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The Leaf Fell (the Leaf): The Online Processing of Unaccusatives

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Abstract

According to the Unaccusative Hypothesis, unaccusative subjects are base-generated in object position and move to subject position. We examined this hypothesis using the cross-modal lexical priming technique, which tests whether and when an antecedent is reactivated during the online processing of a sentence. We compared sentences containing unergative verbs with sentences containing unaccusatives, both alternating and nonalternating, and found that subjects of unaccusatives reactivate after the verb, while subjects of unergatives do not. Alternating unaccusatives showed a mixed pattern of reactivation. The research directly supports the Unaccusative Hypothesis.

Keywords

unaccusatives; Unaccusative Hypothesis; English; priming; gap filling; NP-movement

1 Introduction

1.1 Unaccusative Verbs

Mark Baker remarked that “all seemingly intransitive verbs are not created equal” (1983:1). In this study, we empirically test the theoretical claims regarding the difference between types of intransitives, by testing whether there is an observable difference in the online processing of unaccusatives and unergatives. According to the Unaccusative Hypothesis, there are two classes of intransitive verbs: unaccusatives and unergatives (Perlmutter 1978, Perlmutter and Postal 1984; also see Pullum 1991 for the development of this concept). Semantically, they differ in that the subject of an unaccusative verb, unlike the subject of an unergative, does not actively initiate or is not actively responsible for the action of the verb, but bears the semantic role of theme or patient that is usually associated with the object. According to the Unaccusative Hypothesis, the single argument of unaccusatives is syntactically a direct object, while the single argument of unergatives is the subject. Thus, although superficially the sentences *The leaf fell* and *The bird chirped* both show NP-V word order, the former involves NP-movement from object to subject position (1), while in the latter the NP is base-generated in subject position (2).1

(1) The leaf$_i$ fell t$_i$.

(2) The bird chirped.

Since Burzio's (1986) formulation of the Unaccusative Hypothesis in transformational terms, the distinction between types of intransitive verbs has been widely accepted. It is not, however, uncontroversial: some theorists suggest that unaccusative verbs do not include a direct object at some level, or that unaccusativity should be semantically rather than syntactically encoded (Dowty 1991, Napoli 1988 for English, Van Valin 1990). For example, Rappaport Hovav and Levin (2001:792) conclude, "Our work calls even more seriously into question the existence of any evidence for the syntactic encoding of unaccusativity in English." It is one aim of the current study to discover whether or not unaccusativity is syntactically encoded, and whether unaccusatives include an object at some stage in their derivation.

Another question raised by theorists who accept the Unaccusative Hypothesis relates to the extent of this hypothesis—specifically, to whether alternating and nonalternating unaccusatives involve the same syntactic analysis (see, e.g., Chierchia 2004). Alternating unaccusatives are those intransitive verbs whose subject may also appear as the direct object of a morphologically identical transitive verb, as illustrated by *break* in (3). The subject of a nonalternating unaccusative never appears as the direct object of a morphologically identical verb, as illustrated by *vanish* in (4). Knowing whether or not a verb enters transitivity alternations is part of a speaker's knowledge about the idiosyncratic properties of each root (see Embick 2004).

(3) a. Mr. Cook broke the vase.
b. The vase$_i$ broke t$_i$.
(4) a. *The magician vanished the rabbit.
b. The rabbit vanished.

An alternative to viewing verbs like *break* as alternating unaccusatives is taken by Haegeman (1994), inspired by Belletti (1988:fn. 14), who cites Hale and Keyser (1986) for an earlier inspiration. This view posits that what have been identified as alternating unaccusatives are in fact not. Instead, the grammatical subject is assumed to be base-generated in subject position. Two arguments are made for this claim. The first is that "normal" unaccusatives, such as *vanish*, do not have transitive counterparts that assign accusative case. The second comes from the *there*-construction diagnostics for unaccusative verbs in English: unaccusatives like *come* participate naturally in such constructions (5), but unergatives like *shout* do not (6). According to Haegeman and Belletti, alternating unaccusatives resist this construction, as shown in (7), behaving in this respect like unergatives rather than unaccusatives.2

(5) There came three new sailors on board.

[1]Following Chierchia (1989, 2004), Reinhart (2000), and Reinhart and Siloni (2004), we assume that an operation in the lexicon applies to transitive entries to produce unaccusative verbs, leaving behind only the internal argument. This operation is referred to as Reduction by Chierchia (1989), Reinhart (2000), and Reinhart and Siloni (2004) and as Reflexivization by Chierchia (2004). In these cases, languages like English require the movement of the internal argument to subject position.

[2]Notice, however, that some alternating unaccusatives can appear with *there* (*There hung a picture on the wall*) and that some nonalternating unaccusatives sound strange in this construction (*There expired some milk*). See Levin and Rappaport Hovav 1995 and Kuno and Takami 2004, where it is shown that the restrictions on the *there*-construction are very subtle and context-sensitive.

(Haegeman 1994:335, (85a))

(6) *There shouted three sailors on the deck.

(7) *There broke a vase.

On the basis of these facts, Haegeman posits that *break*-type intransitives (which also include *open*, *close*, *drop*, and *sink*) are therefore base-generated with their single argument in subject position—the same syntactic NP-V configuration shown for unergatives in (2).

