Different time courses of integrative semantic processing for plural and singular nouns: implications for theories of sentence processing

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Received 19 March 2004; revised 30 June 2004; accepted 14 September 2004

Abstract

The research investigated the time course of integrative semantic processing during sentence processing. Reading time was measured on sentences containing an NP composed of an adjective and a noun whose combined meaning was plausible or anomalous (Experiment 1) or was typical or atypical (Experiment 2). The noun in the NP was either plural or singular. Plural nouns were expected to be more rapidly integrated with a preceding adjective than singular nouns because plural nouns can be ruled out as the first noun in a noun compound more rapidly than singular nouns. The results confirmed this prediction, showing that the effects of semantic plausibility and typicality were observed immediately during the processing of plural nouns, but were observed at a delay following the processing of singular nouns. Implications for theories of sentence processing are discussed.

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Over the last three decades, significant progress has been made in understanding the processes involved in sentence comprehension, particularly the processes involved in the resolution of syntactic ambiguity (see Clifton & Duffy, 2000; Frazier, 1997, 1998; MacDonald, 1997). In contrast, much less progress has been made in understanding the processes involved in semantic interpretation (see Ferreira, 2003; Frazier, 1997, 1998). Research has yet to determine how semantic interpretations are computed following
the processing of an incoming word and how a final interpretation is selected. Furthermore, much has yet to be learned about the working memory processes involved in language comprehension (see Gordon, Hendrick, & Levine, 2002; Kennison, 2004). The research described in this paper provides new evidence regarding the time course of integrative semantic processing during online reading comprehension. The results show that effects of semantic plausibility do not always emerge as soon as each new word is processed. For some words, such as plural nouns, effects of semantic plausibility are observed as soon as the word is encountered, but for other words, such as singular nouns, effects of semantic plausibility emerge later during processing.

Marslen-Wilson’s (1975) classic shadowing experiment established that semantic interpretation occurs incrementally during sentence processing. The results showed that comprehenders rapidly integrated an incoming word into a sentence context. Since then, numerous investigations have demonstrated that comprehenders semantically interpret an incoming word within several hundred milliseconds following its encoding. Kutas and colleagues (Kutas & Hillyard, 1980a–c, 1982; Kutas, Van Petten, & Besson, 1988) have observed differences in brain activity (i.e. event-related potentials, ERPs) following the encoding of a semantically anomalous word versus a semantically predictable word (see also De Vincenzi et al., 2003; Osterhout, McLaughlin, Allen, & Inoue, 2002). Differences in ERPs typically begin to emerge around 200 ms and peak around 400 ms following the presentation of a target word. Using eye tracking, Traxler and Pickering (1996) showed that the effect of semantic plausibility could be observed in a reader’s first fixation on a target word (i.e. within 250 ms). Similar estimates for the time course of semantic processing have been obtained in experiments in which participants’ eye movements are recorded as they listen to descriptions of visual displays of objects or listen to instructions directing them to manipulate the objects in the display (Allopenna, Magnuson, & Tanenhaus, 1998; Altmann & Kamide, 1999; Arnold, Eisenband, Brown-Schmidt, & Trueswell, 2000; Chambers, Eberhard, Filip, & Carlson, 2002; Eberhard, Spivey-Knowlton, Sedivy, & Tanenhaus, 1995; Kamide, Scheepers, & Abney, 2003; Sedivy, Tanenhaus, Chambers, & Carlson, 1999; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Trueswell, Sekerina, Hill, & Logrip, 1999).

Contemporary theories of sentence processing have offered different perspectives on when comprehenders initiate semantic interpretation of an incoming word. One of the most prominent and influential models of sentence processing, the garden path model (Frazier & Clifton, 1986; Frazier & Rayner, 1982; Rayner, Carlson, & Frazier, 1983), views semantic interpretation as generally following the construction of a syntactic analysis. The syntactic analysis is constructed using information about the incoming word’s major syntactic category (e.g. the X’s including noun, verb, adjective, etc.) and applying the appropriate syntactic parsing strategy (e.g. minimal attachment or late closure). Following the construction of a syntactic analysis, semantic interpretation can proceed. Due to the strict temporal ordering of syntactic analysis and semantic interpretation, semantic information cannot influence the construction of a syntactic analysis. The effects of semantic information that have been observed during the resolution of syntactic ambiguity have been interpreted as reflecting processes occurring after the determination of an initial syntactic analysis (Ferreira & Clifton, 1986; Kennison, 2001; Speer & Clifton, 1998).
The most prominent alternatives to the garden path approach have been interactive or constraint-based approaches to sentence processing. These approaches view language comprehension as being achieved through highly interactive, parallel processing (MacDonald, Pearlmutter, & Seidenberg, 1994; Sedivy et al., 1999; Tanenhaus et al., 1995; Taraban & McClelland, 1988; Trueswell & Tanenhaus, 1994; Trueswell, Tanenhaus, & Kello, 1993; Tyler & Marslen-Wilson, 1977). Candidate syntactic frames are generated from word-specific (or lexical) information. These syntactic frames are activated in parallel. The activation level of each of the syntactic frames is modulated by the amount of evidence available in the context to support it. Semantic interpretations are built on syntactic frames (MacDonald et al., 1994), but semantic information resulting from interpretative processing can influence the activation of syntactic frames. Consequently, syntactic and semantic analyses may influence one another. Advocates of this approach have argued that the effects of semantic information can occur at the earliest stages of processing (Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Taraban & McClelland, 1988; see also Trueswell, Tanenhaus, & Garnsey, 1994).

Proponents of these two theoretical camps have developed different views regarding the time course of sentence analysis, specifically about the extent to which comprehenders may delay syntactic and semantic decisions. Advocates of the garden path approach have claimed that delays in syntactic and semantic analysis can occur under certain conditions. Frazier and Rayner (1987) proposed that when an incoming word has an ambiguous syntactic (or lexical) category (e.g. trains as in desert trains can be a noun or a verb), syntactic analysis is delayed until following sentence context can be used to disambiguate the syntactic category (c.f. MacDonald, 1993; see also Folk & Morrison, 2003; O’Seaghdha, 1989a,b). Frazier and Rayner (1990) also showed that semantic commitment is initially delayed for words having more than one meaning when they are preceded by a neutral context (e.g. pitcher can refer to a container or an athlete). They also showed that semantic commitment occurs rapidly for words having more than one sense (e.g. newspaper refers only to something that is read, but it may be the paper object or the organization) (see Frazier, Pacht, & Rayner, 1999 for additional case of immediate semantic commitment). Their results suggested that the amount of semantic commitment carried out for a word may vary and that in some circumstances “the human language processor … [may remain] uncommitted about certain features of meaning…” (p. 89).

