created for each experimental item, as illustrated in (1). The gender of the two NPs was always the same within an experimental sentence. We did this because our previous work showed near-ceiling pronominal reference when the genders of the two NPs were different (Karimi et al., 2014). Thus, keeping the genders the same was intended to create enough variation in the forms of referring expressions produced by participants to allow us to test our hypotheses. Five experimental lists were created so that each list contained only one version of an experimental item. We also made 60 fillers that were interspersed with the experimental items in a pseudorandomized order. That is, all the sentences (filler and experimental sentences) were randomized once and all lists were presented in that same order for all participants. The full list of experimental sentences for this experiment is provided in Appendix A.

Procedure. Participants received each experimental list in the form of a booklet and were asked to write a continuation for each sentence. There were no restrictions on how to produce the continuations and the participants were free to say whatever they wished. The participants were encouraged to produce their continuations "quickly" and "with the first thing that comes to mind," but there was no time limit for the experiment. Participants were allowed to take a break whenever they wished, but they were instructed not to look at the pages ahead during the break. The experimental session lasted about 45 min. This experiment was approved by the Institutional Review Board of the University of California, Davis.

Coding. Because syntactic subjects are considerably more likely to be referred to with pronouns relative to syntactic objects (see above), we first coded whether the participants talked about NP1 (i.e., the syntactic subject) or NP2 (the syntactic object) in their responses. Then we coded the main dependent variable, namely, how the participants referred to either NP1 or NP2—with a pronoun or with a repeated noun. Note that coding for the preference to talk about NP1 versus NP2 was critical because any variations in pronominal reference could arise from this preference rather than our manipulations.

Responses were excluded if (a) the referring expression referred to neither the target nor the competitor; (b) collective reference (e.g., *They*, or, *The king and the prince*) was used;[4] (c) neither a pronoun nor a repeated noun was used as a referring expression; (d) the referring expression was not the first-mentioned entity in the response; (e) participants did not produce a new sentence; and (f) the referring expression was part of a subordinate clause in the response (e.g., When he/the prince left, he/the king started contemplating). The application of these criteria resulted in the loss of 502 responses (20.9%).[5] Moreover, because the two NPs were of the same gender, the responses employing pronouns could sometimes be ambiguous. It is important to mention, however, that the majority of responses were unambiguous even when a pronoun

[4] Note that lack of reference to either of the NPs might imply extremely low accessibility for both NPs, and reference to both NPs might imply high and virtually equal accessibility for both NPs. However, because the participants' task was to simply provide a continuation for the given sentences, such responses probably also reflect an attempt to maximize coherence between the prompt sentence and the response for a specific participant, for a specific item and at a specific time. We therefore believe it is safe to exclude such responses. Moreover, excluding such responses is fully consistent with previous research employing the sentence continuation paradigm (Arnold, 2001; Fukumura & Van Gompel, 2010; Stevenson et al., 1994).

[5] We analyzed the rate of excluded responses as a function of modifier position. The results showed no reliable difference between the postmodified and the baseline conditions ($p = .36$), or between the pre- and postmodified conditions ($p = .18$). However, there were significantly more excluded responses in the premodified than the baseline condition ($p = .04$). Because we did not observe this effect between the conditions in our next experiments (see below), we suspect this finding is spurious.

was used in the response. This is because the NP that was *not* the referent of the pronoun was usually mentioned in the response at a later point, revealing the referent of the pronoun. An example would be: "He never trusted the prince." We had 250 truly ambiguous responses in total. To maintain objectivity, these responses were coded by a research assistant who was blind to the purpose of the experiment. To ensure that our results are not biased by ambiguous responses, we repeated the analyses for this experiment (see below) excluding all the 250 ambiguous responses, but the main results stayed the same. The raw frequencies and percentages of references to NP1, NP2, and excluded responses are reported in Appendix B.

Statistical analyses. We coded whether reference to targets or competitors was accomplished through a pronoun (*he*) or a repeated noun (say, *the king*), creating a binomial measure. In other words, we collapsed over the two NPs of the same type (i.e., target or competitor) within each of pre- and postmodified conditions. For the baseline condition, we simply collapsed over the two NPs. Thus, our comparisons always involved comparing the probability of pronominal reference for the following NPs: premodified targets (i.e., *king* in 1b, and *prince* in 1c), premodified competitors (i.e., *prince* in 1b, and *king* in 1c), postmodified targets (i.e., *king* in 1d, and *prince* in 1e), postmodified competitors (i.e., *prince* in 1d, and *king* in 1e), and the two NPs in the baseline condition (i.e., *king* and *prince* in 1a).

It is also important to note that the NPs that were compared always had the same syntactic roles and linear positions. For instance, a comparison between overall pronominal reference to the two NPs in the baseline condition with premodified targets, would be comparing pronominal reference to *king* and *prince* in (1a) with *king* and *prince* in (1b) and (1c), respectively. Critically, whenever we observed a reliable difference in rate of pronominal reference for a particular comparison across conditions, we also report the preference to talk about NP1 (vs. NP2) for that same comparison to see if the results could be reduced to a preference to talk about NP1 (rather than modifier position).

To examine the full effects of our manipulations on forms of reference, we conducted two separate analyses. In the "modification type analysis," we removed the two competitors, creating a three-level predictor: premodified target, postmodified target, and baseline. We then tested whether the probability of pronominal reference differs between pre- and postmodified targets relative to the baseline condition, and also between pre- and postmodified targets. In the "relative richness analysis," we removed the Baseline condition, creating two predictors with two levels each: modifier-position (premodified vs. postmodified), and NP type (target vs. competitor), testing whether the relative semantic richness effect between targets and competitors, if any, varies across pre- and postmodified conditions. In other words, this analysis tested the critical interaction between modifier position and NP type: Does the difference in pronominal reference to targets and competitors vary across the levels of modifier position?

Our analyses incorporated a multilevel modeling approach. Following Barr, Levy, Scheepers, and Tily (2013), we attempted to keep the random-effects structure as "maximal" as possible. However, because most of our models with "full" random-effects structures failed to converge, we had to simplify the models. Specifically, for the models reported in this article, we consistently ran "intercept-only" models for the modification type analysis, but for the relative richness analysis, because the interaction term was the critical effect, we always included by-subject and by-items random slopes for the interaction term, but we did not include random intercepts.

Results

Figure 1 displays the percentage of pronominal reference (out of pronominal plus repeated noun referring expressions) in each condition, and Table 2 reports the results of our statistical analyses. As is clear from this table, in the modification type analysis, we observed significantly more pronominal reference to postmodified targets than to unmodified NPs in the baseline condition. However,

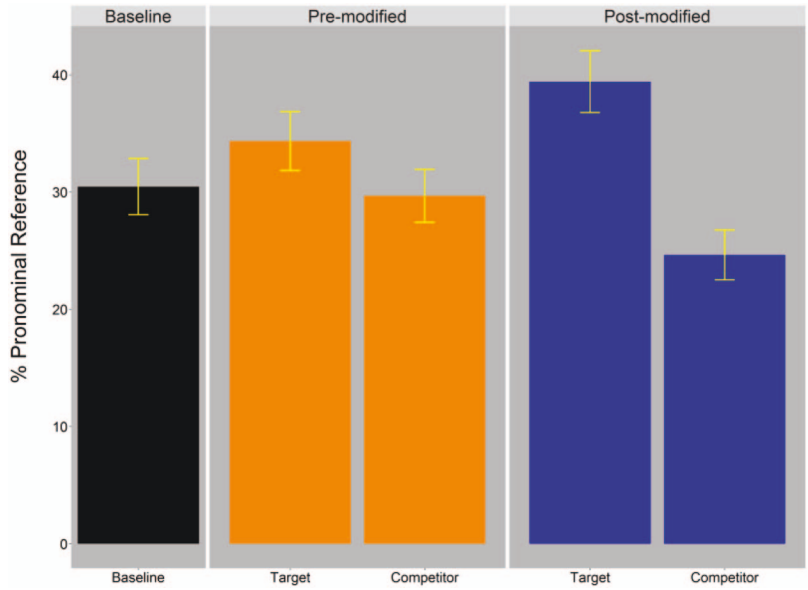

Figure 1. Probability of pronominal reference in each condition. Experiment 1. See the online article for the color version of this figure.

Table 2
Results of Analyses on Probability of Pronominal Reference, Experiment 1

Analysis	Contrast	β	*SE*	*z*	*p*
Modification Type	PreM_Target vs. Baseline	.08	.20	.42	.67
	PostM_Target vs. Baseline	.45	.21	2.15	.03
	PreM_Target vs. PostM_Target	.36	.21	1.75	.08
Relative Richness	Modifier Position	−.01	.11	−.17	.86
	NP Type	.45	.11	4.07	<.001
	Modifier Position × NP Type	.47	.22	2.13	.03
	NP Type Within PreM	−.14	.22	−.64	.52
	NP Type Within PostM	−.58	.26	−2.20	.03

Note. PreM and PostM stand for premodified and postmodified, respectively.

the probability of pronominal reference did not differ between premodified targets relative to the baseline condition. There was also a trend toward more pronominal references to post- than to premodified NPs. In the relative richness analysis, we observed a main effect of NP type, no main effect of modifier position and, critically, a reliable interaction between these two factors. Follow-up simple effects revealed a significant difference between the target and the competitor within the postmodified condition, but not within the premodified condition. The raw frequencies and percentages of pronouns and repeated nouns are provided in Appendix C.

Importantly, there were no significant differences in how often the participants talked about NP1 (vs. NP2) in modification type or in relative richness analyses. The full results for the preference to talk about NP1 versus NP2 are provided in Appendix D.

Discussion

The results of Experiment 1 provided some evidence that postmodifiers might lead to greater memory activation of the associated NPs than premodifiers do: First, while the probability of pronominal reference did not differ between the premodified targets and the unmodified NPs in the baseline condition, there was reliably more pronominal references to postmodified NPs relative to unmodified NPs in the baseline condition. Second, there was a trend toward more pronominal references to post- than to premodified NPs. And third, we observed more pronominal reference to postmodified targets than to copresent competitors, but no difference between premodified targets and copresent competitors. Interestingly, this higher memory activation for postmodified targets seems not only to increase pronominal reference to the targets themselves, but also to decrease pronominal reference to the competitors (compare the blue bars with the black bar in Figure 1). Note that we also observed a trend toward more pronoun use for postmodified NPs compared with the unmodified NPs in the baseline condition. However, because there was also a trend toward talking about NP1 more for postmodified targets than in the baseline condition, this result is difficult to interpret and we will not discuss it further. To the best of our knowledge, these results are the first to show that pre- and postmodifiers result in variations in how easily the associated NPs are retrieved from memory at a subsequent point. We will discuss the theoretical implications of these observations in the discussion section of a meta-analysis that combines the data from the first three experiments (see below).

Experiment 2

While the results of Experiment 1 showed enhanced subsequent retrieval for postmodified NPs, the participants were able to reread the given sentences (theoretically, an endless number of times), which might have mitigated the effect of memory decay caused by the temporal distance between the NPs in the critical sentences and the referring expressions in the responses. Specifically, postnominal relative clauses necessarily increased the distance between a postmodified head noun and when reference production was initiated, and yet they received more pronominal reference than premodified NPs did. However, the greater memory activation for postmodified NPs might have originated from more rereading of postmodified NPs compared with premodified NPs to compensate for the greater temporal (and linear) distance between the head noun of postmodified NPs and the end of the given sentence. Removing the possibility of rereading would help rule out this alternative explanation. In order to control for rereading, we conducted a second experiment in the spoken modality in which participants heard the critical sentences (only once) and spoke their continuations (instead of writing them down).

Method

Participants. Seventy undergraduate students from the participant pool of University of California, Davis took part in this experiment in exchange for course credit. They were all native speakers of American English and reported no language-related disorders.

Stimuli. The experimental sentences were very similar to those used in Experiment 1. The only difference was that one of the NPs was replaced with another NP of a different gender, as illustrated in Table 3. We made the genders of the critical NPs different in this experiment because a former experiment of ours showed overall less pronoun use in the spoken than in the written modality (Karimi et al., 2014). We also know from previous research that same-gender NPs result in less pronoun use (Arnold

Table 3
Sample Experimental Stimuli (Experiment 2)

Modifier position	Order of NPs	Example
a) Baseline	Baseline	The king criticized the princess.
b) Premodified	Target-Competitor	The cruel and merciless $king_{target}$ criticized the $princess_{competitor}$.
c) Premodified	Competitor-Target	The $king_{competitor}$ criticized the cruel and merciless $princess_{target}$.
d) Postmodified	Target-Competitor	The $king_{target}$ who was cruel and merciless criticized the $princess_{competitor}$.
e) Postmodified	Competitor-Target	The $king_{competitor}$ criticized the $princess_{target}$ who was cruel and merciless.