In the current study, we compare the online processing of alternating unaccusatives with that of nonalternating unaccusatives, and the online processing of alternating and nonalternating accusatives with that of unergative verbs, using a measure that is sensitive to reactivation of antecedent arguments: cross-modal lexical priming. If indeed S-V sentences with unaccusatives (or some unaccusatives) are derived by NP-movement, but unergatives are not, we expect to find reactivation effects after the verb in sentences with unaccusatives but not in sentences with unergatives. That is, if the single argument of unaccusative verbs is base-generated in object position and is displaced to subject position through NP-movement, then we should observe activation of the argument in object position; we should not observe activation of the subject NP in object position with unergative verbs. Furthermore, if alternating and nonalternating unaccusatives are derived in similar fashion, then in both cases we should observe activation of the subject NP in object position; if alternating unaccusatives are more like unergatives, then in both of these cases we should not observe activation of the subject.

Finally, we believe this work (and work like it) has more general consequences for both linguistic theory and accounts of sentence processing, and perhaps for the interaction of the two. As explained above, we intend to use sentence-processing data to inform linguistic theory—in this case, to account for the representation of unaccusative verbs. Of course, this tactic is not without precedent. Still, it seems reasonable to suggest that very few details of grammatical theory have come from data sources outside those traditionally considered the domain of linguistics, that is, from judgments of well-formedness and reference. The empirical base for linguistic theories of all kinds comes almost solely from behavior that has been measured *offline*, that is, after final interpretation of a linguistic expression. In the present study, we investigate behavior *online* in an attempt to view the language-processing system as it is operating in real time. We believe these data are most relevant to grammatical theories because they are less likely to be influenced by extralinguistic factors that are easily observed in offline analyses (e.g., memory, contextual, and plausibility constraints). Thus, online tasks may arguably be more sensitive to operations underlying structure. To this end, we now describe such a task and further explain its value.

1.2 What Is Cross-Modal Lexical Priming?

The ease or speed of access to a word during sentence processing has been shown to be affected by several factors. One is frequency: frequent words are accessed more rapidly than infrequent words (all other things being equal). Another is *semantic priming*: when a word is read/heard shortly after a semantically related word, it is accessed more easily or rapidly than when it is read/heard after an unrelated word. For example, the word *ballet* will be accessed more quickly after the word *dancer* than after the word *saucer* (e.g., Meyer, Schvaneveldt, and Ruddy 1975, Neely 1977). This phenomenon has been frequently used in psycholinguistic research to determine when in the course of auditory sentence processing word meanings are activated. When this technique is used to study online processing of movement traces, the idea is this: if reactivation of the antecedent occurs at the trace position, the reactivated item should prime a related word at that position. For example, when the object relative sentence (8) is presented aurally, the visual target word *ballet* will

be primed not only immediately after the listener hears the word *dancer* at the beginning of the sentence (point ①), but also at the trace position (point ②), where it will be reactivated to interpret the sentence and assign the chain its thematic role.

(8) The dancer$_i$① that the mayor adores t$_i$② is very talented.

One method for examining such activation and reactivation during auditory sentence processing is termed *cross-modal lexical priming* (CMLP) (Swinney et al. 1979). In this paradigm, sentences are presented aurally at a normal speaking rate, and at some point during each sentence, a letter sequence (a word or a nonword) is briefly (e.g., 300–500 ms) visually displayed on a screen. The participant is asked to attend to the aurally presented sentence and to also make a lexical decision (word/nonword) about the letter sequence via a button press. With respect to traces of movement, a priming effect in this lexical decision at the trace position means that the moved constituent has been reactivated at the trace, serving as a prime for a semantically associated visual target word. CMLP studies have found that the moved constituent appears to be activated twice in the sentence: once when first encountered and again at the gap indexed by the trace to which it is syntactically linked (Hickok et al. 1992, Love and Swinney 1996, Nicol and Swinney 1989, Swinney et al. 1988, Zurif et al. 1995).

1.3 Cross-Modal Lexical Priming and Movement Traces

In the last two decades, studies using CMLP have found ample evidence that the head of the antecedent NP is reactivated at the trace position of *wh*-chains, in relative clauses and *wh*-questions (Love and Swinney 1996, Nicol and Swinney 1989, Swinney et al. 1988, Swinney, Zurif, and Nicol 1989, Zurif et al. 1993, 1995). Few CMLP studies have looked at the processing of NP-movement. In one CMLP study, however, Osterhout and Swinney (1993) tested reactivation in passives. The participants in this study made lexical decisions about words (and nonwords) that were presented at three locations after the verb during auditory sentence comprehension. Responses to words semantically related to the subject were faster than responses to semantically unrelated words during passive sentences, but not during active sentences, indicating that the moved constituent is reactivated in passive sentences. However, compared with findings from *wh*-chains, the reactivation in passives occurred at a temporally delayed point, some 1,000 ms after the verb (with only a nonsignificant trend for priming immediately after and 500 ms after the verb). The cross-modal paradigm, then, can be used not only to test for sensitivity to grammatical structure, but also to reveal its real-time consequences.

Other studies have also indicated activation of the antecedent in passive sentences. For example, in a series of studies of structures that include NP-trace, Bever and McElree (1988; McElree and Bever 1989) report access to the subject in passives, raising constructions, and *tough*-constructions; and Bever and Sanz (1997) report subject access in sentences with unaccusatives in Spanish, using end-of-sentence probes with visual presentation of sentences (i.e., reading). This methodology can indicate activation subsequent to final interpretation. However, it is limited with respect to detailing online behavior and thus cannot, in principle, tell whether the subject NP was active from the point at which it was encountered in the sentence and then remained active throughout the remainder of the sentence until final interpretation, or whether it was *re*activated in its purported base position. This is an important distinction; the cross-modal methodology allows us to examine sensitivity to grammatical structure before any conscious reflection occurs. By using CMLP, we hope to take a snapshot of the language system as it is operating in real time, before final

interpretation takes place. Nevertheless, Bever and colleagues' work stands out in its attempt to use psycholinguistic data to inform linguistic theory.