In contrast, from the perspective of the interactive or constraint-based approaches, delays in sentence analysis are generally not expected. MacDonald (1993) claimed that the notion of delays in processing conflicts with constraint-based theories, because comprehenders can use “many kinds of information [to] rapidly constrain ambiguity resolution, beginning when the ambiguity is introduced” (p. 694). Sedivy et al. (1999) concluded that “there are no principled limits on the degree of incrementality of semantic processing… In cases of local indeterminacy, information from the context of the utterance can be used to pin down the meaning of a linguistic expression” (p. 114). Nevertheless, any delays in integrative processing that do occur can be explained by the availability of lexical information during processing, as semantic interpretations are viewed as built on syntactic frames, which are generated from lexical information. For example, Boland, Tanenhaus, Garnsey, and Carlson (1995) showed that lexical information influenced how rapidly comprehenders were influenced by semantic...
plausibility during the comprehension of sentences containing wh-questions (e.g. *Which client did John visit?*). Sentences similar to those in 1 were processed in a stop-making-sense judgment task. Sentences contained either biased transitive verbs, such as *visit*, which are used most often with a direct object, as in 1a and 1b, or object control verbs, such as *remind*, which can be used with a direct object NP as well as with an infinitive complement, as in 1c and 1d. For object control verbs, the noun following the

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sentence</th>
<th>Plausibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Biased Transitive Verb Conditions</td>
<td>a. Which client did the salesman visit while in the city?</td>
<td>Plausible</td>
</tr>
<tr>
<td></td>
<td>b. Which prize did the salesman visit while in the city?</td>
<td>Implausible</td>
</tr>
<tr>
<td>Object Control Verb Conditions</td>
<td>c. Which child did your brother remind to watch the show?</td>
<td>Plausible</td>
</tr>
<tr>
<td></td>
<td>d. Which movie did your brother remind to watch the show?</td>
<td>Implausible</td>
</tr>
</tbody>
</table>

wh-word (i.e. the filler noun) could be integrated either as a direct object of the matrix verb or as the object of the infinitive complement. The results showed that the effect of plausibility on the percentage of *NO* judgments (i.e. does not make sense) was observed earlier in processing for sentences containing biased transitive verbs, as in 1b versus 1a, than for sentences containing object control verbs, as in 1d versus 1c. Boland et al. (1995) concluded that during comprehension access to verb-specific lexical information, specifically verb argument structure, enables the processing system to assign “provisional interpretations that are consistent with the likely syntactic alternatives” (p. 800). Follow this view, when a transitive verb was encountered comprehenders began interpreting the verb and the filler noun. In contrast, when an object control verb was encountered, comprehenders considered all possible argument structures in parallel; thus, “both plausible and implausible [filler nouns] were assigned one of the thematic roles offered by the object control verb” (p. 786).

The purpose of the present research was to investigate further how semantic interpretation occurs during online reading comprehension. In the present research, it was reasoned that the time course of integrative semantic processing might be influenced by when comprehenders identify specific structural aspects of a clause or phrase. There have been numerous reading studies reported in which comprehenders take longer to read a word or phrase at the end of a clause than the same words not occurring at the end of the clause (Jarvella, 1971; Just & Carpenter, 1980; Kennison, 2004; Kennison, Sieck, & Briesch, 2003; Mitchell & Green, 1978; Rayner, Kambe, & Duffy, 2000; Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). These end-of-clause *wrap-up effects* have been viewed as resulting when comprehenders carry out high-level comprehension processes related to the integration of information within a clause (Just & Carpenter, 1980; Rayner et al., 1989).

The present research investigated the possibility that the timing of integrative semantic processing may be influenced by when comprehenders identify aspects of syntactic structure within phrases as well as clauses. A number of researchers have proposed that comprehenders may delay semantic interpretation of an NP until after the head of the phrase is encountered (Clifton & Ferreira, 1989; Kamp & Partee, 1995). Clifton and Ferreira (1989) suggested that the interpretation of an NP composed of an adjective and a noun is likely to occur after the head of the phrase has been encountered, as “the interpretation of an adjective (e.g. *red*) generally depends upon its head noun (compare *red*...
hair and red truck). As an extreme case, consider the adjectives good and big and fake. These adjectives do not permit narrowing of the set of referents prior to the receipt of their head noun” (p. 86). Kamp and Partee (1995) also recognized the importance of the head noun in NP interpretation. They provided an extensive examination of the semantics of NPs composed of a head noun preceded by a modifier (i.e. noun or adjective, as in giant midget or tall midget, respectively). They argued that regularities in the final interpretation of combinations such as giant midget support the view that the semantic interpretation of such NPs involves building an interpretation relative to the head of the phrase. The meanings of giant and midget are contradictory. If meaning were constructed incrementally, the combination giant midget would yield no interpretable combination. However, giant midget can be interpretation as referring to a midget who is unusually tall (i.e. for a midget). Kamp and Partee (1995) proposed the head primacy principle to account for this case and other similar cases: “in a modifier-head structure, the head is interpreted relative to the context of the whole constituent, and the modifier is interpreted relative to the local context created from the former context by the interpretation of the head” (p. 161).

Advocates of schema-based theories of conceptual combination (e.g. Murphy, 1990; Wisniewski, 1996) have also suggested that the head noun plays an important role in the interpretation of NPs composed of a head noun and a preceding modifier. A comprehender is believed to interpret an NP by selecting a specific dimension associated with the head noun and modifying it based on the meaning of the modifier. Murphy (1990) showed that participants took longer to judge adjective–noun combinations when the adjective and the noun shared an atypical relation (e.g. filthy hospital) than when the adjective and the noun shared a typical relation (e.g. clean hospital). Wisniewski (1996) showed that participants interpreted modifier–noun compounds by assigning a salient property of the modifier to the head. For example, box clock was interpreted as referring to a square clock. Wisniewski concluded that “the modifier concept provides a property that acts as source of information for the construction of a new property. The head concept provides constraints on how this property is created and instantiated” (p. 181). In these and similar investigations, processing cannot be interpreted as reflecting initial semantic interpretation on the NP. In Wisniewski (1996) studies, participants interpreted NPs off-line, a commonly used technique in the conceptual combination literature. In Murphy’s (1990) experiments, participants interpreted NPs in isolation or in a prose context; however, when NPs were presented in the prose context, critical responses were made following the processing of the prose passage.

A recent investigation by Sedivy et al. (1999) provided clear evidence that during the comprehension of NPs composed of an adjective and a noun, comprehenders do not delay the interpretation of an adjective until after a following noun is processed. In a series of experiments, participants listened to descriptions of visual displays while their eye movements were measured. Analyses of eye movement behavior showed that listeners rapidly interpreted imperative sentences containing an NP composed of an adjective and a noun (e.g. Touch the tall glass). Participants were shown visual displays containing four objects. For example, in Experiment 2, the displays contained: (1) an object that could be interpreted as the referent for the NP (e.g. a tall glass); (2) an instance of the noun in a contrasting form (e.g. short glass); (3) an instance of the adjective associated with
a different noun (e.g. tall pitcher); and (4) an object that was neither an instance of the noun or adjective (e.g. key). Analysis of listeners’ eye movement behavior indicated that prior to the presentation of the noun, participants began interpreting the adjective in relation to the visual display.