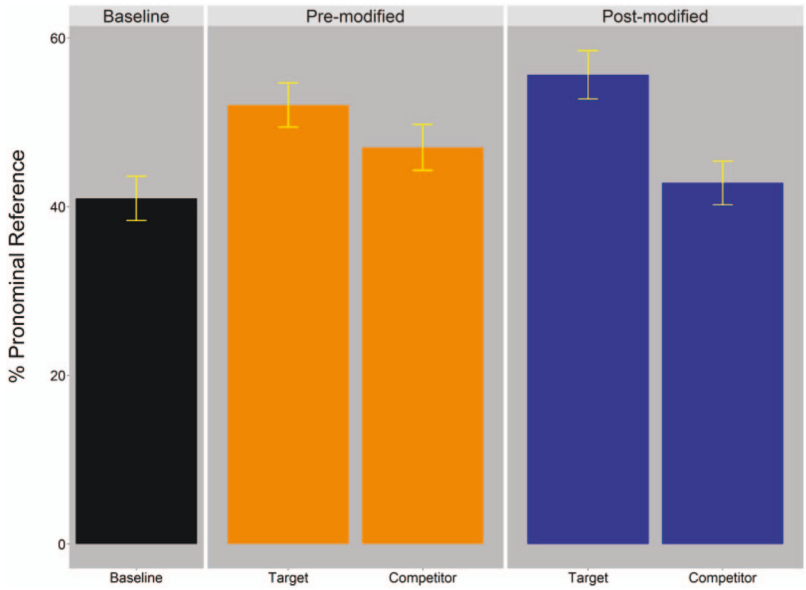

Figure 2. Probability of pronominal reference for each condition. Experiment 2. See the online article for the color version of this figure.

& Griffin, 2007). Thus, keeping genders the same and presenting the sentences auditorily could have resulted in very low pronominal reference rates, obscuring any effects. The full list of experimental sentences for this experiment is provided in Appendix A.

Procedure. The instructions were identical to those used in Experiment 1. The experiment was programmed in PsychoPy2 (v1.83.03). In each experimental trial, the participants pressed the spacebar to hear the prompt sentence. After the presentation of the current sentence was over, a "speak" prompt would appear on the center of the computer screen, indicating that the participants could start speaking their responses. The responses were recorded by an in-built microphone during the time the participants were speaking. Because the length of the responses was expected to vary for each item and participant, we programmed the experiment in a way that the recording of the responses was controlled by the participants themselves; pressing the spacebar during the time the "speak" prompt would terminate recording, and display the prompt for the next trial (i.e., "press the spacebar to hear the next sentence"). This experiment was approved by the Institutional Review Board of the University of California, Davis.

Coding and statistical analyses. The exclusion criteria was identical to that in Experiment 1, except that there were no ambiguous responses. The application of the exclusion criteria resulted in the loss of 1077 (38.4%) of data.[6] The raw frequencies and percentages of references to NP1, NP2, and excluded responses are provided in Appendix E. The statistical analyses were identical to those in Experiment 1.

Results

Figure 2 shows the percentage of pronominal reference (i.e., pronouns out of pronouns plus repeated noun referring expressions) in each condition, and Table 4 reports the results of our statistical analyses. As is clear from this table, in the modification type analysis, we observed reliably more pronominal reference to both the pre- and postmodified targets relative to the baseline condition. However, although the there was a numerical trend toward more pronominal reference for post- than premodified NPs, this effect did not reach statistical significance. In the relative richness analysis, we observed a main NP type effect, with reliably more pronominal reference to targets that to competitors, but no main effect of modifier position. Moreover, the critical interaction between modifier position did not reach statistical significance. The raw frequencies and percentages of pronouns and repeated nouns are reported in Appendix F.

Importantly, talking about NP1 was significantly more likely for premodified targets relative to the baseline condition ($\beta = .39$, $SE = .17$, $Z = 2.28$, $p = .02$). However, the probability of talking about NP1 did not reliably differ between postmodified targets and the baseline condition ($\beta = .19$, $SE = .18$, $Z = -1.05$, $p = .29$). The full results for NP1 versus NP2 reference are provided in Appendix G.

Although the interaction between NP type and modifier position did not reach statistical significance, there was justification to examine the simple effects: First, this interaction was reliable in Experiments 1 and 2. There was a numerical trend in the same direction in the current experiment ($p = .15$), and Experiment 3. The tendency to talk about NP1 was greater for premodified targets than in the baseline condition while this tendency did not reliably vary between postmodified targets and the baseline con-

[6] More data were lost in this experiment compared with Experiment 1 because, in many trials, the participants pressed the spacebar before or during speaking their responses, resulting in additional loss of data. As in Experiment 1, we also analyzed the rate of excluded responses across conditions, but we did not observe any reliable differences (premodified vs. baseline: $p = .98$, postmodified vs. baseline: $p = .44$, premodified vs. postmodified: $p = .27$).

Table 4
Results of Analyses on Probability of Pronominal Reference, Experiment 2

Analysis	Contrast	β	*SE*	*z*	*p*
Modification Type	PreM_Target vs. Baseline	.54	.21	2.59	.009
	PostM_Target vs. Baseline	.84	.22	3.74	<.001
	PreM_Target vs. PostM_Target	.30	.21	1.38	.16
Relative Richness	Modifier Position	−.01	.10	−.11	.90
	NP Type	.35	.10	3.29	<.001
	Modifier Position × NP Type	.31	.21	1.44	.15
	NP Type Within PreM	−.18	.27	−.66	.50
	NP Type Within PostM	−.72	.27	−2.67	.007

Note. PreM and PostM stand for premodified and postmodified, respectively.

dition. This means that premodified targets were more likely than postmodified targets to be subsequently realized with pronouns due to greater NP1 reference, making it difficult for the interaction to reach statistical significance. As shown in Table 4 and consistent with the results of Experiment 1, an analysis of simple effects revealed that the probability of pronominal reference was reliably greater for the target relative to the competitor within the postmodified condition but not within the premodified condition.

Discussion

Consistent with the results of Experiment 1, the results of Experiment 2 also showed a reliably stronger tendency to use pronouns (rather than repeated NPs) to refer to post- than to premodified NPs: The probability of pronominal reference was reliably greater for targets relative to competitors within the postmodified condition, but not within the premodified condition, suggesting that the retrieval of a postmodified NP's representation from memory is relatively easier compared to that of a premodified (and an unmodified) NP. Importantly, because the critical sentences were presented auditorily (and only once), the greater activation of postmodifiers could not be due to rereading of the postmodified NPs. Thus, the results of Experiment 2 lend even stronger support to the observation that postmodifiers lead to greater memory activation of the head noun than premodifiers. We will discuss the theoretical implications of these results after we present a meta-analysis combining the data from the first three experiments (see below).

In addition, unlike in Experiment 1 in which premodifiers not only increased pronominal reference to the target but also decreased pronoun use for the competitor, in Experiment 2 postmodifiers only increased pronominal reference to the target and did not affect the rate of pronoun use for the competitor (compare the blue bars with the black bar in Figure 2). This pattern of results is consistent with our previous findings and seems to be related to the stimulus modality (spoken vs. written, see Karimi et al., 2014). However, because this observation is tangential to our research questions, we will not discuss it any further.

Experiment 3

In the first and second experiments we observed more pronominal reference to post- than to premodified NPs, suggesting that postmodified NPs are more highly activated in memory than premodified NPs are. However, we did not find clear evidence for higher activation of premodified NPs compared with unmodified NPs, which is inconsistent with previous findings (e.g., Hofmeister, 2011). In an attempt to obtain even clearer results for both pre- and postmodified NPs, we made all NP1s inanimate in Experiment 3 in order to reduce the overall probability of talking about NP1 (see Fukumura & Van Gompel, 2011). Because NP1s are already highly activated, we hoped that more reference to NP2 might lead to clearer results of modifier position.

Method

Participants. Sixty undergraduate students from the participant pool of University of California, Davis took part in this experiment in exchange for course credit. The data from one participant was removed from the analysis because they only produced repeated nouns (and no pronouns) in their responses. All participants were native speakers of American English and reported no language-related disorders.

Stimuli. We created 50 experimental items for this experiment. The sentences were very similar to those used in Experiments 1 and 2. The only difference was that NP1 was made inanimate across all the conditions, and as a result of this, the modifying information for animate and inanimate NPs were different, as is shown in Table 5. The full list of experimental sentences for this experiment is provided in Appendix H.

Procedure, coding, and statistical analyses. The procedure was identical to that in Experiment 2, and the coding and statistical analyses were identical to those in Experiments 1 and 2. Note that the pronouns were always unambiguous in this Experiment; "it" for the NP1s and "he" or "she" for NP2s. The application of the exclusion criteria resulted in the loss of 1,144 (38.8%) responses.[7] The raw frequencies and percentages of references to NP1, NP2, and excluded responses are reported in Appendix I. As in the first two experiments, either the "full" or the "no-correlation" or the "slopes-only" models converged (see above and Barr et al., 2013) for all of our analyses, and we therefore did not need to simplify the random effects structures of our models any further. This experiment was approved by the Institutional Review Board of the University of California, Davis.

Results

The animacy manipulation was successful: Participants talked about NP2 (the animate NP) much more than NP1 (the animate NP) across all conditions (NP1 reference = 381, NP2 reference = 1,425), which is consistent with previous research (Fukumura & Van Gompel, 2011). The percentage of pronominal reference (i.e., pronouns out of pronouns plus repeated noun referring expressions) for each condition is shown in Figure 3, and the results of our statistical analyses are reported in Table 6. As can be seen in

[7] As in Experiment 2, we lost additional data in this experiment due to participants terminating the recordings too early (Experiments 2 and 3 were run simultaneously, but the participants were not the same). There were no reliable difference in the probability of excluded responses across the conditions. (premodified vs. baseline: $p = .26$, postmodified vs. baseline: $p = .29$, premodified vs. postmodified: $p = .88$).

Table 5
Sample Experimental Stimuli (Experiment 3)

Modifier position	Order of NPs	Example
a) Baseline	Baseline	The carpet mesmerized the photographer for hours in the museum.
b) Premodified	Target-Competitor	The ancient$_{target}$ and ornate carpet mesmerized the photographer$_{competitor}$ for hours in the museum.
c) Premodified	Competitor-Target	The carpet$_{competitor}$ mesmerized the stylish and artistic photographer$_{target}$ for hours in the museum.
d) Postmodified	Target-Competitor	The carpet$_{target}$ that was ancient and ornate mesmerized the photographer$_{competitor}$ for hours in the museum.
e) Postmodified	Competitor-Target	The carpet$_{target}$ mesmerized the photographer$_{competitor}$ who was stylish and artistic for hours in the museum.

this table, in the Modification Type Analysis, we observed reliably more pronominal reference to postmodified targets relative to the baseline condition. The probability of pronominal reference was also greater for premodified targets relative to the baseline condition, but this effect was marginally significant. The probability of pronominal reference did not differ between the pre- and postmodified conditions. Consistent with Experiments 1 and 2, in the relative richness analysis, the modifier position effect was not significant, but the effect of NP type was statistically reliable, with greater pronominal reference to targets that to competitors. However, similar to Experiment 2, the critical interaction between modifier position and NP type did not reach statistical significance. The raw frequencies and percentages of pronouns and repeated nouns can be found in Appendix J.

Importantly, the rate of talking about NP1 (vs. NP2) was *greater* for the unmodified NPs in the baseline condition relative to the premodified targets. The full results for NP1 versus NP2 reference are provided in Appendix K.

As in Experiment 2, although the main interaction between modifier position and NP type was not significant, we had enough motivation to examine the simple effects because (a) the probability of pronominal reference was reliably greater for postmodified targets relative to the baseline condition, but only marginally greater for premodified targets relative to the baseline; and (b) the results of the previous two experiments did reveal reliable differences in the simple comparisons. As reported in Table 6, and consistent with Experiments 1 and 2, the probability of pronominal reference was reliably greater for targets relative to the competitors within the postmodified condition but not within the premodified condition.