Thus, the cross-modal methodology allows us to examine open questions in linguistics and evaluate competing linguistic accounts. As one example of the benefit of online measurements (and specifically CMLP) to linguistic theory, consider the question of vacuous movement. Some linguistic analyses have suggested that matrix subject questions and relative clauses, unlike object questions and relatives, do not involve movement, whereas others have suggested that movement occurs in these structures too (see, e.g., Chomsky 1973, 1986 for claims against vacuous movement, and Clements et al. 1983 for arguments in favor). Results from CMLP studies suggest some insight into this question. Zurif et al. (1993, 1995) have found that not only object relatives yield reactivation of the antecedent at the *wh*-traces, but also subject relatives, thus supporting movement from the embedded subject position as well. The general suggestion, then, is that online measurements can reveal patterns that sometimes cannot be observed using offline measurements, and that they can inform linguistic theory.

In the current study, we used CMLP to test a particular type of NP-movement (A-chain movement) with unaccusatives. We intended to test the theoretical claim that S-V sentences with unaccusatives are derived by movement of the object to subject position, while S-V sentences with unergatives do not include such movement. Again, if unaccusative subjects undergo movement from object position, the subject should be reactivated in the trace position after an unaccusative verb; such reactivation of the subject should not be observed with an unergative verb. We also intended to detail the *time course* of activation of the subject; as we will show, a time-course analysis yields surprising patterns that can illuminate the internal operations of the sentence processor. A second aim of this study was to compare the two types of unaccusative verbs, alternating and nonalternating, to see whether they behave similarly with respect to reactivation after the verb. This comparison was motivated both by the theoretical claim discussed earlier that the subject of an alternating unaccusative is actually base-generated in subject position (Belletti 1988, Haegeman 1994) and by findings from neuropsychology of language indicating that individuals with Broca's aphasia behave differently on these two types of unaccusatives. Specifically, in an offline comprehension study Piñango (1999) found that Broca's aphasics performed above chance in comprehending subject relative and subject cleft constructions on nonalternating unaccusatives and at chance in comprehending the same constructions on alternating unaccusatives (the difference between the two types of unaccusatives was significant for one of the patients tested, but nonsignificant for the other).

2 Method

2.1 Participants

Participants in our study were 120 undergraduates at the University of California, San Diego (UCSD), who took part in the experiment for course credit. All participants were monolingual native speakers of English, had normal or corrected-to-normal vision and hearing, and had no history of neurological injury or developmental language or reading disorder. Participants for several pretests of the materials are described with each pretest below.

2.2 Materials and Design

Each participant heard 94 aurally presented sentences. Of these, 54 were experimental sentence constructions with an intransitive (unaccusative or unergative) verb, and 40 were filler sentences of the same approximate structure, with a transitive verb. The experimental

and filler sentences were pseudorandomly assigned to positions in a script, such that no more than two of either type appeared successively. The 54 experimental sentences included 18 sentences of each of the three verb types: nonalternating unaccusative verbs, alternating unaccusative verbs, and unergative verbs.

The verbs were selected according to the following criteria and procedure. Initially, 15 verbs were selected for each verb type (see appendix A for a list of all verbs used in the experiment by verb type). For each verb, frequency was calculated as the sum of the frequencies of the verb in present, past, and third person singular present from the Kučera and Francis (1967) database. To balance the overall frequency of verbs among the three verb-type groups, 3 verbs from each group were chosen to be used a second time, so that 18 verbs appeared in each condition. The mean frequencies of the alternating unaccusatives, nonalternating unaccusatives, and unergatives were 136, 127, and 84, respectively, numbers that did not differ significantly, $F(2, 51) = 1.24$, $p = .30$ (frequency ranges 12–466, 15–428, 22–178, SDs 127, 126, 48, respectively). Verbs were chosen in an attempt to reflect the widest range of meanings possible for each verb class. Additionally, efforts were made not to include ambiguous verbs or verbs with multiple argument structures.

Nonalternating unaccusatives were identified on the basis of their behavior with respect to three diagnostics: occurrence in the *there*-construction (9), ungrammaticality with a direct object (10), and inability to undergo passivization (11).

(9) There remained three students after class.
(10) *The teacher remained three students after class.
(11) *Three students were remained after class (by the teacher).

Alternating unaccusatives (the *break*-type intransitives identified by Haegeman (1994) as ergatives) were identified on the basis of their behavior with respect to three diagnostics: existence of a morphologically identical predicate that takes a direct object (12), ability to take a passive subject (13), and inability to occur with a resultative phrase (14) (Levin and Rappaport Hovav 1995).

(12) Simon rolled the ball.
(13) The ball was rolled by Simon.
(14) *The boy rolled scratched.

Unergative intransitives were identified on the basis of their behavior with respect to four diagnostics: ungrammaticality in the *there*-construction (15), ungrammaticality in the resultative construction (16), and inability to occur with a reflexive pronoun (17) unless the reflexive pronoun is followed by a resultative (18).

(15) *There clapped a good little monkey.
(16) *The good little monkey clapped silly.
(17) *The good little monkey clapped himself.
(18) The good little monkey clapped himself silly.

Full NPs were used as subject, and they included 21 inanimate and 33 animate nouns. The letter sequences for lexical decision (i.e., visually presented probes) included 54 words and 40 nonwords. The nonword probes conformed to English orthographic and phonological

rules and appeared with the filler sentences. For the word probes, we created 54 pairs of words; in each pair, one word was related to the head of the subject NP and one was unrelated. Related probes were close semantic associates of the subject NP, as determined by a pretest involving 50 UCSD students who were taking part for course credit and who were all native speakers of English. Each of these participants wrote the first semantic associate he or she thought of for each subject NP; the response given most frequently by these participants for each subject NP was chosen as the NP's related visual target probe.