In the present research, it was reasoned that although some amount of interpretative processing certainly occurs within an NP prior to the processing of the noun, there may be stages of integrative semantic processing that occur only after the comprehender settles on basic aspects of the structural analysis of the incoming noun. When a comprehender encounters a noun following an adjective in English, there is an inherent ambiguity; the incoming noun may or may not be part of a noun compound. Consider the examples in 2. When the noun castle is encountered, it may be analyzed as being an uncompounded noun modified by the preceding adjective ancient, as in 2b, or it may be analyzed as part of a noun compound, as in 2c.

2  a. John said that the ancient castle…
b. John said that the ancient castle was…
c. John said that the ancient castle gate…

The ambiguity proves to be even more complex, because there are multiple types of noun compounds. Consider the examples in 3. The incoming noun may form a compound with a following noun, which is modified by the preceding adjective, as in 3a, or the incoming noun may be interpreted as modified by the preceding adjective and together they may modify the following noun, as in 3b. These two types of compounds have been referred to as left branching and right branching compounds, respectively (see Frazier, 1990).

3  a. …[shy] [castle caretaker]…
   right-branching compound
b. …[remote castle] [caretaker]…
   left-branching compound

Characterizing the ambiguity in syntactic terms is not straightforward, as there is disagreement among linguists regarding the syntactic structure of the NP (see for discussion Emonds, 2000; Haegeman, 1994; Spencer, 1991). A standard analysis within X’-theory is one in which the NP is a maximal projection of a lexical head N⁰. This standard analysis is displayed in Fig. 1. Abney (1987) proposed an alternative structure for the NP, one in which the structure of the NP is parallel to that of the sentence (S). As S is dominated by the functional projection IP (i.e. inflectional phrase), Abney (1987) proposed that the NP is dominated by the functional projection DP (i.e. determiner phrase). Fig. 2 displays this analysis. In psycholinguistic research, the debate about the syntactic structure of the NP has received little attention; however, among linguists, interest in Abney’s (1987) analysis has grown in recent years (see Benmamoun, 2003; Coene & D’hulst, 2003; Ritter, 1991; Siloni, 1997; Szabolcsi, 1987, 1994). For the purposes of the present investigation, the ambiguity occurring when a noun follows as adjective in English can be viewed as involving the level of N⁰; the incoming noun may be analyzed as a simple N⁰ containing only the incoming noun or the incoming noun may be analyzed as a complex N⁰ in which the incoming noun is the first noun in a multi-noun compound. It is not necessarily the case that analyzing an
incoming noun as a simple N0 would lead to an assignment of the noun as the head of the phrase. Even among linguistics who assume the standard analysis of NP, there has been debate regarding how the head of the NP is defined, particularly for morphologically complex nouns (see Di Sciullo & Williams, 1987; Lieber, 1983; Selkirk, 1982; Spencer, 1991; Williams, 1981).

The research described in this paper tested the hypothesis that the time course of integrative semantic processing occurring between a noun and preceding adjective may be influenced by when comprehenders determine that the incoming noun is not part of a compound. Following this hypothesis, comprehenders were expected to integrate plural nouns more rapidly during processing than singular nouns, because plural nouns can be more rapidly eliminated as being part of a compound than singular nouns. Prior research has shown that while singular nouns can be freely compounded in English, plural nouns are rarely compounded (Alegre & Gordon, 1996; Gordon, 1985; Haskell, MacDonald, & Seidenberg, 2003; Kiparsky, 1982). Consider the examples in 4. Kiparsky (1982) originally noted that plural nouns formed with the inflectional affix—s (i.e. regular plural nouns) yielded unacceptable noun compounds, as in 4a. In contrast, singular nouns and irregular plural nouns yielded acceptable compounds, as in 4b and 4c, respectively. Kiparsky (1982) argued that word formation processes are carried out in stages and proposed that the strict ordering of stages can explain the unacceptability of plural nouns
(i.e. level-ordering theory, see Spencer, 1991). Gordon (1985) found that children between the ages of 3 and 5 years formed compounds for singular nouns and irregular plural nouns, but avoided forming compounds using regular plural nouns. Gordon argued that the morphological processes resulting in the prohibition of plural noun compounds are
part of innate language knowledge that is available to the child during language acquisition (see Pinker, 1991, 1999 for discussion).

In a recent investigation, Haskell et al. (2003) investigated the frequency of occurrence in English for noun compounds formed with regular plural nouns, singular nouns, and irregular plural nouns. They analyzed the usage of English nouns in the Brown corpus available from the Penn Treebank project (Marcus, Santorini, & Mancinkiewicz, 1993). The corpus contains approximately one million words. The content includes a various printed (and some spoken) sources collected in the 1960s. Their results showed that regular plural nouns ($n = 44,317$) and irregular plural nouns ($n = 2040$) were each compounded only .5% of the time. In contrast, singular nouns ($n = 107,235$) were

![Plural Noun Conditions](image)

![Singular Noun Conditions](image)

Fig. 4. Mean reading time in milliseconds on regions 4–9 by condition from Experiment 2. The top panel displays mean reading time in milliseconds for plural noun conditions. The bottom panel displays mean reading time in milliseconds for singular noun conditions.
compounded 10% of the time. Haskell et al. (2003) also found that acceptability ratings for compounds containing a plural noun were generally low, while compounds containing singular nouns were generally high. They concluded that the acceptability of plural and singular noun compounds is best represented along a continuum. They claimed that the prohibition of plural noun compounds can be explained best within a constraint-based approach; the more similar a plural noun is to singular nouns in meaning and phonological form, the more acceptable the resulting plural noun compound will be.

Preliminary support for the hypothesis that the time course of integrative semantic processing may differ for plural and singular nouns was found in a survey of prior studies in which reading time was measured on sentences containing plausible and implausible phrases containing nouns (see Garnsey et al., 1997; Pickering & Traxler, 1998; Speer & Clifton, 1998). In these prior studies, when target regions contained many plural nouns, as was the case in the study reported by Speer and Clifton (1998) whose materials contained plural nouns about 50% of the time, the effect of semantic plausibility was observed relatively early in processing (i.e. on the region containing the target noun). When target regions contained mostly singular nouns, as was the case in Garnsey et al. (1997), the effect of semantic plausibility was quite small on the region containing the noun, but was much larger on the regions following the noun. When target regions contained no plural noun, as was the case in the materials tested by Pickering and Traxler (1998), the effect of semantic plausibility was observed at delay, on regions following the region containing the singular noun.