Discussion

Consistent with the results of Experiments 1 and 2, the results of Experiment 3 showed that postmodified NPs are reliably more likely to be subsequently pronominalized than premodified NPs, suggesting that the memory representations associated with postmodified NPs are relatively more accessible in memory than those associated the premodified NPs. Specifically, and in line with the results of the first two experiments, the probability of pronominal reference was significantly greater for targets than for competitors within the postmodified condition, but not within the premodified condition. Moreover, we also observed significantly greater pronominal reference to postmodified targets relative to the baseline condition, whereas pronominal reference was only marginally greater for premodified targets relative to the baseline condition. This pattern of results suggests that postmodified NPs increase the accessibility of the associated memory representation more than

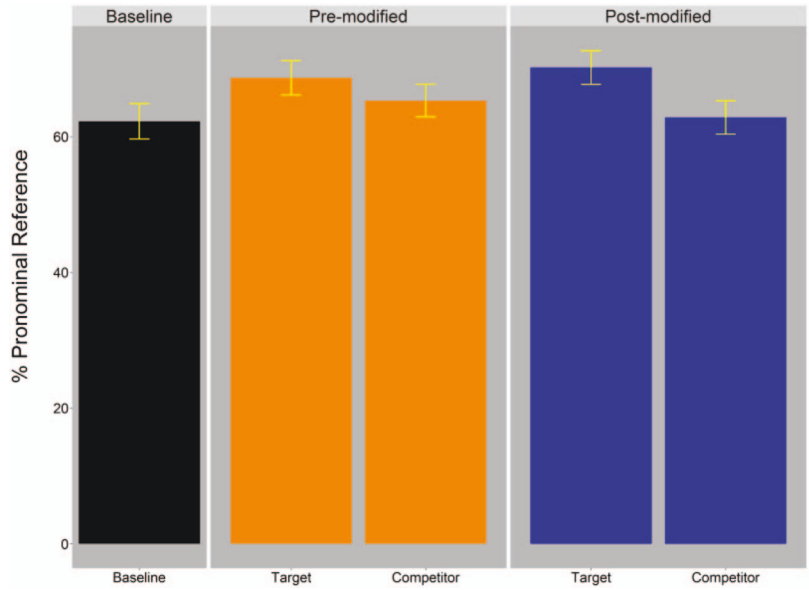

Figure 3. Probability of pronominal reference for each condition. Experiment 3. See the online article for the color version of this figure.

Table 6
Results of Analyses on Probability of Pronominal Reference, Experiment 3

Analysis	Contrast	β	*SE*	*z*	*p*
Modification Type	PreM_Target vs. Baseline	.42	.22	1.92	.05
	PostM_Target vs. Baseline	.62	.22	2.76	.005
	PreM_Target vs. PostM_Target	.19	.22	.87	.38
Relative Richness	Modifier Position	−.01	.11	−.16	.87
	NP Type	.24	.11	2.15	.03
	Modifier Position × NP Type	.17	.22	.80	.42
	NP Type Within PreM	−.35	.33	−1.06	.28
	NP Type Within PostM	−.90	.31	−2.83	.004

Note. PreM and PostM stand for premodified and postmodified, respectively.

premodifiers do. In other words, these observations suggest that although both pre- and postmodification of an NP boosts the accessibility of the associated memory representation, postmodifications result in greater activation boosts than premodifications. Note that although only marginally significant, the greater pronominal reference to the premodified NPs relative to the baseline condition is consistent with previous studies (Hofmeister, 2011). We will discuss the far-reaching theoretical implications of our results below where we present the results of a meta-analysis that combines the data from the first three experiments.

Experiments 1, 2, and 3 Combined

In the three experiments reported above, only in Experiment 1 (and not in Experiments 2 and 3) did we observe a greater probability of pronominal reference to post- than to premodified targets. Moreover, the critical main interaction between modifier position and NP type in the relative richness analysis was statistically reliable only in Experiment 1. Importantly, it is this interaction that can provide direct evidence for a statistically reliable difference between pre- and postmodification. However, because we consistently observed greater pronominal reference rates to targets than to competitors within the postmodified condition but not within the premodified condition across all three experiments, we believe the reason the main interaction did not reach statistical significance in Experiments 2 and 3 is simply lack of statistical power. It is important to note that both of the targets were semantically rich and therefore resulted in numerically more pronominal reference relative to the competitors, making it more difficult for the main interaction to reach statistical significance. However, a direct comparison between pre- and postmodified targets as well as testing the main interaction between modifier position and NP type are critical for our claims. This is because if postmodifiers do result in higher memory activation of the head noun than premodifiers, there should be more pronominal reference to post- than premodified targets, and the difference in pronominal reference between targets and competitors should be greater within the postmodified condition relative to the premodified condition.

To maximize statistical power, we combined the data from all three experiments reported above and repeated the modification type and relative richness analyses. Table 7 reports the results of these analyses and Figure 4 displays the proportion of pronouns (out of pronouns plus repeated nouns) for all conditions.

As can be seen in Table 7, the modification type analysis showed that the probability of pronominal reference was significantly greater for both pre- and postmodified targets than to the unmodified NPs in the baseline condition. Critically, however, this analysis also revealed that postmodified targets were significantly more likely to be subsequently realized with pronouns than premodified targets were. Moreover, the relative richness analysis showed a significant main interaction between modifier position and NP type such that the probability of pronominal reference was reliably greater for targets relative to competitors within the postmodified condition but not within the premodified condition. Thus, the results from our combined analysis lends direct support to the finding that postmodified NPs are more accessible in memory than are premodified NPs. We observed no reliable differences in the probability of talking about NP1 versus NP2 in the Modification Type or Relative Richness analyses. The full results for the preference to talk about NP1 versus NP2 are reported in Appendix L.

Discussion

The analysis of the combined data from the first three experiment revealed a clear advantage for postmodified NPs relative to premodified NPs in terms of probability of pronominal reference: Postmodified NPs were significantly more likely to be subsequently realized with pronouns than were premodified NPs, and targets were reliably more likely to be pronominalized than competitors within the postmodified condition but not within the premodified condition.

To the best of our knowledge, our results are the first to demonstrate that the position of modifiers causes variations in ease of subsequent retrieval. The greater accessibility of post- versus premodified NPs could be caused by a greater perceptual significance attached to post- than premodifiers, or by the fact they are consistent with a relationally given-before-new information structure (see Motivation and Predictions), or by the smaller memory demands associated with processing postmodifiers (see Introduction).

In any case, because the modifying adjectives were constant across the pre- and postmodified NPs, these results indicate that distinctiveness is not the only cause for retrieval ease of semantically richer NPs, and that other perceptual, information structure or

Table 7
Results of Analyses on Probability of Pronominal Reference, Experiments 1, 2, and 3 Combined

Analysis	Contrast	β	*SE*	*z*	*p*
Modification Type	PreM_Target vs. Baseline	.34	.12	2.82	.004
	PostM_Target vs. Baseline	.63	.12	4.99	<.001
	PreM_Target vs. PostM_Target	.29	.12	2.31	.02
Relative Richness	Modifier Position	−.00	.06	−.07	.93
	NP Type	.32	.06	5.23	<.001
	Modifier Position × NP Type	.31	.12	2.51	.01
	NP Type within PreM	−.18	.12	−1.48	.13
	NP Type within PostM	−.75	.14	−5.32	<.001

Note. PreM and PostM stand for premodified and postmodified, respectively.

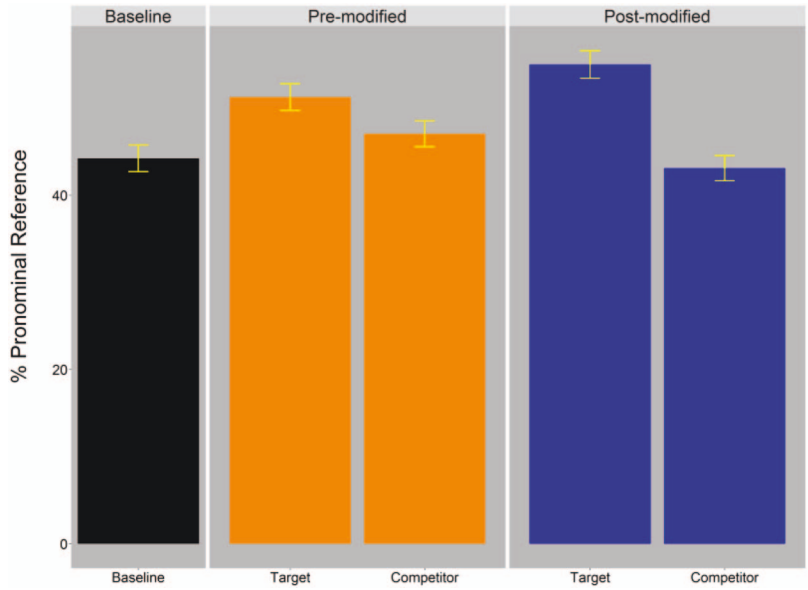

Figure 4. Probability of pronominal reference for each condition. Experiments 1, 2 and 3 combined. See the online article for the color version of this figure.

memory factors have a role to play. Moreover, the results clearly show that memory decay does not negatively impact the retrieval of postmodified NPs despite the fact that they increased the temporal distance between the encoding of the retrieval of the head noun, which is consistent with previous findings (Karimi & Ferreira, 2016b; Karimi, Swaab, & Ferreira, 2018). Finally, the fact the postmodified NPs led to more pronominal reference than did premodifiers clearly suggests that predictability of the head noun category does not play a key role during the encoding of semantically rich words: Although the syntactic category of "noun" could be predicted in the case of premodified NPs, but not in the case of postmodified NPs, we actually observed more pronominal reference to post- than to premodified NPs.

Experiment 4

Experiments 1, 2, and 3 assessed the effect of modifier position on subsequent retrieval during language production, and pronominal reference was used as a measure of retrieval ease. However, some previous studies have investigated the semantic richness effect during online language comprehension, using reading times as a measure of memory activation and ease of retrieval (Hofmeister, 2011; Troyer et al., 2016). In order to assess whether our results from language production also apply to language comprehension using a more conventional measure of memory activation/retrieval, we conducted a self-paced reading experiment using experimental stimuli such as (4) and (5). To simplify the design, we also removed the competitor form the experimental sentences.

Previous research has demonstrated that pronouns trigger the retrieval of the representations associated with their referents (Dell et al., 1983; Gernsbacher, 1989; Gerrig & McKoon, 1998; Lucas et al., 1990; MacDonald & MacWhinney, 1990; Sanford & Garrod, 1989, 2005), and that the ease of that retrieval directly influences the ease of processing the pronoun (Karimi et al., 2018). As such, if the results from the first three experiments generalize to language comprehension, we should observe faster reading times on the pronoun (and/or the subsequent regions) following postmodified than following premodified NPs.

Method

Participants. Sixty undergraduate students from the participant pool of University of California, Davis took part in the experiment in exchange for course credit. We removed the data from one participant because they did not complete the experiment. All participants were native speakers of American English and reported no language-related disorders.

Stimuli. We created 33 experimental discourse segments such as those illustrated in Table 8. Each sentence contained one human NP (*the king*) which always assumed the syntactic subject role, and

Table 8
Sample Experimental Stimuli: Experiment 4

Sentence 1	
(a) Baseline	The king was diagnosed with a terminal disease.
(b) Premodified	The cruel and merciless king was diagnosed with a terminal disease.
(c) Postmodified	The king who was cruel and merciless was diagnosed with a terminal disease.
Sentence 2	
For almost 2 months, he had no idea because no one would dare break the news.	

was either unmodified, premodified, or postmodified, creating the three conditions of interest, as illustrated in (4). All three versions of an experimental item were followed by the same second sentence that contained a pronoun (either *he* or *she*) referring to the NP in the first sentence. The full list of stimuli for this experiment is provided in Appendix M. The experimental sentences were intermixed with 40 other fillers that in fact served as experimental stimuli for another independent study which did not investigate pronoun processing. The 33 experimental sentences and the 40 fillers were distributed among three lists such that each participant was exposed to only one version of each experimental sentence. The order of the sentences in each list was randomized for each participant such that each participant viewed each list in a different order. Twelve experimental sentences and 20 fillers were tagged with a true/false comprehension question to ensure that participants pay close attention to the task. The experiment was programmed in PsychoPy2 (v1.83.03) which presented the stimuli and recorded RTs for each button press (see below).

Procedure. The experiment was conducted individually and in a quiet room. First, the instructions appeared on the screen which stated that the participants were about to read two-sentence stories, and that their job is to read them for comprehension. The instructions also stated that a comprehension question in the form of a true/false statement would appear for a random number of stories. An experimental trial started with participants pressing the spacebar on the keyboard, which led to the display of the first sentence on the computer screen all at once. When the participant was done reading the first sentence, they pressed the spacebar again to trigger the presentation of the second sentence. Unlike the first sentence, the second sentence was presented one word at a time, each word appearing with the press of the spacebar and staying on the screen until the spacebar was pressed again, which triggered the presentation of the next word, and so on and so forth until the second sentence ended. If the current item had a comprehension question, it would appear on the screen (in full) after the last word of the second sentence was read, and the participant had to press "1" on the Num Lock pad to indicate true and "2" to indicate false. If there was no question for the current trial, the screen would show "no question" and the participants had to press 0 on the Num Lock pad to make it disappear, and press spacebar to move on to the next item. This experiment was approved by the Institutional Review Board of the University of California, Davis.