For each related probe, an unrelated probe was chosen that matched it in number of letters, number of syllables, and frequency, and then, most critically, a single unrelated probe was chosen from among these candidates on the basis of matched baseline reaction time for lexical decision. The baseline reaction time was determined by a study in which 54 participants (UCSD students taking part for course credit, all of whom were native speakers of English) made lexical decisions via button press for several hundred visually presented words and nonwords (equal numbers of each), which included the related and potentially matched unrelated items. The matched unrelated probe was chosen from those tested on the basis of a priori lexical decision times derived from this pretest. The mean base lexical decision time for the final set of related probes was 538.5 ms, and that for the final set of matched unrelated probes was 539.5 ms (these reaction times did not differ significantly from each other, $t(53) = 1.09$, $p = .28$). The difference in lexical decision time for each related-unrelated probe pairing was always less than 4 ms. Each head of subject NP and each probe appeared only once per participant during the entire sentence list.

As examples (19)–(21) show, visual targets appeared at three probe positions in each sentence (counterbalanced across the entire experimental design). The location of the first two probe positions was determined structurally: Probe Position 1 was immediately at the offset of the head of the subject, and Probe Position 2 was immediately at the offset of the verb (at the trace). Probe Position 3 was 750 ms after Probe Position 2. This "downstream" positioning of the third probe was based on Osterhout and Swinney's (1993) finding that reactivation of an NP-trace takes place downstream from the verb.3

(19) *Nonalternating unaccusative*
The **tailor**① from East Orange, New Jersey, mysteriously **disappeared**② when it was③
time to adjust the tuxedos and dresses for the participants in the wedding party.
(20) *Alternating unaccusative*
The **table**① in the basement of the old house finally **dried**② after the leaking③ window
was sealed a month ago.
(21) *Unergative*
The **surgeon**① with a brown felt fedora hat and matching coat eagerly **smiled**② when
the beautiful③ actress walked down the corridor to exam room three.

[3]In typical gap-filling experiments, a pregap position is often compared with a gap position, so that an argument can be made about reactivation rather than continuous activation from the filler. However, we needed to test at the antecedent (to see if there is a priming effect at all for each head) and at the trace, and given previous studies on passives we understood that another probe position is needed 750 ms after the verb. This already added up to three probe positions per participant, and given the large number of conditions and sentences per participant, our design could not accommodate yet another probe position before the verb. As it turns out, we did find decay and reactivation: Probe Position 2 showed less priming effect than Probe Position 1, while Probe Position 3 did show priming for the unaccusative verbs (see section 3).

Given this probe position placement, sentential material was added to the subject NP so that enough time (and/or sentential material) would elapse between the antecedent and the trace to allow for decay in activation from the initial appearance of the subject NP. Given previous data indicating that 1.5 s or 3–5 syllables are typically required to detect decay in priming (Love and Swinney 1996, Onifer and Swinney 1981, Swinney 1979), the head of the antecedent was "padded" to include a PP modifying the N and an adverb, together adding between 5–10 words (mean: 8 words) comprising 10–20 syllables (mean: 14). The "padding words" between the antecedent and the gap were unrelated to the head of the subject NP and to the related or the unrelated probe. Approximately 10 words (18 syllables) were also added after the verb in order to avoid end-of-sentence effects and to allow the participant to respond to both Probe Positions 2 and 3 while the sentence was still running (see, e.g., Balogh et al. 1998).

2.3 Design

So that no participant would hear any sentence more than once, six scripts comprising identical experimental (54) and filler (40) sentences were created (see appendix B for a list of the experimental sentences and the probes they appeared with). The three probe positions and two probe types (related/unrelated) for each experimental sentence were then completely counterbalanced (equally distributed) across the six scripts. Each of the six scripts was presented to 20 participants, the assignment of participant to script being random. Each participant heard each sentence only once, with one of the combinations of probe position and probe type. Within a script, participants heard one-third of the sentences containing each verb type paired with a probe in each of the three probe positions and, for half of each of these, the probe was either a related or a control (unrelated) probe. Thus, every participant experienced equal numbers of experimental items in every possible experimental condition, but across scripts, these conditions were completely counterbalanced across individual sentential items.

2.4 Procedure

Participants sat in a small soundproof testing booth in front of a computer monitor and a button response box. The experimental sentences were presented over headphones via a digital tape recorder. As each sentence unfolded, a lexical decision probe appeared centrally (for 500 ms) on the monitor. Participants were requested to attend carefully to the aurally presented sentences and also to make a lexical decision as quickly and accurately as possible whenever a letter string appeared on the screen, by pressing one of two response keys (labeled *word*, *nonword*). Reaction times (RT) for this decision were recorded by the computer. In 20% of the trials, participants were asked a yes/no comprehension question about the sentence they had just heard, to ensure that they were paying attention to the sentences.

Prior to the test, five training (practice) sentences were presented to each participant, two coupled with words, three coupled with nonwords.

RTLab software was used to deliver stimuli and record RTs via the computer.

Priming effects were assessed by comparing lexical decision times to probes that were semantically related to the head of the subject NP with reaction times to unrelated probes.

3 Results

3.1 An Analysis of Priming Effect as an Indication for Reactivation

The main issue under investigation in this study was whether or not the subject NP is reactivated after the verb in unergatives and unaccusatives (of the two types). This was examined by analyzing the priming pattern in the various probe positions for the different verb types—specifically, by comparing priming effects within a verb type both between probe positions and within a single probe position between verb types.