The present paper reports two reading experiments that provide additional evidence that the time course of integrative semantic processing differs for plural and singular nouns. In both experiments, reading time was compared for sentences containing an NP composed of an adjective and a noun. NPs were either semantically plausible or implausible (Experiment 1) or typical or atypical (Experiment 2). In both experiments, NPs were either singular or plural. Consider the examples of semantically plausible and implausible conditions in 5. The combination of the adjective and the noun is plausible in 5a and 5c, but implausible in 5b and 5d. There is ample evidence that

<table>
<thead>
<tr>
<th>5.</th>
<th>Singular noun conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. John said that the ancient castle… Plausible Combination</td>
<td></td>
</tr>
<tr>
<td>b. John said that the careful castle… Implausible Combination</td>
<td></td>
</tr>
<tr>
<td>Plural Noun Conditions</td>
<td></td>
</tr>
<tr>
<td>c. John said that the ancient castles… Plausible Combination</td>
<td></td>
</tr>
<tr>
<td>d. John said that the careful castles… Implausible Combination</td>
<td></td>
</tr>
</tbody>
</table>

words that do not fit plausibility into a context are processed more slowly then words that fit plausibly into a context (e.g. Balota, Pollatsek, & Rayner, 1985; Duffy, Henderson, & Morris, 1988; Ehrlich & Rayner, 1981; Simpson, Peterson, Casteel, & Burgess, 1989; Stanovich & West, 1979, 1981). The results of both experiments reported in this paper showed that for plural NPs, the effects of semantic plausibility and typicality occurred rapidly during the processing of the region containing plural nouns; however, for singular NPs, the effects of semantic plausibility and typicality occurred at a delay, on regions of the sentence following singular nouns.
1. Experiment 1

Reading time was measured on sentences containing NPs composed of an adjective and a noun whose combination was either plausible or anomalous. The noun in the combination was either plural, or singular. Nouns with salient count noun interpretations were used (see Akmajian, Demers, Farmer, & Harnish, 1995 for discussion of mass versus count nouns). All nouns referred to inanimate objects. NPs occurred in sentences composed of two clauses. The NP was always the subject of the second clause. Sample sentences are displayed in Table 1. Reading time was measured using a self-paced phrase-by-phrase moving window. In Table 1, asterisks indicate the presentation boundaries that were used in the experiment.

1.1. Method

1.1.1. Participants

Seventy-two undergraduates enrolled in psychology courses at Oklahoma State University participated in exchange for course credit. All were native speakers of American English and were naïve to the purposes of the experiment.

1.1.2. Materials

Sixteen sets of experimental sentences were constructed for the experiment. Each of the 16 sets of experimental sentences had four versions. Each experimental sentence in a set contained the same target noun. In two of the four versions, the noun was singular, and in the other two versions, the noun was plural. The adjective and the noun either formed a plausible or an anomalous combination. Adjectives that were used within the same sentence frame were closely matched on length (±2 characters) and printed frequency (as assessed by Francis & Kučera, 1982). Adjectives that were used in the anomalous condition were typical modifiers of animate nouns. Appendix A provides a complete list of experimental sentences used in Experiment 1.

In order to confirm that plausible and anomalous conditions differed as intended, plausibility ratings were obtained from an additional group of 40 undergraduates at

| Table 1 |
| Sample sentences from Experiment 1 |

<table>
<thead>
<tr>
<th>Adjective–noun condition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plural noun conditions</strong></td>
<td></td>
</tr>
<tr>
<td>Anomalous</td>
<td>Fred *read *that *the careful *castles *had been *studied *for *centuries <em>by historians.</em></td>
</tr>
<tr>
<td>Plausible</td>
<td>Fred *read *that *the ancient *castles *had been *studied *for *centuries <em>by historians.</em></td>
</tr>
<tr>
<td><strong>Singular noun conditions</strong></td>
<td></td>
</tr>
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<td>Anomalous</td>
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<td>Plausible</td>
<td>Fred *read *that *the ancient *castle *had been *studied *for *centuries <em>by historians.</em></td>
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Oklahoma State University. Each participant received a list of 105 adjective–noun combinations. Besides each adjective noun combination, a seven-point rating scale was presented (1 = low plausibility, 7 = high plausibility). Participants were instructed to circle the number that corresponded to their plausibility judgment. Of the 105 items in the questionnaire, 40 items had two versions, a plausible adjective–noun combination and an anomalous adjective–noun combination. Two counterbalancing lists were used to ensure that each noun was viewed only once by each participant, but was viewed equally often across participants paired with a plausible adjective and with an anomalous adjective. Each of the two counterbalancing lists was used to make a version of the questionnaire containing all singular nouns and a version of the questionnaire containing all plural nouns. Ten participants completed each of the resulting four lists. Of the 16 adjective–noun pairs used in Experiment 1, the mean ratings of plausibility for the four conditions were as follows: plausible combinations with a plural noun: 6.26 (SD = .30); plausible combinations with a singular noun: 6.23 (SD = .29); anomalous combinations with a plural noun: 1.45 (SD = .19); and anomalous combinations with a singular noun: 1.49 (SD = .21).

1.1.3. Procedure

Sentences were presented on a cathode ray tube (CRT) controlled by MicroExperimental Laboratory II (MEL2) on an IBM compatible microcomputer. Sentences were presented using a phrase-by-phrase self-paced moving window (Kennedy & Murray, 1984). This procedure involved the use of preview dashes. Readers were first presented with an array of dashes; each dash corresponded to the position of a letter in the current sentence. When the reader pressed a key, the first presentation region of the sentence appeared, replacing the corresponding dashes. When the reader completed reading the first presentation region and pressed a key again, the second presentation region appeared, replacing the corresponding dashes, and the first presentation region disappeared and was replaced with corresponding dashes. This procedure was repeated until the last presentation region was read. Each sentence was followed by a TRUE/FALSE comprehension question in order to ensure that participants were fully engaged in the task of comprehending sentences. Comprehension questions did not refer to meaning of the adjective–noun combinations. Four counterbalancing lists were used to ensure that each item was viewed in each condition equally often across participants. Each participant was randomly assigned to one of four counterbalancing lists. Each participant was tested individually in a private well-lit cubicle. Each participant was given a practice session of 16 sentences, followed by the set of 120 sentences, which was composed of 16 experimental sentences and 104 filler sentences. Filler sentences were constructed to be highly plausible and to involve a variety of sentence structures. Each participant received a unique random order for the 120 sentences. Each session lasted between 30 and 45 min.

1.1.4. Experimental design

A repeated measures design was used. The two within-participant factors were semantic plausibility (plausible vs. anomalous) and the type of noun (singular vs. plural).
1.2. Results and discussion

Accuracy to comprehension questions was 96% on average, indicating that participants complied with the instructions and were fully engaged in the comprehension task. Mean reading time in milliseconds was calculated at each presentation region for each condition. Regions 1 and 2 contained the subject of the sentence and the main verb, respectively. Region 3 contained the complementizer that. Region 4 contained the determiner and adjective in the target NP. The adjective either formed a plausible or anomalous combination with the following noun. Region 5 contained the target noun, which was either singular or plural. Regions 6–10 contained the remainder of the sentence, which was the same across all conditions. Table 2 displays these results. For both of the experiments reported in this paper, the reading time data were analyzed in analyses of variances (ANOVAs). Participants ($F_1$) and sentences ($F_2$) were treated as random effects, following Clark (1973). An alpha level of .05 was used.