Statistical analyses. We performed linear mixed effects regression models on the data, with reading time as the dependent variable, and modifier position as the predictor. We Helmert coded the predictor to test both the general effect of modifications (baseline vs. the average of premodified and postmodified), as well as the direct contrast between the two modifiers (premodified vs. postmodified). For this experiment, models including the "full" random effects structure (i.e., with random intercepts for both subjects and items as well as by-subjects and by-items random slopes for the effect of modifier position) always converged and we did not need to simplify the random structure of our models (Barr et al., 2013). We considered any t values greater than 2 as statistically significant (Gelman & Hill, 2006).

Results

Prior to analyzing the data, we log-transformed the reading times to approach a normal distribution of reading times. We then removed RTs that fell 2.5 *SD*s below or above the overall mean (425, or 1.7% of the total trials). We also noticed that a few of the first sentences had unreasonably fast or slow reading times. Because the manipulations occurred in the first sentence and a failure to read those sentences would result in no exposure to the manipulation, we also removed trials where the reading time of the first sentence was too long or too short (29, or .001% trials). Unreasonable reading times on Sentence 1 were defined in the following way: We first calculated the fastest reasonable reading time as 2.5 *SD*s below the mean reading time of the shortest Sentence 1, and the longest reasonable reading time as 2.5 *SD*s above the mean of the longest Sentence 1. We then removed any reading times that were faster than the fastest reasonable reading time or slower than the longest reasonable reading time. Figure 5 displays the reading times for the four words preceding and the five words following the critical pronoun (represented by "n") in Sentence 2.

Table 9 reports the results of our statistical analyses. As is clear from this table, there was a general effect of modification in the

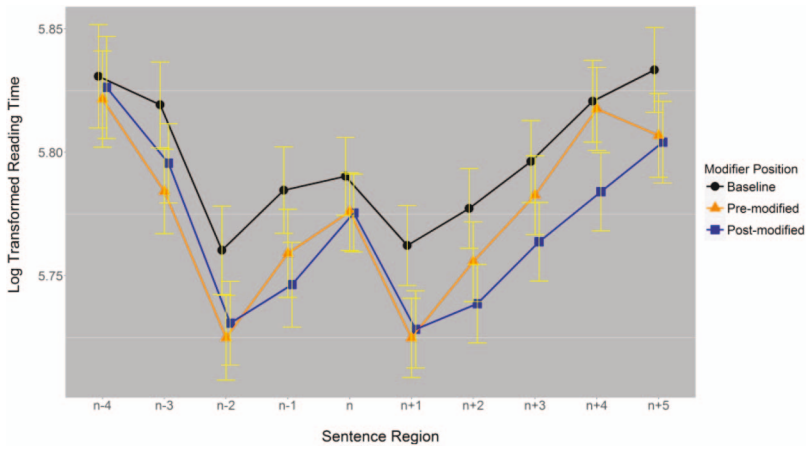

Figure 5. Reading time by region and modifier position. Experiment 4. "n" represents the critical pronoun. See the online article for the color version of this figure.

Table 9
Results for the Statistical Analyses for Experiment 4

Region	Contrast	Estimate	*SE*	*t*
n − 4	Baseline vs. (PreM & PostM)	−.00	.01	−.06
	PreM vs. PostM	−.00	.01	−.00
n − 3	Baseline vs. (PreM & PostM)	.02	.01	1.72
	PreM vs. PostM	−.00	.01	−.40
n − 2	Baseline vs. (PreM & PostM)	.02	.01	1.86
	PreM vs. PostM	−.00	.01	−.26
n − 1	Baseline vs. (PreM & PostM)	.02	.01	1.64
	PreM vs. PostM	.01	.01	1.02
n	Baseline vs. (PreM & PostM)	.01	.01	1.02
	PreM vs. PostM	.00	.01	.29
n + 1	Baseline vs. (PreM & PostM)	.03	.01	2.39
	PreM vs. PostM	−.00	.01	−.03
n + 2	Baseline vs. (PreM & PostM)	.02	.01	2.01
	PreM vs. PostM	.01	.01	1.13
n + 3	Baseline vs. (PreM & PostM)	.02	.01	1.67
	PreM vs. PostM	.01	.01	.94
n + 4	Baseline vs. (PreM & PostM)	.01	.01	1.21
	PreM vs. PostM	.03	.01	2.23
n + 5	Baseline vs. (PreM & PostM)	.02	.01	1.53
	PreM vs. PostM	.00	.01	.25

two regions immediately following the critical pronoun ("n + 1" and "n + 2"), with reading times in the average of pre- and postmodified conditions being faster than the baseline condition. Importantly, on the fourth word following the critical pronoun ("n + 4"), we also observed faster reading times for the postmodified condition relative to the premodified condition.

Accuracy for answering the comprehension questions was 91.1% in the baseline condition, 87.2% in the premodified condition, and 87.8% in the postmodified condition respectively. The differences in accuracy rates were not statistically reliable between any of the conditions (premodified vs. baseline: $p = .21$, postmodified vs. baseline: $p = .25$, premodified vs. postmodified: $p = .92$).

Discussion

Consistent with the results of the production experiments, the results of the comprehension experiment showed easier retrieval for postmodified NPs relative to premodified (and unmodified) NPs. Specifically, reading times for the fourth word following the critical pronoun was faster for postmodified than for unmodified NPs. Moreover, the results of Experiment 4 also revealed a general modification effect, with faster reading times for the average of pre- and postmodified NPs relative to unmodified NPs on the two words immediately following the critical pronoun, which is fully consistent with previous findings (Hofmeister, 2011; Karimi & Ferreira, 2016b; Karimi et al., 2014; Troyer et al., 2016). A potential explanation for why the pre- versus postmodification effect emerges rather late (i.e., four words after the critical pronoun) could be that immediately following the pronoun, the retrieval of the head noun's representation is facilitated for both pre- and postmodified NPs (as evidenced by the general modification effect), which makes it difficult for any differences between them to emerge. However, later on, the memory representation of the head noun might somewhat fade, making the difference between pre- and postmodified representations easier to detect.

In any case, faster reading times for post- than premodified NPs provide further evidence that the choice between pre- and postmodifiers results in measurable processing cost differences, which might be due to the greater perceptual significance associated with postmodifiers, or the relationally given-before-new structure of postmodified NPs (see above), or a maintenance cost associated with processing premodified NPs. Moreover, and consistent with the results of the previous three experiments, the results of the current experiment demonstrate that distinctiveness is not sufficient for explaining why semantically richer NPs are subsequently retrieved faster from memory, that the effect of time-based decay is overridden by postmodifying information, and also that prediction of the head noun may not facilitate encoding over and above semantic richness.

It is also important to mention that although not statistically reliable, the general modification effect was numerically present in the regions leading to the critical pronoun (i.e., "n − 3", "n − 2", and "n − 1"). If it is the pronoun that triggers the retrieval of the associated referent, why would the effect start to arise before the pronoun in encountered? We think this is probably because the integration of the entire second sentence is easier following semantically richer first sentences, that is, following pre- and postmodified conditions relative to the unmodified condition. In fact, based on Figure 5, reading times are faster for pre- and postmodified conditions relative to the baseline condition for virtually *all* the words of the second sentence. This speed-up might occur because a richer discourse representation might facilitate the integration of new information in general, regardless of whether the new information triggers retrieval of a specific previously encoded NP or not.

General Discussion

In four experiments, we observed that postmodified NPs are more accessible in memory than are premodified NPs. In Experiments 1, we observed significantly more pronominal reference to postmodified NPs than to unmodified competitors, whereas pronominal reference to premodified NPs and unmodified competitors did not reliably differ. Moreover, in the first three experiments, we consistently observed a relatively stronger pronominalization tendency for post- than to premodified NPs such that postmodified targets were realized with significantly more pronouns than unmodified NPs, whereas pronominalization rates did not differ between premodified and unmodified NPs. However, even stronger evidence for the higher memory of post- relative to premodified NPs during language production came from the meta-analysis of the first three experiments: In the combined dataset, we observed significantly more pronominal reference to post- than to premodified NPs, and also significantly more pronominal reference to targets than to competitors when the target NPs were postmodified, but not when they were premodified. Finally, in Experiment 4, we observed faster reading times for pronouns following pre- and postmodified NPs relative to unmodified NPs. However, and critically, we also observed decreased reading times for pronouns following postmodified compared to premodified NPs.

The linear position of modifications is a syntactic choice in English that may or may not have processing consequences. However, although the processing cost associated with alternative syn-

tactic constructions has been extensively studied for many syntactic forms (see the Introduction for a brief review), to the best of our knowledge, the potential effect of modifier position has not been investigated. Thus, our results are the first to show that the linear position of modifiers affects subsequent retrieval of associated memory representations.

Our results are consistent with previous studies showing that semantically richer NPs are more accessible in memory (Hofmeister, 2011; Hofmeister & Vasishth, 2014; Karimi et al., 2014; Karimi & Ferreira, 2016b; Troyer et al., 2016); in all of our experiments, both pre- and postmodified NPs were pronominalized more than unmodified NPs, and were also read faster than unmodified NPs. However, our results contribute to this literature by demonstrating that the way in which semantic richness is conferred (via pre- vs. postmodifiers) also affects the accessibility of the resulting representations. As mentioned above, all three possibilities about the encoding and retrieval of pre- versus postmodifiers are supported by the current psycholinguistic literature. One possibility was that compared with postmodifiers, premodifiers might be encoded more efficiently in memory because they have the advantage of rendering the syntactic category (plus perhaps some of the semantic features) of the head noun predictable, as well as the advantage of a shorter temporal distance between the head noun and the retrieval point. Another possibility was that there might have been no difference between the encoding efficiency of pre- and postmodifiers, because the modifying adjectives were constant across our critical condition, and therefore the associated representations should be equally distinct in memory, resulting in the same degree of interference during retrieval.

However, our data clearly supported the third possibility, namely, that postmodified NPs are encoded more efficiently in memory than premodified NPs. We propose three reasons for this effect: First, postmodifying relative clauses might be more perceptually significant than premodifying adjectives. This greater perceptual significance might stem from the fact that postmodifying relative clauses convey more complex information. For instance, unlike premodifying adjectives, postmodifying relative clauses can include whole clauses ("The king who was *sitting on the throne*"), additional NPs ("The king who kissed *the queen*"), more specific information ("The king who was cruel *in the past*"), among other types of complex information. Such functional distribution of pre- versus postmodifiers are perhaps learned by comprehenders, causing them to devote more attentional and/or memory resources to post- than to premodifiers, which in turn may lead to more robust representations for postmodified NPs. Note that this explanation is consistent with previous research showing that comprehenders are sensitive to the significance of subordinate versus main clauses. For example, past research has demonstrated that comprehenders are significantly less likely to detect false assertions when they occur in subordinate clauses than in main clauses (Baker & Wagner, 1987), and that subordinate clauses are more likely to be processed in a shallow manner than main clauses (Christianson, Hollingworth, Halliwell, & Ferreira, 2001; Christianson, Williams, Zacks, & Ferreira, 2006; Ferreira, Christianson, & Hollingworth, 2001; also see Ferreira, Bailey, & Ferraro, 2002; Karimi & Ferreira, 2016a; Sanford & Sturt, 2002). Similarly, it has been argued that prediction of upcoming information is less likely to occur in subordinate clauses compared to main clauses (Ferreira & Lowder, 2016). Clearly, the perceptual significance explanation for the greater accessibility of post- versus premodified NPs is also consistent with previous research showing that comprehenders are sensitive to statistical regularities of linguistic input, and can learn from these regularizes to facilitate future processing (Chang, Dell, & Bock, 2006; Chang, Dell, Bock, & Griffin, 2000; Clark, 2013; Conway, Bauernschmidt, Huang, & Pisoni, 2010; Jaeger, 2010; Kleinschmidt, Fine, & Jaeger, 2012; Levy, 2008; MacDonald, 2016; McDonald & Shillcock, 2003).