Our findings, elaborated below, were that priming occurred right after the head for all three verb types and that reactivation at Probe Position 3 occurred for the unaccusative verbs (nonalternating and some alternating), but not for the unergative verbs. The dependent variable used in all analyses was the *priming effect*: the facilitation in RT for the related probe, which is calculated as the RT for the unrelated probe minus the RT for the matched related probe in the same condition.

As is standard in such analyses, prior to data analysis, data points for errors in lexical decision or for which the RT was longer than 2,000 ms were discarded (2% of the data points). In addition, 2 participants were dropped from the data analysis because their average RTs were more than 3 standard deviations above the mean for all participants.4 It was decided a priori that any sentences for which priming was not found immediately after the subject NP (Probe Position 1) would be dropped from further analysis, on the grounds that the visual probes for such items were clearly not "related" enough to provide (the well-documented) immediate priming effect that could then be examined for reactivation. On these a priori grounds, eight sentences (which distributed relatively evenly across verb types) were dropped from further analysis.

We calculated mean priming effect (RTs for related minus RTs for control probes) for each verb type and averaged these over either subjects or items, depending on which was treated as a random variable. (Namely, we calculated both the priming effect per subject, per probe point, and per verb type, as well as per sentence and per probe point.) These data were submitted to inferential analysis with both items and subjects as random variables. The two cases revealed similar findings and are reported separately below.

The overall mean priming effect for each verb type and probe position calculated across all data is presented in table 1. (The data reported here are from the item analysis, collapsing over subjects; results of the analysis collapsing across items are nearly identical.) Analysis of the data with items (sentences) as the random variable (F2) yielded a significant main effect of probe relatedness; related probes (624.8 ms) yielded significantly faster RTs than unrelated probes (657.1 ms), $F(1, 45) = 18.84$, $p < .0001$. A significant effect of relatedness was revealed also when the data were analyzed with subjects as the random variable, $F(1, 117) = 60.36$, $p < .0001$, mean related probes: 624.2 ms, mean unrelated probes: 655.0 ms.

Since our main interest was in whether *re*activation takes place with each of the verb types, we ran preplanned (a priori) trend analyses for linear and quadratic contrasts for the priming effect. A linear trend would mean that there is a constant decrease in priming from Probe Position 1 through Probe Position 3, indicating that the head of the subject NP decays and does not reactivate. A quadratic trend would suggest a U-shaped activation pattern, with

[4]Some participants were discarded from the analysis on a priori decision-based grounds. These included 3 participants who made more than 10% errors in lexical decision (including failure to respond within 2 s), 1 participant who scored below 70% correct on the comprehension questions, and 1 participant who was not a monolingual native speaker of English. In addition, during some experimental runs computer or other hardware (sound) difficulties resulted in no data being collected (9 participants). Additional students were recruited to replace all of these participants in the data analysis.

priming for the subject when measured at Probe Position 1, decay in activation as measured at Probe Position 2, and then reactivation of the antecedent when measured at Probe Position 3. The analyses for each verb type, with items (sentences) as the random variable, yielded the following trends. The nonalternating unaccusatives showed a significant quadratic trend, indicating reactivation of the antecedent at Probe Position 3, $F(1, 14) = 4.23$, $p = .05$, and no linear trend. The unergatives and the alternating unaccusatives showed a linear trend and no quadratic trend; that is, the activation of the antecedent decayed and the antecedent was not reactivated at Probe Position 3, $F(1, 12) = 12.4$, $p = .004$ for the unergatives, $F(1, 17) = 4.95$, $p = .04$ for the alternating unaccusatives.

An analysis of the data with subjects as the random variable (F1) yielded similar results. A two-way ANOVA with two within-subjects factors (verb type and probe position) revealed a significant effect of probe position, $F(2, 214) = 3.74$, $p = .03$.

Like the analysis by items, preplanned contrasts for each of the verb types showed a linear trend for the unergatives, $F(1, 107) = 4.05$, $p = .04$, a linear trend for the alternating unaccusatives, $F(1, 117) = 4.33$, $p = .04$, and no quadratic effect for either of them; the nonalternating unaccusatives showed a nonsignificant quadratic trend, $F(1, 117) = 2.82$, $p = .09$, and no linear trend, $F(1, 117) = 0.48$, $p = .83$.

A comparison between the verb types at each probe position, carried out by a one-way ANOVA for each probe position with verb type as the repeated measure, yielded no difference between the verb types for Probe Position 1 or for Probe Position 2, but yielded a significant effect of verb type for Probe Position 3, $F(2, 214) = 3.58$, $p = .03$, with significant differences between nonalternating unaccusatives and unergatives, $F(1, 107) = 5.13$, $p = .03$, and between alternating and nonalternating unaccusatives, $F(1, 107) = 5.69$, $p = .02$. This supports the pattern of antecedent activation for the three verb types shown in table 1; reactivation occurs at Probe Position 3 for nonalternating unaccusatives, but not for the other two verb types.