The results showed that semantic plausibility influenced reading times earlier in processing for plural noun conditions than for singular noun conditions. Fig. 1 displays mean reading time for plural and singular noun conditions for regions 4–7. Reading time on the target noun in region 5 was significantly determined by an interaction of semantic plausibility and the type of the noun, as reading time on plural nouns was influenced by semantic plausibility, but reading time on singular nouns was not, $F_1(1,71) = 5.40; \text{MSE} = 103,437; P < .05; F_2(1,15) = 5.86; \text{MSE} = 24,964; P < .05$. Additional comparisons confirmed that the effect of semantic plausibility was significant for plural noun conditions, $F_1(1,71) = 9.47; \text{MSE} = 246,016; P < .05, F_2(1,15) = 4.76; \text{MSE} = 52,326; P < .05$, but was not significant for singular noun conditions, $F_s < 1$. Further comparisons revealed that reading time in anomalous conditions was significantly longer for plural nouns than for singular nouns, $F_1(1,71) = 12.93; \text{MSE} = 301,767; P < .05, F_2(1,15) = 12.42; \text{MSE} = 80,000; P < .05$, but reading time in plausible conditions did differ for plural and singular nouns, $F_s < 1$. At region 5, the main effects of semantic plausibility and the type of the noun were significant, $F_1(1,71) = 9.53; \text{MSE} = 207,261; P < .05, F_2(1,15) = 5.34; \text{MSE} = 58,564; P < .05$, and $F_1(1,71) = 7.03; \text{MSE} = 144,274; P < .05, F_2(1,15) = 3.22; \text{MSE} = 27,390; P < .05$, respectively.

Reading times on the regions 6 and 7, the two regions following the noun (Fig. 3), were influenced by semantic plausibility in both singular and plural noun conditions. Reading time on region 6 was significantly influenced by an main effect of semantic plausibility, $F_1(1,71) = 26.81; \text{MSE} = 575,575; P < .05, F_2(1,15) = 15.41; \text{MSE} = 129,789; P < .05$. The interaction between type of noun and semantic plausibility was not significant, $F_s < 1$. Additional comparisons confirmed that the effect of semantic plausibility was indeed significant for singular noun conditions, $F_1(1,71) = 19.02; \text{MSE} = 381,821; P < .05, F_2(1,15) = 15.03; \text{MSE} = 85,181; P < .05$, as well as plural noun conditions, $F_1(1,71) = 12.25; \text{MSE} = 207,025; P < .05, F_2(1,15) = 7.49; \text{MSE} = 47,355; P < .05$. The main effect of type of noun was not significant, $F_s < 1$. Reading time on region 7, two regions downstream from the target noun, was longer for anomalous conditions than for plausible conditions. The main effect of semantic plausibility was significant in the participants analysis only, $F_1(1,71) = 6.60; \text{MSE} = 49,324; P < .05, F_2(1,15) = 3.59; \text{MSE} = 10,252; P < .08$. The interaction between type of noun and semantic plausibility was not
The main effect of type of noun, $F_s < 1$. Analyses of reading time on regions 8–10 revealed no significant results.

Additional analyses were carried out to verify that semantic plausibility influenced reading time earlier for plural noun conditions than for singular noun conditions. Reading time for regions 5–7 was analyzed in ANOVAs in which presentation region, semantic plausibility, and type of noun were included as three within-participants factors. These analyses confirmed that reading time was significantly influenced by the three-way interaction involving presentation region, plausibility, and type of noun, $F_1(2,142) = 3.89$; $MSE = 64,924$; $P < .05$; $F_2(2,30) = 3.90$; $MSE = 17,687$; $P < .05$. Furthermore, these analyses showed that although the effect of semantic plausibility developed later for singular noun conditions than for plural noun conditions, the overall magnitude of the effect of semantic plausibility across the three presentation regions did not differ significantly for singular and plural noun conditions, as the interaction between the type of the noun and semantic plausibility was not significant, $F_s < 1$.

In sum, the results of Experiment 1 showed that the time course of integrative semantic processing differed for plural and singular nouns. These results provide the first evidence showing that the time course of online integrative processing differs for different types of nouns. A second experiment was conducted in order to confirm that the pattern of processing observed in Experiment 1 reflected general processing involved in the semantic interpretation of NPs, rather than processing specifically involved in the comprehension of semantic anomalies. In Experiment 1, adjectives and nouns in the semantically anomalous condition did not yield interpretable combinations (e.g. careful castles). The purpose of Experiment 2 was to determine whether the same pattern of processing would be observed when comprehenders process sentences containing NPs composed of an adjective and a noun whose meaning was always interpretable, even in low plausibility conditions.

Table 2
Mean reading time in milliseconds per presentation region by condition from Experiment 1

<table>
<thead>
<tr>
<th>Adjective–noun condition</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
<th>R9</th>
<th>R10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plural noun conditions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anomalous</td>
<td>446</td>
<td>466</td>
<td>417</td>
<td>560</td>
<td>667</td>
<td>566</td>
<td>449</td>
<td>483</td>
<td>480</td>
<td>722</td>
</tr>
<tr>
<td>Plausible</td>
<td>466</td>
<td>433</td>
<td>419</td>
<td>540</td>
<td>529</td>
<td>486</td>
<td>431</td>
<td>457</td>
<td>461</td>
<td>697</td>
</tr>
<tr>
<td>Difference</td>
<td>−20</td>
<td>+33</td>
<td>−2</td>
<td>+20</td>
<td>+138</td>
<td>+80</td>
<td>+18</td>
<td>+26</td>
<td>+19</td>
<td>+25</td>
</tr>
<tr>
<td><strong>Singular noun conditions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anomalous</td>
<td>444</td>
<td>460</td>
<td>437</td>
<td>573</td>
<td>550</td>
<td>562</td>
<td>471</td>
<td>449</td>
<td>488</td>
<td>745</td>
</tr>
<tr>
<td>Plausible</td>
<td>466</td>
<td>453</td>
<td>417</td>
<td>543</td>
<td>533</td>
<td>475</td>
<td>428</td>
<td>455</td>
<td>460</td>
<td>655</td>
</tr>
<tr>
<td>Difference</td>
<td>−22</td>
<td>+7</td>
<td>+20</td>
<td>+30</td>
<td>+17</td>
<td>+87</td>
<td>+43</td>
<td>−6</td>
<td>+28</td>
<td>+90</td>
</tr>
</tbody>
</table>

$^1$ Huynh-Feldt significance levels and errors are reported with unadjusted degrees of freedom for all analyses involving presentation region (see Huynh & Feldt, 1970).
2. Experiment 2

In Experiment 2, reading time was measured on sentences containing NPs composed of an adjective and a noun in which the adjective specified either a typical instance of the noun (e.g. salty olive) or an atypical instance of the noun (e.g. sugary olive) (see Murphy, 1990, for prior comparison of typical and atypical adjective–noun combinations). Unlike the semantic anomaly condition in Experiment 1, the atypical condition in Experiment 2 yielded an interpretation that could be integrated into the meaning of the sentence. As in Experiment 1, typical and atypical adjective–noun combinations were embedded in sentences composed of two clauses. The NP occurred as the subject of a complement clause. The noun was either plural or singular. As in Experiment 1, all nouns had salient count noun interpretations. Sample sentences are displayed in Table 3. Reading time was measured using a self-paced phrase-by-phrase moving window. In Table 3, asterisks indicate the presentation boundaries used in the experiment.

2.1. Method

2.1.1. Participants

Seventy-two additional undergraduates enrolled in psychology courses at Oklahoma State University participated in exchange for course credit. All were native speakers of American English and were naïve to the purposes of the experiment.