Second, postmodified NPs are consistent with the relationally given-before-new information structure, and this structure has been shown to facilitate processing (Ariel, 1990, 1996; Benatar & Clifton, 2014; Chafe, 1976; Clark & Clark, 1978; Gundel, 1978, 1988; Halliday, 1967; Haviland & Clark, 1974). Because the head noun functions as the topical concept to which the modifications are predicated, the head noun of modified NPs may constitute relationally "given" information, whereas the modifications may constitute relationally "new" information (see Motivation and Predictions). Critically, because modifying information follows the head noun in the case of postmodified NPs, but precedes it in the case of premodified NPs, postmodified NPs are consistent with the given-before-new format of how information is packaged, whereas premodified NPs are not. As such, postmodified NPs might be easier to process and therefore easier to encode, leading to facilitated subsequent retrieval. An important point pertaining to the information structure of pre- versus postmodified NPs also merits discussion here: Under some theories of language processing, ease of sentence comprehension is largely determined by preferences during language production, with constructions preferred and generated more frequently during production being easier to comprehend (Hopman & MacDonald, 2018; MacDonald, 2013, 2016; also see Levy, 2008). Because production proceeds in an incremental manner (Bock, 1982; Bock & Warren, 1985; De Smedt & Kempen, 1987; Kempen & Hoenkamp, 1987; Levelt, 1989), with easier bits being produced earlier than harder bits (Ferreira, 1996; Ferreira & Swets, 2002; Stallings, MacDonald, & O'Seaghdha, 1998; Yamashita & Chang, 2001; see also Lau, & Hwang, 2016), it could be the case that postmodified NPs are easier to produce than premodifiers, and therefore more frequently encountered by comprehenders. This might again be due the fact the postmodified NPs conform to the "given-before-new" principle. Because given information is easier to access from memory than new information, postmodified NPs might be easier to produce than premodifiers, which in turn might facilitate their encoding and therefore their subsequent retrieval. It is important to note that, based on some previous findings, the frequency of pre- versus postmodified NPs could have had the reverse effect on referential processing, with pronouns associated with the *less* frequent structure forming more salient representations in memory during encoding and resulting in *easier* subsequent retrieval (see Van Gompel, & Majid, 2004). However, our data clearly did not lend any support to this possibility.

Third, premodifying adjectives need to be maintained in memory until the head noun is revealed and before integration can take place. As such, there might be a maintenance cost and/or a delayed integration associated with the processing premodified NPs (Wagers & Phillips, 2014), whereas the integration of postmodifying information can start immediately, with no maintenance cost.[8] These factors might

[8] Note that this maintenance cost and/or delayed integration does not seem to be strong enough to reverse the semantic richness effect. This is because our first three experiments as well as previous researchers have demonstrated easier retrieval for premodified than for unmodified NPs (Hofmeister, 2011).

then complicate the encoding of premodified NPs compared with postmodified NPs. Future research is needed to distinguish between these three (and potentially other) explanations for the modifier position effect.

As mentioned in the Introduction, one of the potential mechanisms offered by memory-based theories of language processing to explain the semantic richness effect is the *head-reactivation* account. Based on this account, the memory representation of the head noun becomes reactivated as the modifying information is being encoded (Lewis & Vasishth, 2005; Lewis et al., 2006). Importantly, this explanation has only been shown for cases in which a head category (such as a verb) can be predicted and therefore preactivated (e.g., Jaeger, Fedorenko, & Gibson, 2005; Konieczny, 2000; Vasishth & Lewis, 2006), which raises the question as to whether prediction is a necessary requirement for head-reactivation. Although our results suggest no evidence that prediction facilitates encoding over and above semantic richness, the head-reactivation account could still explain our results. Specifically, it could be the case that for premodifiers, only the syntactic category of the head noun (plus perhaps a little semantic information) is reactivated because this is only information that can be predicted based on the premodifying adjectives. However, because the full lexical semantics of the head noun is available in the case of postmodifiers, head-reactivation could involve both syntactic as well as semantic information in the case of postmodified NPs, leading to more robust representations. Note that the head-reactivation account also provides a reasonable explanation for why time-based decay cannot reduce the activation level of postmodified NPs. Time-based decay is an established effect in memory and psycholinguistics based on the fact that memory representations fade (i.e., their activation drops) due to passage of time (Baddeley, 2000; Chomsky, 1965; Gibson, 1998; Lewis & Vasishth, 2005; Lewis et al., 2006; Van Dyke & Lewis, 2003). Interestingly, relative to premodified NPs, the head of postmodified NPs was always necessarily farther from the retrieval point, meaning that decay actually worked against postmodified NPs and in favor of premodified NPs. As such, the observation that postmodified NPs have higher accessibility than premodified NPs requires a mechanism for how the effect of decay is overridden in the case of postmodified NPs. The head-reactivation account provides precisely that mechanism.

Although our results are interpretable in terms of head-reactivation (Lewis & Vasishth, 2005; Lewis et al., 2006), the current memory-based models do not readily provide an explanation for the retrieval ease differences between pre- and postmodified NPs. This is because under the current versions of these models, it is unclear what gets reactivated in the case of modified NPs; is it only syntactic features? Or could both syntactic and semantic features get reactivated, as we suggest in this study? Moreover, the current models are not clear on how exactly predictive processing interacts with reactivation (see Parker et al., 2017). We believe the results of our study poses interesting challenges for the current memory-based models of language processing, and that resolving these challenges would help improve these models.

One major limitation of our study is that it is entirely based on English where premodifications are always limited and bounded to adjectives, and postmodifiers are either relative clauses or prepositional phrases. Some of the possibilities proposed above could be tested by investigating the role of modifier position in languages that allow adjectives to modify a noun both before and after (e.g., Tagalog). This investigation would allow testing how much of the modifier position effect is due to the availability of the head noun. Similarly, studying languages that permit only postmodifiers but through both simple adjectives as well as relative clauses (e.g., Persian) would allow testing the contribution of the type of modifier to the current results. Relatedly, we believe that our results open up new and exciting avenues for investigating the role of memory, information structure, discourse, and perceptual factors in the encoding and retrieval of words during sentence and/or discourse processing. For example, if our results indeed generalize to other languages, how would they contribute to our understanding of encoding and retrieval operations during language processing? Would variations in memory capacity and linguistic knowledge modulate the modifier position effect? We believe that further experimental as well as modeling research investigating these (and similar) questions would considerably improve our understanding of how words and encoded and retrieved during language production and comprehension.

Another limitation of our study is that most of the adjectives that we employed lend themselves to "intersective" as opposed nonintersective interpretations. An intersective interpretation of an adjective applies the quality of the adjective to the real-life referent of the noun, whereas a nonintersective interpretation does not apply the quality to the referent entirely but to some subset of it. For instance, in *Arthur was a brave king*, the intersective interpretation would be that Arthur is a king and Arthur is brave, whereas a nonintersective interpretation would be that Arthur is brave as a king but not necessarily brave in his other roles (say, as a husband). It is therefore unclear what effect these two particular semantic interpretations might have an impact on the accessibility of associated NPs and future research is required to investigate this issue. A final limitation of our study is that we did not use strongly constraining adjectives, thereby rendering the head nouns not maximally predictable in the case of premodified NPs. Future research should look into the potential effect of the constraining power of adjectives on the subsequent accessibility of the head of pre- versus postmodified NPs.

Conclusion

In four experiments, we demonstrated that postmodified NPs are encoded more robustly in memory than are premodifiers, leading to easier subsequent retrieval. These results are the first showing encoding variations as a function of modifier position. Our results contribute to the current memory-based models of language processing by showing that distinctiveness alone cannot account for the retrieval ease of semantically rich NPs, that the effect of time-based decay is overridden by the accessibility conferred by postmodifiers, and also that predictability of the head noun does not facilitate encoding. We suggest that processes related to perception, memory, and information structure are responsible for this effect. Future experimental and modeling research in English and other languages is required to tease apart the relative contributions of these cognitive factors.

References

Almor, A. (1999). Noun-phrase anaphors and focus: The informational load hypothesis. *Psychological Review, 106,* 748–765. http://dx.doi.org/10.1037/0033-295X.106.4.748

Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S., Lebiere, C., & Qin, Y. (2004). An integrated theory of the mind. *Psychological Review, 111,* 1036–1060. http://dx.doi.org/10.1037/0033-295X.111.4.1036

Ariel, M. (1990). *Accessing noun-phrase antecedents*. London, UK: Routledge.

Ariel, M. (1991). The function of accessibility in a theory of grammar. *Journal of Pragmatics, 16,* 443–463. http://dx.doi.org/10.1016/0378-2166(91)90136-L

Ariel, M. (1996). Referring expressions and the ± coreference distinction. In J. K. G. T. Fretheim (Ed.), *Reference and referent accessibility* (pp. 13–35). Amsterdam, the Netherlands: Benjamins. http://dx.doi.org/10.1075/pbns.38.02ari

Arnett, N., & Wagers, M. (2017). Subject encodings and retrieval interference. *Journal of Memory and Language, 93,* 22–54. http://dx.doi.org/10.1016/j.jml.2016.07.005

Arnold, J. E. (2001). The effect of thematic roles on pronoun use and frequency of reference continuation. *Discourse Processes, 31,* 137–162. http://dx.doi.org/10.1207/S15326950DP3102_02

Arnold, J., & Griffin, Z. M. (2007). The effect of additional characters on choice of referring expression: Everyone counts. *Journal of Memory and Language, 56,* 521–536. http://dx.doi.org/10.1016/j.jml.2006.09.007

Baddeley, A. D. (1986). *Working memory*. Oxford, UK: Clarendon Press.

Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4,* 417–423. http://dx.doi.org/10.1016/S1364-6613(00)01538-2

Baker, L., & Wagner, J. L. (1987). Evaluating information for truthfulness: The effects of logical subordination. *Memory & Cognition, 15,* 247–255.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68,* 255–278. http://dx.doi.org/10.1016/j.jml.2012.11.001

Benatar, A., & Clifton, C., Jr. (2014). Newness, givenness and discourse updating: Evidence from eye movements. *Journal of Memory and Language, 71,* 1–16. http://dx.doi.org/10.1016/j.jml.2013.10.003

Bock, J. K. (1982). Toward a cognitive psychology of syntax: Information processing contributions to sentence formulation. *Psychological Review, 89,* 1–47. http://dx.doi.org/10.1037/0033-295X.89.1.1

Bock, J. K., & Warren, R. K. (1985). Conceptual accessibility and syntactic structure in sentence formulation. *Cognition, 21,* 47–67. http://dx.doi.org/10.1016/0010-0277(85)90023-X

Branigan, H. P., Pickering, M. J., & Tanaka, M. (2008). Contributions of animacy to grammatical function assignment and word order during production. *Lingua, 118,* 172–189. http://dx.doi.org/10.1016/j.lingua.2007.02.003

Brennan, S. E. (1995). Centering attention in discourse. *Language and Cognitive Processes, 10,* 137–167. http://dx.doi.org/10.1080/01690969508407091

Brennan, S. E., Friedman, M. W., & Pollard, C. J. (1987, July). *A centering approach to pronouns*. Poster presented at the Proceedings of the 25th annual meeting on Association for Computational Linguistics, Stanford, CA.

Chafe, W. L. (1976). Givenness, contrastiveness, definiteness, subjects, topics, and point of view. In C. N. Li (Ed.), *Subject and topic* (pp. 25–56). New York, NY: Academic Press.

Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. *Psychological Review, 113,* 234–272. http://dx.doi.org/10.1037/0033-295X.113.2.234

Chang, F., Dell, G. S., Bock, K., & Griffin, Z. M. (2000). Structural priming as implicit learning: A comparison of models of sentence production. *Journal of Psycholinguistic Research, 29,* 217–229. http://dx.doi.org/10.1023/A:1005101313330

Chomsky, N. (1965). *Aspects of the theory of syntax*. Cambridge, MA: MIT Press.

Chomsky, N. (1971). Deep structure, surface structure, and semantic interpretation. In D. Steinberg & L. Jacobovits (Eds.), *Semantics, an interdisciplinary reader in linguistics, philosophy and psychology* (pp. 183–216). Cambridge, NY: Cambridge University Press.

Chomsky, N. (1986). *Knowledge of language: Its nature, origin, and use*. Westport, CT: Greenwood Publishing Group.

Chomsky, N. (1993). *Lectures on government and binding: The Pisa lectures* (No. 9). Berlin, Germany: Walter de Gruyter.

Chomsky, N. (1995). Categories and transformations. In N. Chomsky (Ed.), *The minimalist program* (pp. 219–394). Cambridge, MA: MIT Press.