3.2 Analysis of Reaction Time for the Unrelated Probes as an Indication of Processing Load

To this point, we have analyzed the priming effect at different positions of the experimental sentences, and these analyses have yielded a priming effect for (some of) the unaccusative verbs downstream from the verb. Still, the data lend themselves to another type of analysis. If we treat the RT for the unrelated probes as an indication of processing load (see Fodor et al. 1996, Piñango 1999, Shapiro et al. 1993, Shapiro, Nagel, and Levine 1993, Shapiro, Zurif, and Grimshaw 1987, 1989), and if gap filling induces processing load (since the listener has to compute the coreference relation between the two positions, as well as fill the position with the antecedent), then the RTs for unrelated probes can serve as an indication of gap filling. The analysis yielded an increase in RT for the unrelated probes at Probe Position 3 compared with Probe Position 2 for both types of unaccusatives but not for the unergatives. At Probe Position 3, there was a 25-ms *increase* for the nonalternating unaccusatives, an 11-ms increase for the alternating unaccusatives, and a 7-ms *decrease* for the unergatives. These patterns suggest, then, that increased processing load is observed in sentences with unaccusatives and not in sentences with unergatives because the underlying subject is activated in the former and not the latter, buttressing the priming effect (see table 2). The difference in item analysis between the nonalternating unaccusatives and the unergatives was statistically significant, $t(26) = 1.74$, $p = .04$. These results, showing increased processing load at Probe Position 3 for the nonalternating unaccusatives but not for the unergatives, are in line with the results of the priming analyses. The increase in processing load can be interpreted as a result of gap filling (reactivation of the antecedent), while no such process occurred for sentences with unergative verbs. As in the priming

analysis, the alternating unaccusatives showed a trend toward an increase in processing load at Probe Position 3, but it was not statistically significant.

3.3 A Verb-by-Verb Analysis of the Alternating Unaccusatives

A verb-by-verb analysis of the reactivation pattern of the alternating unaccusative verbs showed that the unclear pattern of priming in this verb class came about because the verbs did not all behave alike (unlike the consistent pattern that the other verb types showed). The analysis examined priming effects at each probe position for each verb, considering only priming effects greater than 15 ms. For the three repeating verbs, an average of both sentences was calculated. This analysis revealed that *dried*, *sank*, *opened*, *bounced*, *froze*, and *grew* behaved exactly like the nonalternating unaccusatives, with priming at the antecedent, decay at Probe Position 2, and reactivation at Probe Position 3 (a decrease in priming effect of 60 ms between Probe Positions 1 and 2, and then an increase of 69 ms from Probe Position 2 to Probe Position 3). By contrast, *closed*, *cooked*, *broke*, *rolled*, *spun*, *moved*, *cracked*, *swung*, and *shut* showed decay from Probe Position 2 to Probe Position 3. Further analysis of the latter verbs reveals that *cracked*, *swung*, and *shut* behaved like unergatives, with a linear decay in priming from Probe Position 1 to Probe Position 2 to Probe Position 3 (an average decrease in priming effect of 53 ms between Probe Positions 1 and 2, and another decrease of 44 ms from Probe Position 2 to Probe Position 3); *closed, cooked, broke, rolled, moved*, and *spun* showed an unclear pattern of priming with either n-shaped (*closed, cooked, broke*) or no change in priming between two adjacent probe positions. We discuss this variable behavior below.

4 Discussion

The main findings of this study are that the processing of sentences with unaccusative verbs includes reactivation of the subject's antecedent after the verb, while the processing of sentences with unergative verbs does not. The reactivation pattern of the unaccusative subject NPs is similar to the activation pattern found with another NP-movement structure—passive—in that the reactivation does not occur immediately at the trace position, but rather a short time following it.

These findings have several implications. First, they indicate that S-V sentences with unaccusative and unergative verbs are processed differently and that the subject is reactivated after the verb in the former but not in the latter,5 thus supporting the Unaccusative Hypothesis and analyses that argue for movement in unaccusative sentences from object to subject position.6 In fact, these findings support the notion that unergatives and unaccusatives map their respective subjects to different positions, the subject of unergatives being mapped externally, namely merged into a specifier position, and the

[5]We would not expect to find reactivation of the subject of unergatives even though it moves from VP-internal subject position or Spec,vP because such reactivation should take place before the verb rather than after, whereas we measured reactivation that follows the verb. It might also be that such movement does not require reactivation at all, given that it does not result in a change in linear order.

[6]Are the results consistent with Hale and Keyser's seminal work on unaccusativity? Hale and Keyser (1993, 1999, 2002) suggest that argument structure should be viewed as syntax occurring in the lexicon. Under their analysis, lexical incorporation—a head movement that takes place in the lexicon—occurs both in unergative denominal verbs and in unaccusatives. With respect to unergatives, although movement takes place in their lexical derivation, it is the head N that moves (say, the N *laugh* for the verb *laugh*) and not the NP-external subject; therefore, no reactivation would be predicted after the unergative verb, similar to our findings. However, under Hale and Keyser's analysis, it is not completely clear whether the internal argument of an unaccusative verb is in a complement position or already occupies Spec,VP when it is inserted into the s-syntax. If it moves to Spec,IP from the complement position of V, then Hale and Keyser's analysis would predict reactivation after the verb, as we found. However, if the argument is already in Spec,VP when it is inserted from the lexicon, then no difference in activation pattern would be expected between unaccusatives and unergatives, contrary to what we found. In fact, Hale and Keyser (1993:97) themselves discuss this point, emphasizing that such a view does not fully reflect the differences in syntactic behavior between verbs like *dance* and verbs like *break*.

subject of unaccusatives being mapped internally, into complement position (see Horvath and Siloni 2003 for discussion).

A second implication of the findings is that the reactivation following a verb (here and in other CMLP studies) is *not* a result of all the verb's arguments being reactivated when the verb is encountered, as some have claimed (Nicol 1993; see also Walenski 2002 for a review and discussion). If this were the case, then we would have observed reactivation of the subject not only after unaccusative verbs but also after unergative verbs; but we did not. Indeed, CMLP studies examining reactivation have predominantly found such effects only for those NPs that have been displaced or copied from their base-generated positions (e.g., Shapiro et al. 2003).7

Another point raised by the current results, taken together with previous findings regarding activation patterns in online sentence-processing studies, is the difference in activation patterns between relative clauses and *wh*-questions on the one hand, and passives and unaccusatives on the other. Both involve reactivation of the moved constituent, but the time course of this reactivation is different. Whereas relatives and *wh*-questions show reactivation at the gap, passives and unaccusatives show reactivation only at a later point in the sentence. At first glance, this could be taken as another type of support for the distinction made between two types of NP-movement: A-movement (or NP-movement to subject position) and Ā-movement (or movement to Spec,CP). Movement to Spec,CP results in immediate reactivation at the gap, whereas movement to subject position yields slower reactivation.