2.1.2. Materials

Sixteen additional sets of experimental sentences were constructed for Experiment 2. All sentences contained two clauses, a main clause followed by a complement clause. The subject NP of the complement clause was composed of an adjective and noun. Each experimental sentence within a set contained the same head noun. The noun was preceded by an adjective that resulted in a typical adjective noun combination or atypical adjective noun combination. The noun was either singular or plural. Typical and atypical adjective noun combinations were selected from Murphy (1990). Appendix B contains a complete list of the experimental sentences used in Experiment 2.

In order to confirm that typical and atypical combinations differed as intended, typicality ratings were obtained from an additional group of 40 undergraduates at Oklahoma State University. Each participant received a list of 40 adjective–noun combinations. Beside each adjective noun combination, a seven-point rating scale was

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Sample sentences from Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adjective–noun condition</strong></td>
<td><strong>Example sentence</strong></td>
</tr>
<tr>
<td><strong>Plural noun conditions</strong></td>
<td></td>
</tr>
<tr>
<td>Atypical</td>
<td>Hank <em>said</em> that the sugary <em>olives</em> were <em>likely</em> the source <em>of</em> the <em>bacteria.</em></td>
</tr>
<tr>
<td>Typical</td>
<td>Hank <em>said</em> that the salty <em>olives</em> were <em>likely</em> the source <em>of</em> the <em>bacteria.</em></td>
</tr>
<tr>
<td><strong>Singular noun conditions</strong></td>
<td></td>
</tr>
<tr>
<td>Atypical</td>
<td>Hank <em>said</em> that the sugary <em>olive</em> was <em>likely</em> the source <em>of</em> the <em>bacteria.</em></td>
</tr>
<tr>
<td>Typical</td>
<td>Hank <em>said</em> that the salty <em>olive</em> was <em>likely</em> the source <em>of</em> the <em>bacteria.</em></td>
</tr>
</tbody>
</table>
presented (1 = low typicality, 7 = high typicality). Participants were instructed to circle the number that corresponded to their plausibility judgment. Of the 40 items in the questionnaire, 16 items had two versions, a typical adjective–noun combination and an atypical adjective–noun combination. Two counterbalancing lists were used to ensure that each noun was viewed only once by each participant, but was viewed equally often across participants paired with a typical adjective and with an atypical adjective. Each of the two counterbalancing lists was used to make a version of the questionnaire containing all singular nouns and a version of the questionnaire containing all plural nouns. Ten participants completed each of the resulting four lists. Of the 16 adjective–noun pairs used in Experiment 1, the mean ratings of plausibility for the four conditions were as follows: typical combinations with a plural noun: 5.88 (SD = .76); typical combinations with a singular noun: 5.75 (SD = .94); atypical combinations with a plural noun: 2.32 (SD = 1.25); and atypical combinations with a singular noun: 2.63 (SD = 1.29).

2.1.3. Procedure
The procedure was the same as in Experiment 1. As in Experiment 1, the comprehension questions were presented following each sentence. The questions following experimental sentences did not refer to the meaning related to the adjective–noun combinations. Four counterbalancing lists were used to ensure that each item was viewed in each condition equally often across participants. Each participant was randomly assigned to a counterbalancing condition and tested individually in a private well-lit cubicle. Each participant was given a practice session of 16 sentences, followed by the set of 120 sentences, which was composed of 16 experimental sentences and 104 filler sentences. Filler sentences were constructed to be highly plausible and to involve a variety of sentence structures. Each participant received a unique random order for the 120 sentences. Each session lasted between 30 and 45 min.

2.1.4. Experimental design
A repeated measures design was used. Semantic typicality (typical vs. atypical) and type of noun (singular vs. plural) were the two within-participant factors.

2.2. Results and discussion

Accuracy to comprehension questions was 95% on average, indicating participants complied with instructions and were fully engaged in the comprehension task. As in Experiment 1, mean reading time in milliseconds was calculated at each presentation region for each condition. Presentation regions were similar to those used in Experiment 1. Regions 1 and 2 contained the subject of the sentence and the main verb, respectively. Region 3 contained the complementizer that. Region 4 contained the determiner and adjective, which either formed a typical or atypical combination with the following noun. Region 5 contained the target noun, which was either singular or plural. Regions 6–10 contained the remainder of the sentence, which was the same across all conditions. Table 4 displays these results.

As in Experiment 1, the results showed that the effect of typicality emerged earlier in processing for plural noun conditions than for singular noun conditions. The effect of
Typicality was first observed in reading times at region 5, the region containing the target noun. Fig. 2 highlights the primary results, displaying mean reading time for regions 4–8. Reading time on the target noun was determined by an interaction of semantic typicality and the type of the noun, stemming from the fact that semantic typicality influenced reading time on the noun when the noun was plural, but did not when the noun was singular, \( F_1(1,71) = 8.42; \) MSE = 256,567; \( P < .05; \) \( F_2(1,15) = 14.34; \) MSE = 51,076; \( P < .05. \) Additional comparisons confirmed that the effect of semantic typicality was significant for plural NPs, \( F_1(1,71) = 10.12; \) MSE = 359,500; \( P < .05; \) \( F_2(1,15) = 17.15; \) MSE = 65,794; \( P < .05, \) but was not significant for singular NPs, \( F_s < 1. \) Further analyses revealed that reading time for semantically atypical conditions was significantly longer for plural nouns than for singular nouns, \( F_1(1,71) = 12.12; \) MSE = 415,058; \( P < .05; \) \( F_2(1,15) = 11.75; \) MSE = 80,903; \( P < .05. \) However, reading time in conditions containing typical semantic relations did not differ for singular and plural nouns, \( F_s < 1.20; \) \( P_s > .28. \)

The main effect of type of the noun was also significant, \( F_1(1,71) = 4.41; \) MSE = 116,564; \( P < .05; \) \( F_2(1,15) = 5.23; \) MSE = 18,701; \( P < .05. \) The main effect of semantic typicality was significant in the participants analysis only, \( F_1(1,71) = 5.93; \) MSE = 163,687; \( P < .05; \) \( F_2(1,15) = 3.36; \) MSE = 31,064; \( P > .05. \)

Reading times on the regions 6 and 7, the two regions following the noun (Fig. 4), indicated that semantic typicality influenced processing in both singular and plural noun conditions. Reading time on regions 6 and 7 was longer for atypical conditions than for typical conditions, resulting in a significant main effect of typicality, \( F_1(1,71) = 5.73; \) MSE = 70,469; \( P < .05; \) \( F_2(1,15) = 4.66; \) MSE = 18,976; \( P < .05 \) and \( F_1(1,71) = 4.02; \) MSE = 79,567; \( P < .05; \) \( F_2(1,15) = 6.36; \) MSE = 25,841; \( P < .05, \) respectively. Additional comparisons confirmed that the effect of semantic typicality was indeed significant for singular noun conditions when reading time for regions 6 and 7 were pooled, \( F_1(1,71) = 8.19; \) MSE = 153,689; \( P < .05; \) \( F_2(1,15) = 9.89; \) MSE = 37,394; \( P < .05, \) but were not significant for plural noun conditions, \( F_1(1,71) = 1.69; \) MSE = 24,182; \( P > .05; \) \( F_2(1,15) = 1.74; \) MSE = 11,051; \( P > .05. \) The interactions between type of noun and semantic typicality at region 6 was not significant, \( F_s < 1. \) At region 7, the interaction between type of noun and semantic typicality approached, but failed to reach significance, \( F_1(1,71) = 2.98; \) MSE = 47,048; \( P > .05; \)