Christianson, K., Hollingworth, A., Halliwell, J. F., & Ferreira, F. (2001). Thematic roles assigned along the garden path linger. *Cognitive Psychology, 42,* 368–407. http://dx.doi.org/10.1006/cogp.2001.0752

Christianson, K., Williams, C. C., Zacks, R. T., & Ferreira, F. (2006). Misinterpretations of garden-path sentences by older and younger adults. *Discourse Processes, 42,* 205–238. http://dx.doi.org/10.1207/s15326950dp4202_6

Clark, A. (2013). Whatever next? Predictive brains, situated agents, and the future of cognitive science. *Behavioral and Brain Sciences, 36,* 181–204. http://dx.doi.org/10.1017/S0140525X12000477

Clark, E., & Clark, H. (1978). Universals, relativity and language processing. In J. Greenberg (Ed.), *Universals of human language* (Vol. 1, pp. 225–277). Palo Alto, CA: Stanford University Press.

Conway, C. M., Bauernschmidt, A., Huang, S. S., & Pisoni, D. B. (2010). Implicit statistical learning in language processing: Word predictability is the key. *Cognition, 114,* 356–371. http://dx.doi.org/10.1016/j.cognition.2009.10.009

Cook, A. E. (2014). Processing anomalous anaphors. *Memory & Cognition, 42,* 1171–1185. http://dx.doi.org/10.3758/s13421-014-0415-0

Dell, G. S., McKoon, G., & Ratcliff, R. (1983). The activation of antecedent information during the processing of anaphoric reference in reading. *Journal of Verbal Learning and Verbal Behavior, 22,* 121–132. http://dx.doi.org/10.1016/S0022-5371(83)80010-3

De Smedt, K., & Kempen, G. (1987). Incremental sentence production, self-correction and coordination. In *Natural language generation* (pp. 365–376). Dordrecht, the Netherlands: Springer. http://dx.doi.org/10.1007/978-94-009-3645-4_23

Dillon, B. W. (2011). *Structured access in sentence comprehension* (PhD dissertation). University of Maryland, College Park, MD.

Dillon, B., Chow, W. Y., Wagers, M., Guo, T., Liu, F., & Phillips, C. (2014). The structure-sensitivity of memory access: Evidence from Mandarin Chinese. *Frontiers in Psychology, 5,* 1025. http://dx.doi.org/10.3389/fpsyg.2014.01025

Dillon, B., Clifton, C., Jr., & Frazier, L. (2014). Pushed aside: Parentheticals, memory and processing. *Language, Cognition and Neuroscience, 29,* 483–498. http://dx.doi.org/10.1080/01690965.2013.866684

Dillon, B., Clifton, C., Jr., Sloggett, S., & Frazier, L. (2017). Appositives and their aftermath: Interference depends on at-issue vs. not-at-issue status. *Journal of Memory and Language, 96,* 93–109. http://dx.doi.org/10.1016/j.jml.2017.04.008

Ferreira, F. (2003). The misinterpretation of noncanonical sentences. *Cognitive Psychology, 47,* 164–203. http://dx.doi.org/10.1016/S0010-0285(03)00005-7

Ferreira, F., Bailey, K. G., & Ferraro, V. (2002). Good-enough representations in language comprehension. *Current Directions in Psychological Science, 11,* 11–15. http://dx.doi.org/10.1111/1467-8721.00158

Ferreira, F., Christianson, K., & Hollingworth, A. (2001). Misinterpretations of garden-path sentences: Implications for models of sentence

processing and reanalysis. *Journal of Psycholinguistic Research, 30,* 3–20. http://dx.doi.org/10.1023/A:1005290706460

Ferreira, F., & Henderson, J. M. (1990). Use of verb information in syntactic parsing: Evidence from eye movements and word-by-word self-paced reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 555–568. http://dx.doi.org/10.1037/0278-7393.16.4.555

Ferreira, F., & Lowder, M. W. (2016). Prediction, information structure, and good-enough language processing. *Psychology of Learning and Motivation, 65,* 217–247. http://dx.doi.org/10.1016/bs.plm.2016.04.002

Ferreira, F., & Swets, B. (2002). How incremental is language production? Evidence from the production of utterances requiring the computation of arithmetic sums. *Journal of Memory and Language, 46,* 57–84. http://dx.doi.org/10.1006/jmla.2001.2797

Ferreira, V. S. (1996). Is it better to give than to donate? Syntactic flexibility in language production. *Journal of Memory and Language, 35,* 724–755. http://dx.doi.org/10.1006/jmla.1996.0038

Fletcher, C. R. (1984). Markedness and topic continuity in discourse processing. *Journal of Verbal Learning and Verbal Behavior, 23,* 487–493. http://dx.doi.org/10.1016/S0022-5371(84)90309-8

Foraker, S., & McElree, B. (2007). The role of prominence in pronoun resolution: Active versus passive representations. *Journal of Memory and Language, 56,* 357–383.

Fukumura, K., & Van Gompel, R. P. G. (2010). Choosing anaphoric expressions: Do people take into account likelihood of reference? *Journal of Memory and Language, 62,* 52–66. http://dx.doi.org/10.1016/j.jml.2009.09.001

Fukumura, K., & Van Gompel, R. P. G. (2011). The effects of animacy in the choice of referring expressions. *Language and Cognitive Processes, 26,* 1472–1504. http://dx.doi.org/10.1080/01690965.2010.506444

Gallo, D. A., Meadow, N. G., Johnson, E. L., & Foster, K. T. (2008). Deep levels of processing elicit a distinctiveness heuristic: Evidence from the criterial recollection task. *Journal of Memory and Language, 58,* 1095–1111. http://dx.doi.org/10.1016/j.jml.2007.12.001

Gelman, A., & Hill, J. (2006). *Data analysis using regression and multilevel/hierarchical models*. New York, NY: Cambridge University Press. http://dx.doi.org/10.1017/CBO9780511790942

Gernsbacher, M. A. (1989). Mechanisms that improve referential access. *Cognition, 32,* 99–156. http://dx.doi.org/10.1016/0010-0277(89)90001-2

Gernsbacher, M. A., & Hargreaves, D. J. (1988). Accessing sentence participants: The advantage of first mention. *Journal of Memory and Language, 27,* 699–717. http://dx.doi.org/10.1016/0749-596X(88)90016-2

Gerrig, R. J., & McKoon, G. (1998). The readiness is all: The functionality of memory-based text processing. *Discourse Processes, 26,* 67–86. http://dx.doi.org/10.1080/01638539809545039

Gibson, E. (1998). Linguistic complexity: Locality of syntactic dependencies. *Cognition, 68,* 1–76. http://dx.doi.org/10.1016/S0010-0277(98)00034-1

Givón, T. (1983). Topic continuity in discourse: An introduction. In T. Givón (Ed.), *Topic continuity in discourse: A quantitative cross-language study* (pp. 1–41). Amsterdam, the Netherlands: John Benjamins. http://dx.doi.org/10.1075/tsl.3.01giv

Gordon, P. C., Grosz, B. J., & Gilliom, L. A. (1993). Pronouns, names, and the centering of attention in discourse. *Cognitive Science, 17,* 311–347. http://dx.doi.org/10.1207/s15516709cog1703_1

Grosz, B. J., Joshi, A. K., & Weinstein, S. (1995). Centering: A framework for modelling the local coherence of discourse. *Computational Linguistics, 21,* 203–225.

Gundel, J. K. (1978). Stress, pronominalization and the given-new distinction. *University of Hawaii Working Papers in Linguistics, 10,* 1–13.

Gundel, J. K. (1988). Universals of topic-comment structure. *Studies in Syntactic Typology, 17,* 209–239.

Gundel, J. K., & Fretheim, T. (2004). Topic and focus. *The Handbook of Pragmatics, 175,* 196.

Gundel, J. K., Hedberg, N., & Zacharski, R. (1993). Cognitive status and the form of anaphoric expressions in discourse. *Language, 69,* 274–307. http://dx.doi.org/10.2307/416535

Hale, J. (2001). A probabilistic Earley parser as a psycholinguistic model. *Proceedings of North American Association of Computational linguistics, 2,* 159–166.

Hale, J. (2006). Uncertainty about the rest of the sentence. *Cognitive Science, 30,* 643–672. http://dx.doi.org/10.1207/s15516709cog0000_64

Halliday, M. (1967). Notes on transitivity and theme in English, Part II. *Journal of Linguistics, 3,* 199–244. http://dx.doi.org/10.1017/S0022226700016613

Haviland, S. E., & Clark, H. H. (1974). What's new? Acquiring new information as a process in comprehension. *Journal of Verbal Learning and Verbal Behavior, 13,* 512–521. http://dx.doi.org/10.1016/S0022-5371(74)80003-4

Hemforth, B., Konieczny, L., & Scheepers, C. (2000). Syntactic attachment and anaphor resolution: The two sides of relative clause attachment. In M. Crocker, M. Pickering, & C. Clifton (Eds.), *Architectures and mechanisms for language processing* (pp. 259–281). Cambridge, NY: Cambridge University Press.

Hofmeister, P. (2011). Representational complexity and memory retrieval in language comprehension. *Language and Cognitive Processes, 26,* 376–405. http://dx.doi.org/10.1080/01690965.2010.492642

Hofmeister, P., & Vasishth, S. (2014). Distinctiveness and encoding effects in online sentence comprehension. *Frontiers in Psychology, 5,* 1237. http://dx.doi.org/10.3389/fpsyg.2014.01237

Hopman, E. W. M., & MacDonald, M. C. (2018). Production practice during language learning improves comprehension. *Psychological Science, 29,* 961–971. http://dx.doi.org/10.1177/0956797618754486

Jackendoff, R. (1972). *Semantic interpretation in generative grammar*. Cambridge, MA: MIT Press.

Jacoby, L., & Craik, F. (1979). Effects of elaboration of processing at encoding and retrieval: Trace distinctiveness and recovery of initial context. In L. Cermak & F. Craik (Eds.), *Levels of processing in human memory* (pp. 1–21). Hillsdale, NJ: Erlbaum.

Jaeger, T. F., Fedorenko, E., & Gibson, E. (2005, April). *Dissociation between production and comprehension complexity*. In Poster Presentation at the 18th Annual CUNY Sentence Processing Conference, Tuscon, AZ.

Jaeger, T. F. (2010). Redundancy and reduction: Speakers manage syntactic information density. *Cognitive Psychology, 61,* 23–62. http://dx.doi.org/10.1016/j.cogpsych.2010.02.002

Jäger, L. A., Engelmann, F., & Vasishth, S. (2017). Similarity-based interference in sentence comprehension: Literature review and Bayesian meta-analysis. *Journal of Memory and Language, 94,* 316–339. http://dx.doi.org/10.1016/j.jml.2017.01.004

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99,* 122–149.

Karimi, H., & Ferreira, F. (2016a). Good-enough linguistic representations and online cognitive equilibrium in language processing. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 69,* 1013–1040. http://dx.doi.org/10.1080/17470218.2015.1053951

Karimi, H., & Ferreira, F. (2016b). Informativity renders a referent more accessible: Evidence from eyetracking. *Psychonomic Bulletin & Review, 23,* 507–525. http://dx.doi.org/10.3758/s13423-015-0917-1

Karimi, H., Fukumura, K., Ferreira, F., & Pickering, M. J. (2014). The effect of noun phrase length on the form of referring expressions. *Memory & Cognition, 42,* 993–1009. http://dx.doi.org/10.3758/s13421-014-0400-7

Karimi, H., Swaab, T. Y., & Ferreira, F. (2018). Electrophysiological evidence for an independent effect of memory retrieval on referential processing. *Journal of Memory and Language, 102,* 68–82. http://dx.doi.org/10.1016/j.jml.2018.05.003

Kempen, G., & Hoenkamp, E. (1987). An incremental procedural grammar for sentence formulation. *Cognitive Science, 11,* 201–258. http://dx.doi.org/10.1207/s15516709cog1102_5

Kleinschmidt, D., Fine, A. B., & Jaeger, T. F. (2012). A belief-updating model of adaptation and cue combination in syntactic comprehension. In *Proceedings of the 34th Annual Meeting of the Cognitive Science Society* (pp. 599–604). Austin, TX.

Konieczny, L. (2000). Locality and parsing complexity. *Journal of Psycholinguistic Research, 29,* 627–645. http://dx.doi.org/10.1023/A:1026528912821

Kush, D. (2013). *Respecting relations: Memory access and antecedent retrieval in incremental sentence processing* (PhD dissertation). University of Maryland, College Park, MD.

Lau, S. H., & Hwang, H. (2016). The effects of frequency on pronoun production. *Journal of Cognitive Science, 17,* 547–569. http://dx.doi.org/10.17791/jcs.2016.17.4.547

Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.