Why do the two types of movement yield distinct online processing patterns? One possibility is that the surface cues signaling a subsequent gap are more apparent in structures derived from Ā-movement than in those derived from A-movement. Consider the types of Ā-movement chains that have been studied using the CMLP task: *wh*-questions and relative clauses. Both display an explicit cue early in the sentence for the existence of a trace downstream: in questions, it is the *wh*-word, and in relative clauses, it is the complementizer *that* or *who*. In passives and unaccusatives, no unique, reliable, and "early" visible cue is available, and the parser realizes that reactivation is required only when presented with the verb. This surface difference might give rise to the difference in the temporal properties of reactivation in *wh*-questions and relative clauses on the one hand, and passives and unaccusatives on the other: a parser that encounters a complementizer or a *wh*-morpheme can reactivate once it encounters a verb that takes an NP complement; a parser that encounters a sentence with an unaccusative (or passive) may require more time to proceed from the verb, which is the first indication of the need for reactivation, to the reactivation itself (Fodor 1993, Nicol 1993).8

[7]Similarly, a reviewer has suggested that what we interpret as gap filling after the unaccusative verb is in fact a reflex of integrating the subject into the evolving representation of the sentence. If that were the case, we would have observed the subject being activated at the point where the unergative verb was encountered, as well. As our data clearly show, this is not the case. In addition, notice that we found not only increased RTs after the unaccusative verbs, but also an important indication that the antecedent is reactivated: a priming effect for the related probe, which occurred only in sentences with unaccusative verbs. That is, the observed priming patterns show that unaccusatives *reactivate* their subjects, but with unergative verbs we found no evidence for subject activation past the point where the subject was encountered.

[8]An interesting prediction is that if the reason for the late activation in cases involving NP-movement is the lack of a cue, then if an early cue were available in an NP-movement structure, no priming delay would be expected. If, on the other hand, it is the type of movement that is the reason for late activation, then we would expect late activation in NP-movement structures even when there is an early cue for movement. A relevant case, suggested to us by Idan Landau, is quirky passives and unaccusatives in Icelandic, where the argument promoted to subject position bears visible inherent case (dative/genitive), which is possible only on internal arguments. This case marking would be the early cue for displacement and should yield activation at the gap if indeed late priming results from lack of a cue for movement.

This possibility is supported by a study that compared relative clauses with and without the complementizer *who* (Swinney and Osterhout 1989). The study showed that when the (optional) relativizer was omitted in English object relative constructions (which are derived by Ā-movement), reactivation of the direct object was delayed by at least 300 ms.

There is an important unresolved issue related to the observed patterns in our experiment. The alternating unaccusatives did not consistently show reactivation effects. Prima facie, this could mean that indeed they are not processed similarly to the nonalternating unaccusatives and that they are not derived by movement from object position. However, the verb-by-verb analysis seems to suggest otherwise; verbs within this group show variable behavior. Some of the verbs induced reactivation of the subject after the verb, whereas others did not.

This variable behavior could be ascribed to inherent differences in the semantic and syntactic analyses of these verbs, but it can also be ascribed to a strategy the processor adopts in the face of uncertainty. On the side of inherent differences, several researchers have suggested that unaccusativity can be linked to factors such as agentivity, aktionsart, or telicity (Dowty 1991, Van Valin 1990, Wechsler 2001) or to position along a continuum of unaccusativity (Sorace 2000). In Borer's (1994, 2004) account for the variable behavior of intransitive verbs, the lexical entry is radically underspecified, and the unaccusative/unergative distinction is driven not by the information in a particular lexical entry concerning the projection of a verb's arguments, but by the properties of the entire predicate. (But see Reinhart 2000 for arguments against aspectual or "external causation" terms.)

However, we would like to suggest that the variable behavior observed in our experiment could be ascribed to a strategy the processor adopts in the face of ambiguity. The most important point that should be taken into account when thinking of the unruly reactivation behavior of alternating unaccusatives is that unlike nonalternating unaccusatives, alternating unaccusatives in English are formally identical to transitive verbs. When the parser meets an alternating unaccusative, it is unsure of how its lexical properties will be reflected in the structure of the sentence; that is, the verb could in principle be transitive and hence not require reactivation, or it could be unaccusative, in which case a trace and reactivation will be required. Thus, when the parser encounters such a verb, it may consider it initially as transitive and thus not reactivate initially. In this case, reactivation would occur only later. This possibility could be examined in a follow-up priming study that would examine priming of antecedents of alternating unaccusatives at later positions in the sentence. Also, if indeed the reason for the alternating unaccusatives' variable behavior is the identity of the transitive and intransitive verb forms, it would be interesting to examine these verbs in a language like Hebrew, where the transitive and unaccusative counterparts differ morphologically (Borer 2004, Reinhart 2000).