### Table 4
Mean reading time in milliseconds for each presentation region by condition from Experiment 2

<table>
<thead>
<tr>
<th>Adjective–noun condition</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
<th>R9</th>
<th>R10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plural noun conditions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atypical</td>
<td>456</td>
<td>473</td>
<td>446</td>
<td>568</td>
<td>647</td>
<td>524</td>
<td>499</td>
<td>587</td>
<td>513</td>
<td>762</td>
</tr>
<tr>
<td>Typical</td>
<td>456</td>
<td>494</td>
<td>440</td>
<td>558</td>
<td>540</td>
<td>495</td>
<td>491</td>
<td>623</td>
<td>537</td>
<td>795</td>
</tr>
<tr>
<td>Difference</td>
<td>0</td>
<td>-21</td>
<td>6</td>
<td>10</td>
<td>107</td>
<td>8</td>
<td>8</td>
<td>-36</td>
<td>-24</td>
<td>-33</td>
</tr>
<tr>
<td><strong>Singular noun conditions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atypical</td>
<td>462</td>
<td>468</td>
<td>434</td>
<td>557</td>
<td>547</td>
<td>520</td>
<td>540</td>
<td>584</td>
<td>507</td>
<td>759</td>
</tr>
<tr>
<td>Typical</td>
<td>493</td>
<td>471</td>
<td>426</td>
<td>532</td>
<td>559</td>
<td>487</td>
<td>481</td>
<td>577</td>
<td>508</td>
<td>726</td>
</tr>
<tr>
<td>Difference</td>
<td>-31</td>
<td>-3</td>
<td>8</td>
<td>25</td>
<td>12</td>
<td>33</td>
<td>59</td>
<td>7</td>
<td>-1</td>
<td>33</td>
</tr>
</tbody>
</table>

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$F_2(1, 15) = 3.18; \text{MSE} = 14,221; P > .05$. When reading time was pooled across the two regions, the interaction was not significant, $F_s < 1$. The main effects of type of noun for the two regions were not significant in any analysis, $F_s < 1.85, P_s > .05$. Analyses of reading time on regions 8–10 revealed no significant results.

Additional analyses were conducted to confirm that semantic typicality influenced reading time earlier for plural noun conditions than for singular NPs. Reading time for regions 5–7 was analyzed in ANOVAs in which presentation region, typicality, and the type of the noun were included as three within-participants factors. These analyses revealed that reading time was significantly influenced by the three-way interaction, $F_1(2, 142) = 7.70; \text{MSE} = 172,217; P < .05; F_2(2, 30) = 10.54; \text{MSE} = 29,966; P < .05$. As in Experiment 1, although the effect of typicality developed later for singular nouns than for plural nouns, the overall magnitude of the effect of typicality across the three presentation regions did not differ significantly for singular and plural noun conditions, as the interaction between the type of the noun and semantic plausibility was not significant, $F_s < 1.20; P_s > .20$.

In sum, the results of Experiment 2 were highly similar to those observed in Experiment 1. The effect of semantic typicality occurred earlier during processing for plural NPs than for singular NPs. When the noun was plural, the effect of semantic typicality was observed in the time taken to read the plural noun; however, when the noun was singular, the effect of semantic typicality occurred at a delay, two regions downstream from the region containing the singular noun.

3. General discussion

The research described in this paper provided evidence that the time course of semantic interpretation can vary for different types of words. Two reading experiments tested the hypothesis that a plural noun may be integrated with a preceding adjective more rapidly than a singular noun because plural nouns are less likely to be part of a noun compound than are singular nouns. The results of both experiments supported this hypothesis, showing that the effects of semantic plausibility and typicality were observed earlier in plural noun conditions than for singular noun conditions. In plural noun conditions, effects of semantic plausibility and typicality were observed as soon as the plural noun was processed. In singular noun conditions, effects of semantic plausibility and typicality were observed on the regions following the singular noun.

The results are reconcilable with both major theories of sentence processing. From the perspective of interactive or constraint-based approaches to language processing, there are two possible accounts of the present results. Both accounts assume that when the singular or plural noun is encountered, interpretation is carried out immediately. For both types of nouns, multiple interpretations are pursued in parallel, one interpretation in which the noun is the complete $\text{N}_0^0$ and one interpretation in which the noun is the first noun in a noun compound. When one of the interpretations proves to be implausible, the remaining interpretation is pursued. Processing cost is observed when the only remaining interpretation proves to be implausible (c.f. Boland
et al., 1995). For plural noun conditions, the compound interpretation can be eliminated as soon as the plural noun is encountered. For singular noun conditions, the compound interpretation can be eliminated only when the comprehender determines that the word following the singular noun is not a noun.

A second account offered from the constraint-based approach is that different time courses of semantic interpretation for singular and plural nouns are due to differences in how quickly comprehenders can settle on a final interpretation in the two conditions. When the incoming noun is processed, multiple competing interpretations are generated. Each interpretation is activated according to the frequency of usage for each analysis. Activation levels change according to how much evidence there is for each analysis (see the Partial Activation Hypothesis, MacDonald et al., 1994). The amount of time needed for comprehenders to settle on an interpretation is related to the amount of competition occurring between the two possible interpretations. Competition is relatively low in plural noun conditions, because the N\textsuperscript{0} interpretation is much more highly activated than the noun compound interpretation. Competition is relatively high in singular noun conditions, because the N\textsuperscript{0} interpretation and the noun compound interpretation have similar activation levels. Settling on a final interpretation occurs more rapidly when competition is low, as in plural noun conditions, than when competition is high, as in singular noun conditions.

From the perspective of the garden path theory, the results of the present research can be viewed as supporting the claim that certain aspects of high-level integrative semantic processing for an incoming word occur only after the comprehender determines the word’s syntactic analysis. The specific analysis may involve determining that the incoming noun is the head of phrase (see Clifton & Ferreira, 1989; Kamp & Partee, 1995; Murphy, 1990; Wisniewski, 1996) or may involve determining that the incoming noun is an entire word (i.e. an entire N\textsuperscript{0}).\textsuperscript{2} Advocates of this account may find it impossible to determine whether the critical decision involves head identification or whole word identification, particularly in experiments in which English sentences are tested. In English, the head of the NP and the end of a noun compound are each located at the right edge of the NP. The point in processing at which comprehenders are able to locate the head of the NP is the same point in processing at which comprehenders are able to locate the end of the noun compound. The ideal language for testing the predictions of these two possibilities would need to be one in which the head of the NP and the end of the noun compound occur in different positions with the NP. It remains to be determined whether a language having these properties exists.