Levy, R. (2008). Expectation-based syntactic comprehension. *Cognition, 106,* 1126–1177. http://dx.doi.org/10.1016/j.cognition.2007.05.006

Lewis, R. L., & Vasishth, S. (2005). An activation-based model of sentence processing as skilled memory retrieval. *Cognitive Science, 29,* 375–419. http://dx.doi.org/10.1207/s15516709cog0000_25

Lewis, R. L., Vasishth, S., & Van Dyke, J. A. (2006). Computational principles of working memory in sentence comprehension. *Trends in Cognitive Sciences, 10,* 447–454. http://dx.doi.org/10.1016/j.tics.2006.08.007

Lucas, M. M., Tanenhaus, M. K., & Carlson, G. N. (1990). Levels of representation in the interpretation of anaphoric reference and instrument inference. *Memory & Cognition, 18,* 611–631. http://dx.doi.org/10.3758/BF03197104

Macdonald, M. C. (2013). How language production shapes language form and comprehension. *Frontiers in Psychology, 4,* 226. http://dx.doi.org/10.3389/fpsyg.2013.00226

MacDonald, M. C. (2016). Speak, act, remember: The language-production basis of serial order and maintenance in verbal memory. *Current Directions in Psychological Science, 25,* 47–53. http://dx.doi.org/10.1177/0963721415620776

MacDonald, M. C., & MacWhinney, B. (1990). Measuring inhibition and facilitation from pronouns. *Journal of Memory and Language, 29,* 469–492. http://dx.doi.org/10.1016/0749-596X(90)90067-A

McDonald, S. A., & Shillcock, R. C. (2003). Low-level predictive inference in reading: The influence of transitional probabilities on eye movements. *Vision Research, 43,* 1735–1751. http://dx.doi.org/10.1016/S0042-6989(03)00237-2

Nairne, J. S. (2006). Modeling distinctiveness: Implications for general memory theory. *Distinctiveness and Memory,* 27–46.

Parker, D., Shvartsman, M., & Van Dyke, J. A. (2017). The cue-based retrieval theory of sentence comprehension: New findings and new challenges. In L. Escobar, V. Torrens, & T. Parodi (Eds.), *Language processing and disorders* (pp. 121–144). Newcastle, UK: Cambridge Scholars Publishing.

Rosenbach, A. (2008). Animacy and grammatical variation—Findings from English genitive variation. *Lingua, 118,* 151–171. http://dx.doi.org/10.1016/j.lingua.2007.02.002

Rubio-Fernández, P. (2016). How redundant are redundant color adjectives? An efficiency-based analysis of color overspecification. *Frontiers in psychology, 7,* 153.

Sanford, A. J., & Garrod, S. C. (1981). *Understanding written language*. Chichester, UK: Wiley.

Sanford, A. J., & Garrod, S. (1989). What, when and how: Questions of immediacy in anaphoric reference resolution. *Language and Cognitive Processes, 4,* 235–263. http://dx.doi.org/10.1080/01690968908406369

Sanford, A. J., & Garrod, S. C. (2005). Memory-based approaches and beyond. *Discourse Processes, 39,* 205–224. http://dx.doi.org/10.1080/0163853X.2005.9651680

Sanford, A., & Sturt, P. (2002). Depth of processing in language comprehension: Not noticing the evidence. *Trends in Cognitive Sciences, 6,* 382–386. http://dx.doi.org/10.1016/S1364-6613(02)01958-7

Stallings, L. M., MacDonald, M. C., & O'Seaghdha, P. G. (1998). Phrasal ordering constraints in sentence production: Phrase length and verb disposition in heavy-NP shift. *Journal of Memory and Language, 39,* 392–417. http://dx.doi.org/10.1006/jmla.1998.2586

Stevenson, R. J., Crawley, R. A., & Kleinman, D. (1994). Thematic roles, focus and the representation of events. *Language and Cognitive Processes, 9,* 519–548. http://dx.doi.org/10.1080/01690969408402130

Troyer, M., Hofmeister, P., & Kutas, M. (2016). Elaboration over a discourse facilitates retrieval in sentence processing. *Frontiers in Psychology, 7,* 374. http://dx.doi.org/10.3389/fpsyg.2016.00374

Trueswell, J. C., Tanenhaus, M. K., & Kello, C. (1993). Verb-specific constraints in sentence processing: Separating effects of lexical preference from garden-paths. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 528–553. http://dx.doi.org/10.1037/0278-7393.19.3.528

Vallduví, E., & Vilkuna, M. (1998). On rheme and kontrast. *Syntax and Semantics, 29,* 79–108.

Van Dyke, J. A., & Lewis, R. L. (2003). Distinguishing effects of structure and decay on attachment and repair: A cue-based parsing account of recovery from misanalyzed ambiguities. *Journal of Memory and Language, 49,* 285–316. http://dx.doi.org/10.1016/S0749-596X(03)00081-0

Van Dyke, J. A., & McElree, B. (2011). Cue-dependent interference in comprehension. *Journal of Memory and Language, 65,* 247–263. http://dx.doi.org/10.1016/j.jml.2011.05.002

van Gompel, R. P., & Majid, A. (2004). Antecedent frequency effects during the processing of pronouns. *Cognition, 90,* 255–264. http://dx.doi.org/10.1016/S0010-0277(03)00161-6

Vasishth, S., & Lewis, R. L. (2006). Argument-head distance and processing complexity: Explaining both locality and anti-locality effects. *Language, 82,* 767–794. http://dx.doi.org/10.1353/lan.2006.0236

Wagers, M. W., & Phillips, C. (2014). Going the distance: Memory and control processes in active dependency construction. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 67,* 1274–1304. http://dx.doi.org/10.1080/17470218.2013.858363

Yamashita, H., & Chang, F. (2001). "Long before short" preference in the production of a head-final language. *Cognition, 81,* B45–B55. http://dx.doi.org/10.1016/S0010-0277(01)00121-4

(*Appendices follow*)

Appendix A

Experimental Stimuli for Experiments 1 and 2

Item	Sentence	Modification
1	The cameraman/actress slapped the actor.	frustrated and visibly upset
2	The boxer ignored the cowboy/cowgirl.	terribly distressed and anxious
3	The clergyman/monk supported the monk/ godmother.	worried
4	The choirboy/boy approached the boy scout/girl.	unpopular
5	The mermaid encountered the goddess/god.	fearless, brave, and adventurous
6	The stableman bothered the shepherd/shepherdess.	fussy and demanding
7	The saleswoman contacted the businesswoman/businessman.	rich and successful
8	The noblewoman blackmailed the countess/count.	struggling
9	The sorcerer misunderstood the god/goddess.	distracted
10	The housemaid followed the lady/gentleman.	tall and good-looking
11	The schoolgirl/schoolboy poked the woman.	lively and energetic
12	The ballerina/football player photographed the cheerleader.	outgoing and well-connected
13	The friar supported the congressman/congresswoman.	enthusiastic
14	The policeman/policewoman accused the detective.	undercover
15	The emperor/empress betrayed the colonel.	completely weak and powerless
16	The policewoman/stewardess helped the godmother/godfather.	wise and considerate
17	The baroness visited the empress/baron.	scared
18	The deliveryman phoned the milkman/maid.	impatient and terribly irate
19	The shepherdess/lady congratulated the princess/shepherd.	deeply happy and relieved
20	The nun attacked the widow/priest.	inexperienced
21	The governess bribed the mistress/governor.	cunning and appallingly dishonest
22	The headmaster tripped the governor/headmistress.	lazy and disorganized
23	The nobleman/heiress misled the lord.	greedy and selfish
24	The Dutchman/Dutchwoman rescued the sportsman.	strong and muscular
25	The gunman/ballerina shot the pilot.	heartless
26	The sorceress/wizard killed the witch.	cold and ruthless
27	The baron/heroine defied the bishop.	panicked and incompetent
28	The bachelorette spotted the girl/bachelor.	smart and vigilant
29	The chairwoman/chairman argued with the duchess.	obstinate and confrontative
30	The camerawoman/cameraman welcomed the actress/camerawoman.	world-famous
31	The wizard/sorceress trapped the sailor.	loyal and patriotic
32	The choirgirl/choirboy photographed the bridesmaid.	creative and artistic
33	The housewife mistreated the maid/milkman.	mentally ill
34	The barmaid missed the waitress/waiter.	kind and caring
35	The clergyman supported the monk/priestess.	knowledgeable and dedicated
36	The salesgirl/salesman consulted with the nanny.	sad and lonely
37	The horseman intimidated the huntsman/queen.	courageous
38	The fisherman negotiated with the gentleman/salesgirl.	highly cautious
39	The anchorman debated with the spokesman/spokeswoman.	eloquent and articulate
40	The prince/princess criticized the king.	cruel and merciless

Note. Only the unmodified (baseline) condition is shown. Premodified and postmodified versions can be made by attaching the modification to the two NPs as preceding adjectives, or as postmodifying relative clauses (using "who was"), respectively. The experimental stimuli for Experiment 2 can be constructed by replacing the underlined NP with the NP to the left of "/".

(*Appendices continue*)

Appendix B

The Raw Frequencies of Talking About NP1, NP2, and Excluded Responses in Experiment 1

Modifier position	NP Type	Choice	Frequency	% NP1 Reference
Baseline	Baseline	NP1	126	33.96
Baseline	Baseline	NP2	245	
Baseline	Excluded	Excluded	109	—
Premodified	Target	NP1	134	37.12
Premodified	Target	NP2	227	
Premodified	Competitor	NP1	162	39.42
Premodified	Competitor	NP2	249	
Premodified	Excluded	Excluded	188	—
Postmodified	Target	NP1	143	41.45
Postmodified	Target	NP2	202	
Postmodified	Competitor	NP1	167	40.73
Postmodified	Competitor	NP2	243	
Postmodified	Excluded	Excluded	205	—

Appendix C

The Raw Frequencies of Pronominal Reference to Targets and Competitors in Experiment 1

Modifier position	NP Type	Form	Frequency	% Pronominal Reference
Baseline	Baseline	Pronoun	113	30
Baseline	Baseline	Repeated Noun	258	
Premodified	Target	Pronoun	124	34
Premodified	Target	Repeated Noun	237	
Premodified	Competitor	Pronoun	122	30
Premodified	Competitor	Repeated Noun	289	
Postmodified	Target	Pronoun	136	39
Postmodified	Target	Repeated Noun	209	
Postmodified	Competitor	Pronoun	101	25
Postmodified	Competitor	Repeated Noun	309	

Appendix D

The Full Results for Talking About NP1 Versus NP2 in Experiment 1

Analysis	Contrast	β	*SE*	*z*	*p*
Modification Type	PreM_Target vs. Baseline	.09	.17	.55	.58
	PostM_Target vs. Baseline	.27	.17	1.58	.11
	PreM_Target vs. PostM_Target	.18	.17	1.04	.29
Relative Richness	Modifier Position	.11	.10	1.12	.26
	NP Type	−.03	.10	−.32	.74
	Modifier Position × NP Type	.12	.21	.60	.54
	NP Type within PreM	.17	.17	.97	.33
	NP Type within PostM	.04	.18	.23	.81

(*Appendices continue*)

Appendix E

The Raw Frequencies of Talking About NP1, NP2, and "Other" (i.e., Excluded) Responses in Experiment 2

Modifier position	NP Type	Choice	Frequency	% NP1 Reference
Baseline	Baseline	NP1	142	40.69
Baseline	Baseline	NP2	207	
Baseline	Other	Other	211	—
Premodified	Target	NP1	186	50.68
Premodified	Target	NP2	181	
Premodified	Competitor	NP1	161	47.92
Premodified	Competitor	NP2	175	
Premodified	Other	Other	417	—
Postmodified	Target	NP1	140	46.36
Postmodified	Target	NP2	162	
Postmodified	Competitor	NP1	152	41.19
Postmodified	Competitor	NP2	217	
Postmodified	Other	Other	449	—

Appendix F

The Raw Frequencies of Pronominal Reference to NP1 and NP2 in Experiment 2

Modifier position	NP Type	Form	Frequency	% Pronominal Reference
Baseline	Baseline	Pronoun	143	40.97
Baseline	Baseline	Repeated Noun	206	
Premodified	Target	Pronoun	191	52.04
Premodified	Target	Repeated Noun	176	
Premodified	Competitor	Pronoun	158	47.02
Premodified	Competitor	Repeated Noun	178	
Postmodified	Target	Pronoun	168	55.63
Postmodified	Target	Repeated Noun	134	
Postmodified	Competitor	Pronoun	158	42.82
Postmodified	Competitor	Repeated Noun	211	

Appendix G

The Full Results for Talking About Each NP in Experiment 2

Analysis	Contrast	β	*SE*	*z*	*p*
Modification Type	PreM_Target vs. Baseline	.39	.17	2.28	.02
	PostM_Target vs. Baseline	.19	.18	1.05	.29
	PreM_Target vs. PostM_Target	−.20	.17	−1.13	.25
Relative Richness	Modifier Position	−.21	.11	−1.96	.04
	NP Type	.16	.11	1.45	.14
	Modifier Position × NP Type	.09	.28	.34	.73
	NP Type Within PreM	−.02	.18	−.13	.89
	NP Type Within PostM	−.20	.25	−.82	.41

(*Appendices continue*)

Appendix H

Experimental Stimuli for Experiment 3

Item	Sentence	NP1 modification	NP2 modification
1	The carpet mesmerized the photographer for hours in the museum.	ancient and ornate	stylish and artistic
2	The castle pleased the knight after the long and dangerous expedition.	clean and orderly	prim and proper
3	The necklace had sentimental value for the miner.	fine and golden	lonely and emotional
4	The chain disgusted the stuntman.	slimy and filthy	pampered
5	The mural delighted the painter during the exhibition.	lively and colorful	internationally famous
6	The fire strengthened the hunter on the cold winter night.	warm and crackling	scared
7	The statue resembled the warrior from a distance.	marble and detailed	brave and crafty
8	The wave made the surfer very anxious.	enormous and rapid	naïve and reckless
9	The helicopter reached the tourist within the hour.	swift and agile	distraught and injured
10	The rope frustrated the climber during the descent.	tangled and slippery	skilled and professional
11	The poll infuriated the politician greatly.	crucial and determining	rich and powerful
12	The tank startled the protestor a couple of times.	noisy and rumbling	meek and disoriented
13	The tractor terrified the cyclist.	rusty and sharp-bladed	drunk
14	The plan baffled the councilor quite a bit.	extensive and highly complicated	liberal and environmental
15	The battleship frightened the sniper all of a sudden.	huge and heavily armed	unsuspecting and overconfident
16	The raft rescued the mountaineer in the raging river.	strong and well-made	old and bearded
17	The newspaper undermined the fraudster at long last.	small but independent	dastardly
18	The ambulance took the boy to the hospital in time.	reliable and well-equipped	unconscious
19	The nail enabled the prisoner to break free.	long and narrow	patient and persistent
20	The noise made the guard suspicious in the dark night.	buzzing and strange	tired and cranky
21	The dungeon intimidated the slave at first sight.	dark and daunting	helpless and abused
22	The motorbike followed the lady for the whole day.	stealthy and quiet	short and brunette
23	The jeep transported the soldier across the battle field.	big and heavy-duty	wounded and bleeding
24	The cabin calmed the peasant during the storm.	sturdy, well-built and cozy	frail and vulnerable
25	The decision influenced the resident quite clearly.	hasty and irrational	newly-settled
26	The wagon irritated the cowboy all night long.	loud and extremely squeaky	exhausted
27	The cage guarded the girl during the raid.	empty and spacious	terribly frightened
28	The salary offended the executive a great deal.	unexpectedly low	cocky and entitled
29	The letter disillusioned the queen.	confidential and informative	kind and sympathetic
30	The gift made the youngster happy at the party.	expensive and unexpected	shy and reserved
31	The legislation disappointed the immigrant a great deal.	unfair and prodiscrimination	hopeful and hardworking
32	The gate nudged the doorman a bit.	wide open and wooden	distracted and confused
33	The plane endangered the pilot quite seriously.	new and untested	newly-trained
34	The island astonished the mermaid at the end of the long journey.	stunningly beautiful	miserable and desperate
35	The portrait amused the artist quite noticeably.	priceless and masterfully drawn	very curious
36	The condition satisfied the applicant in most cases.	realistic and sensible	unbelievably ambitious
37	The stained glass enchanted the villager for hours on end.	intricate and vibrant	humble and pious
38	The mannequin shocked the passer-by a couple of times.	eerily and lifelike	mentally unstable
39	The salad impressed the customer yesterday.	fresh and organic	adventurous and gluttonous
40	The moon inspired the novelist.	bright and full	young and promising
41	The report confused the officer throughout the investigation.	poorly written and unconfirmed	belligerent and short-tempered
42	The boat stressed out the swimmer in the lagoon.	seemingly out-of-control and swerving	poor and timid
43	The song entertained the teenager throughout the night.	catchy and widely popular	homeless and disheveled
44	The food poisoned the diner quite seriously.	weird and sour-tasting	slim and petite
45	The sandwich worried the grandma during the lunch rush.	sloppily-made and discolored	finicky and picky
46	The cookie made the child salivate profusely.	aromatic and delicious-looking	hungry and hyperactive
47	The magazine disturbed the newsreader yesterday.	alien and occult	unbelievably paranoid
48	The steamboat troubled the sailor for the whole day.	large, heavy and slow	crazy and overweight
49	The vehicle provoked the driver into an accident.	damaged and speeding	rushed and frantic
50	The sled carried the Eskimo during the hunting trip.	traditional but very efficient	unrelenting and muscular

(*Appendices continue*)

Appendix I

The Raw Frequencies of Talking About NP1, NP2, and "Other" (i.e., Excluded) Responses in Experiment 3

Modifier position	NP Type	Choice	Frequency	% NP1 Reference
Baseline	Baseline	NP1	90	25.94
Baseline	Baseline	NP2	257	
Baseline	Other	Other	243	
Premodified	Target	NP1	63	18.81
Premodified	Target	NP2	272	
Premodified	Competitor	NP1	77	19.64
Premodified	Competitor	NP2	315	
Premodified	Other	Other	453	
Postmodified	Target	NP1	78	22.81
Postmodified	Target	NP2	264	
Postmodified	Competitor	NP1	73	18.72
Postmodified	Competitor	NP2	317	
Postmodified	Other	Other	448	

Appendix J

The Raw Frequencies of Pronominal Reference to NP1 and NP2 in Experiment 3

Modifier position	NP Type	Form	Frequency	% Pronominal Reference
Baseline	Baseline	Pronoun	216	62.25
Baseline	Baseline	Repeated Noun	131	
Premodified	Target	Pronoun	230	68.66
Premodified	Target	Repeated Noun	105	
Premodified	Competitor	Pronoun	256	65.31
Premodified	Competitor	Repeated Noun	136	
Postmodified	Target	Pronoun	240	70.18
Postmodified	Target	Repeated Noun	102	
Postmodified	Competitor	Pronoun	245	62.82
Postmodified	Competitor	Repeated Noun	145	

Appendix K

The Full Results for Talking About Each NP in Experiment 3

Analysis	Contrast	β	*SE*	*z*	*p*
Modification Type	PreM_Target vs. Baseline	−.40	.20	−2.01	.04
	PostM_Target vs. Baseline	−.17	.19	−.92	.35
	PreM_Target vs. PostM_Target	.22	.20	1.09	.27
Relative Richness	Modifier Position	.09	.13	.69	.48
	NP Type	.09	.13	.74	.45
	Modifier Position × NP Type	.30	.26	1.15	.24
	NP Type Within PreM	.13	.26	.49	.62
	NP Type Within PostM	−.20	.19	−1.05	.29

(*Appendices continue*)

Appendix L

The Full Results for Talking About Each NP in the Combined Data From Experiments 1, 2, and 3

Analysis	Contrast	β	*SE*	*z*	*p*
Modification Type	PreM_Target vs. Baseline	.07	.10	.74	.45
	PostM_Target vs. Baseline	.12	.10	1.12	.26
	PreM_Target vs. PostM_Target	.04	.10	.40	.68
Relative Richness	Modifier Position	−.02	.06	−.36	.71
	NP Type	.08	.06	1.27	.20
	Modifier Position × NP Type	.09	.12	.71	.47
	NP Type Within PreM	.05	.10	.48	.62
	NP Type Within PostM	−.13	.11	−1.16	.24

Appendix M

Experimental Stimuli for Experiment 4

Item	Sentence 1/Sentence 2	Modification/Question
1	The actor received an Oscar award last year.	very talented and ambitious
1	In a funny accident, however, he tripped on the red carpet.	He received an Oscar award a couple of years ago.
2	The cowgirl counted the tumbleweeds that rolled on by.	bored and listless
2	After a while, she gradually started to feel thirsty.	She started to feel sleepy.
3	The monk was in a cleaning frenzy.	severely anxious and frantic
3	By the end of the day, he made the monastery shine like a beacon.	No Question
4	The mermaid followed the current all the way to the magic island.	adventurous and daring
4	Right before sunrise, she could finally see the palm trees moving in the wind.	She wanted to go to an island.
5	The salesgirl found a new job.	extremely rude and distracted
5	But after only six weeks, she was fired and had to start over.	She lost her job very soon.
6	The businessman was going bankrupt.	impulsive and emotional
6	To everyone's surprise, he kept blaming other people for the predicament.	He refused to take responsibility for the bankruptcy.
7	The housemaid had the face of an angel.	kind and innocent
7	In a lucky incident, she was invited to model for a fashion magazine.	She was invited to act in a romance movie.
8	The schoolboy could never finish a test.	slow and annoying
8	After a few minutes into a test, he would start to dream of adventure and mischief.	He was very focused.
9	The actress wanted more money for the movie.	greedy and selfish
9	However, after a long discussion, she finally decided to sign the contract.	No Question
10	The boxer did not want to fight.	scared and unprepared
10	As an excuse, he told the press his arm was injured.	He told the truth to the press.
11	The godmother donated a lot of money to the hospital.	caring and selfless
11	Many years later, she had a successful heart surgery in the same hospital.	No Question
12	The boy was exceptionally good at math.	horribly mean and evil
12	After some research, it turned out that he had a psychological condition.	He had an astonishing talent in math
13	The girl went shopping on Sunday morning.	rich and fashionable
13	When the sun was setting, she finally finished shopping and returned home.	No Question
14	The king was diagnosed with a terminal disease.	cruel and merciless
14	For almost two months, he had no idea because no one would dare break the news to him.	No Question
15	The kitchenmaid made an ethnic dinner.	calm and organized
15	From the color of it, though, she realized the most important ingredient was missing.	No Question
16	The nun took care of the orphanage	trustworthy and motherly
16	According to the kids, she was the nicest person on Earth.	She was in charge of a day care center.
17	The football player was feeling a little dizzy.	overwhelmed and nervous
17	At the end of the game, he collapsed on the bench while walking.	No Question
18	The cheerleader had found a new hobby.	creative and artistic
18	Every day after work, she would collect leaves and petals.	No Question
19	The congressman made many bold promises.	power-hungry and misleading

(*Appendices continue*)

Appendix M (*continued*)

Item	Sentence 1/Sentence 2	Modification/Question
19	After the elections were over, he was not the same person at all.	No Question
20	The friar managed the huge ceremony.	smooth and savvy
20	For the whole following week, he was the talk of the town.	He supervised a big ceremony.
21	The policeman knocked on the door.	polite and civilized
21	With the strange noise, he was sure that something was going on in the house.	No Question
22	The detective was on a very difficult case.	shrewd and extremely intelligent
22	In an astonishing record, he solved it in just 24 hours.	No Question
23	The empress ruled for 50 years.	prosperous and affluent
23	When the kingdom fell, she committed suicide in prison.	No Question
24	The colonel led the war to victory.	strict and authoritative
24	After the war was formally over, he received a medal of honor from the president.	No Question
25	The stewardess had never seen such a strong wind during a flight.	poised and experienced
25	When the wings started fluttering, she started to feel very terrified.	No Question
26	The godfather was taking a trip across the country.	impatient and ill-tempered
26	Even at the destination, he never stopped complaining.	No Question
27	The baron was getting married.	humble and modest
27	When the ring went missing on the wedding day, he started to panic and broke his arm while searching for it.	No Question
28	The lady strolled through the park.	carefree and relaxed
28	On bright and sunny days, she would always take a walk in the local park.	No Question
29	The shepherd rounded up the flock.	careful and thorough
29	With the dense and dark clouds, he wanted to make sure the sheep will be safe.	No Question
30	The priest left home in the early morning.	pious and devout
30	For the Sunday service, he would always get very excited.	No Question
31	The woman refused to listen.	biased and uncaring
31	According to everyone, she was totally beyond reasoning.	No Question
32	The ballerina performed during a dance festival.	graceful and enchanting
32	After the show, she received a standing ovation from the audience.	She performed during Christmas celebrations.
33	The widow was very unhappy.	sorrowful and miserable
33	For 20 years, she had been unsuccessful in finding the right man.	No Question

Received August 11, 2018
Revision received January 10, 2019
Accepted January 11, 2019 ■