A remaining question concerns the nature of the difference in interpretative processing occurring before and after the incoming noun is ruled out as part of a compound. Certainly, comprehenders carry out interpretative processing prior to making the decision that the incoming noun is not part of a compound (see Sedivy et al., 1999). However, the exact nature of the semantic processing occurring before and

\textsuperscript{2} I thank an anonymous reviewer for suggesting this alternative hypothesis as well as the details regarding how to test its predictions.
after the head of the phrase is encountered remains a mystery. It is certain that some amount of integrative interpretation occurs rapidly. Sedivy et al. (1999) showed that comprehenders integrated the meaning of an incoming adjective with relevant semantic content of objects in a visual display. Participants’ eye movements revealed that the adjective had been interpreted. Nevertheless, the results of the present experiment showed that although various amounts of integrative semantic processing may have been occurring between the adjective and the noun prior to the analysis of the noun as a simple N0, the interpretative processing did not result in processing cost in implausible conditions versus plausible conditions. In sentences containing singular nouns, reading time on the region containing the noun did not differ significantly for conditions in which the noun was preceded by an implausible adjective versus a plausible adjective. The processing cost due to implausibility was observed only after readers had moved past the region containing the singular noun, and presumably, only after the comprehender had determined that the singular noun was not part of noun compound. Nevertheless, it is possible that in future research, differences in reading time on the region containing the singular noun may be observed for plausible and implausible conditions if reading time is measured using a technique more sensitive than the self-paced moving window.

The present results point out that much has yet to be learned about the nature of online interpretation. Future research may reveal that the details regarding when integrative semantic processing occurs during online sentence processing are exceedingly complex. Consider the case of how comprehenders carry out the semantic integration of a direct object NP contained within a verb phrase (VP) in English, as in *John liked the kite*. Comprehenders may delay integration of the noun and the preceding verb until after determining that the noun is or is not part of a noun compound within the local NP (e.g., *John liked the kite saleswoman*). Based on the present results, comprehenders would be expected to integrate plural direct object NPs more rapidly than singular direct object NPs. An even more complex case is a sentence in which an object NP is composed of an adjective and a noun, as in *John liked the sturdy kite* or *John liked the heavy kite*. Comprehenders may integrate the meaning of the adjective and the noun in the local NP before integrating the meaning of the entire direct object NP with the preceding verb. Certainly, future research is needed to test each of these hypotheses.

In sum, the present research showed that the time course of integrative semantic processing differed for plural and singular NPs. The results provide one of the first demonstrations that the time course of integrative semantic processing can differ for different types of words. The results strongly suggest that the timing of high-level integrative semantic processing may be influenced by how quickly comprehenders determine that the incoming noun is unlikely to be part of a noun compound. Plural nouns can be ruled out as part of a noun compound more rapidly than singular nouns in English, because plural nouns are much more rarely compounded than singular nouns. The research provides directions for future investigations into the nature of integrative semantic processing during sentence comprehension.
Acknowledgements

I would like to thank Professor Jacques Mehler and three anonymous reviewers for their comments on an earlier version of this manuscript. I would also like to thank Lyn Frazier, Charles Clifton, John, Huitema, and A. René Schmauder for their collaboration on a previous project that greatly influenced my views on the topic of NP comprehension. I would also like to thank Stanna Brazeel who collected plausibility ratings for the project. I thank Fawna Mason, Brent Larue, and Melissa Lampman for testing participants in the reading experiments.

Appendix A

The following list contains the experimental sentences from Experiment 1. The adjectives separated by a slash were used in plausible and anomalous conditions, respectively.

1. Bob *hoped *that *the cracked/bossy *plate(s) *would *not *upset *the dinner *guests.*
2. Larry *mentioned *that *the shiny/witty *key(s) *had *been *moved *earlier *in the *day.*
3. Nathan *said *that *the washed/insulted *apple(s) *was(were) *still *very *good *to *eat.*
4. Ann *found *that *the dirty/clever *bowl(s) *irritated *her *mother-in-law *during *every *visit.*
5. Fred *read *that *the ancient/careful *castle(s) *had been *studied *for *centuries *by *historians.*
6. Rita *supposed *that *the tiny/rude *pillow(s) *could be *purchased *at *a local *craft shop.*
7. Kyle *worried *that *the heavy/early *brick(s) *would *be *stolen *from *the job site.*
8. Joan *said *that *the delicious/talented *banana(s) *was(were) *on *everyone’s *mind *today.*
9. Ted *agreed *that *the antique/bashful *bed(s) *looked *better *positioned *in the corner *of the room.*
10. Vince *demanded *that *the shattered/spiteful *bottle(s) *be *replaced *by *the parents *of the child.*
11. Eric *thought *that *the cheap/proud *stove(s) *would *sell *quickly *during the flea *market.*
12. Iris *remembered *that *the decorated/talented *window(s) *needed *to *be *cleaned *badly.*
13. Susan *knew *that *the raw/kind *carrot(s) *would not *be *a popular *appetizer among the teenagers.*
14. Alvin *wished *that *the mechanical/intelligent *pencil(s) *was(were) *much *easier *to *use.*
15. Eddie *mentioned *that *the noisy/cruel *truck(s) *had been *discussed *at the last *city council *meeting.*
16. Peter *saw *that *the elegant/impatient *boat(s) *attracted *lots *of *attention *from passersby.*

Appendix B

The following list contains the experimental sentences from Experiment 2. The adjectives separated by a slash were used in typical and atypical conditions, respectively.

1. Hank *said *that *the salty/sugary *olive(s) *was(were) *likely *the source *of the *bacteria.*
2. Eric *mentioned *that *the blunt/sharp *hammer(s) *had *been *imported *from *Germany.*
3. Stanley *noticed *that *the shiny/rusty *ring(s) *had been *moved *from *one display case *to another.*
4. Monica *described *how *the furry/slimy *bear(s) *had *frightened *her *at *the wildlife park.*
5. Nancy *found *that *the white/yellow *paper(s) *had been *scattered *all *around *the room.*
6. Brenda *exclaimed *that *the slimy/furry *snail(s) *would *be *perfect *for *the science project.*
7. Robert *realized *that *the yellow/white *lemon(s) *would *appeal *to *the gourmet *food retailers.*
8. Calvin *hoped *that *the loud/soft *drum(s) *would *improve *the tempo *of *the song.*
9. Hillary *saw *that *the pointy/dull *pencil(s) *had *not been *put away *yesterday *afternoon.*
10. Stephanie *thought *that *the orange/purple *flame(s) *looked *pretty *against *the dark *horizon.*
11. Kenneth *suspected *that *the fertile/barren *pasture(s) *would *get *a lot of attention *from *the area farmers.*
12. Kimberly *admitted *that *the strong/weak *mule(s) *might *need *to be examined *by *a veterinarian.*
13. Garth *knew *that *the noisy/quiet *truck(s) *was(were) *driven by *his *best friend’s *father.*
14. Jacob *proposed *that *the clean/filthy *hospital(s) *receive *surprise *inspections *every *six months.*
15. Marsha *claimed *that *the sweet/bitter *candy(candies) *would *appeal *to weight conscious *teenagers *and their parents.*
16. Sandra *wondered *whether *the filthy/clean *slum(s) *would need *to be torn down *before *the end *of the year.*
References