Taking this observed distinction at face value for now, our results suggest that the argument structure of the verb helps predict upcoming structure. The verb has to be marked as unaccusative, and that information must be available to the parser; otherwise, how could the parser know that reactivation is required in such cases relative to unergatives?[9] This

[9]The information contained in the sentence proper is not a likely candidate for telling the parser what to do. Previous studies have shown that whether or not the subject is semantically appropriate to serve as an antecedent for a structurally detected gap is not something the parser takes into account when reactivating at the gap. Hickok et al. (1992) and Swinney (1991) found that the parser postulates a gap at every structurally licensed position, regardless of semantic/pragmatic plausibility. Phrases that were semantically implausible as a direct object of the matrix verb were nonetheless reactivated in that position if they were structurally appropriate. For our discussion of reactivation in sentences with unaccusatives, this means that whether or not the subject in a sentence is animate or inanimate (and thus more or less likely to refer to an intrinsic causer of the event described by the verb) should not be a factor that the parser takes into account when deciding whether to reactivate the antecedent after the verb.

suggests, then, that it is only the verb's underlying argument structure—whether it is unergative, unaccusative, or transitive—that is used, initially, during parsing routines. Thus, lack of activation of the argument of alternating unaccusatives at Probe Position 3 might also be related to visibility considerations.

5 Conclusion

Data from the online processing of sentences with intransitive verbs show that unaccusatives (nonalternating, and some alternating) reactivate their subjects after the verb whereas unergatives do not, thus supporting the view that unaccusative subjects are base-generated in object position. To our minds, this result is evidence that online techniques, by providing a snapshot of the language-processing system, can address important controversies in linguistic theory.

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Appendix A: Verbs Used in the Experiment

Unergatives	Nonalternating unaccusatives	Alternating unaccusatives
barked	appeared	bounced
crawled	arises	broke
screamed	arrived	grew
hesitates	stood	dried
laughed	emerged	closed
cried	departed	froze
jumped	existed	cracked
winked	disappeared	shut
escaped	fell	moved
smiled	flowered	opened
shouted	occurs	rolled
slept	remained	sank
sang	rises	spun
waved	bloomed	swung
trembled	vanished	cooked
laughed	departed	grew
smiled	disappeared	closed
waved	vanished	rolled

Appendix B: Experimental Sentences by Verb Type and the Probes That Appeared with Them

Type	Sentence	Related probe	Unrelated probe
Nonalternating unaccusative	The runner with the funny accent and humble attitude unfortunately **disappeared** when the important scout arrived at the gymnasium.	track	trend
	The fireman with a passion for television game-shows accidentally **fell** after the heroic rescue of the Siamese kitten from the peak of the burning house.	fire	pork
	The Marine from the northern part of the state of California swiftly **departed** after the telephone rang loudly in the middle of the night.	ship	text
	The banker from the very conservative and prestigious group frequently **arises** very early in the mornings as the alarm clock rings with an annoying buzz.	money	music
	The weed with many green and brown prickly points unexpectedly **flowered** after a little girl ran across the lawn with a bottle of water.	grass	match
	The summer in countries in the Southern Hemisphere **occurs** at the same time it is winter in the Northern Hemisphere.	sun	top
	The lieutenant with the well-ironed shirt and shiny loafers obediently **rises** when the higher officers enter the room late at night after attending parties.	army	data
	The rose outside the entryway to the expensive home finally **bloomed** after the owners were already completely desperate.	garden	butter
	The company with the flashy silver, gold, and red spiral logo **emerged** on the international scene just a few short weeks ago.	business	boundary
	The ballerina with the blue tights and purple taffeta tutu graciously **appeared** on stage in front of the applauding audience after the show ended.	ballet	ladder
	The poet from the tiny province in southern France unexpectedly **remained** after most of the other guests left the charity function for the literary guild.	word	mice
	The carpenter with the huge collection of black and white pictures fearfully **stood** in the corner of the mansion for seventeen hours during the blizzard Tuesday.	wood	duke
	The tailor from East Orange, New Jersey, mysteriously **disappeared** when it was time to adjust the tuxedos and dresses for the participants in the wedding party.	suit	shoe
	The cook from the small village outside of Anchorage, Alaska, quickly **departed** while the Yankees were playing the Padres in the World Series.	food	list
	The comet with the long and flashing fiery tail apparently **existed** long before the first telescope was used.	sky	ice
	The queen with an incredible tendency to offend the media mysteriously **vanished** when the committee was about to announce the winner of the personality of the year contest.	king	rice
	The tourist in the expensive French restaurant unexpectedly **vanished** right before it was time to pay the very expensive dinner bill.	vacation	interior
	The cameraman from the most prestigious area of the city **arrived** by taxi to the crime scene a few hours after the robbery occurred on Friday.	camera	carpet
Alternating unaccusative	The table in the basement of the old house finally **dried** after the leaking window was sealed a month ago.	chair	speed

Type	Sentence	Related probe	Unrelated probe
	The kite with many colors and an extremely long and shiny tail **swung** from the tree after the boys and girls went chasing after the neighborhood clown.	string	blonde
	The tavern at the edge of the quiet town finally **opened** after the high school graduation ceremony finished.	beer	knee
	The parrot with red and green and yellow colors repeatedly **bounced** from swing to swing for many hours Monday morning.	bird	moon
	The granite with an intricate black-, white-, and silver-colored pattern suddenly **rolled** down the mountain when the earthquake hit.	rock	bond
	The hive in the tree outside the window uncontrollably **spun** when the Santa Ana wind came blowing from the east.	bee	lap
	The course on quantum mechanics and plasma physics unexpectedly **closed** when the teacher got a better offer from Berkeley.	class	north
	The kid with the vintage comic-book collection surprisingly **grew** two inches in the last seven months.	child	price
	The pie with grandma's secret ingredients gently **cooked** in the kitchen for an hour before the guests arrived.	apple	detail
	The market at the edge of the rural and friendly town unexpectedly **shut** in the middle of the annual Celebration of Spring parade.	store	frame
	The street in the bustling center of Kansas City unfortunately **froze** just before the pizza delivery girl crossed with two large pepperoni pizzas.	road	belt
	The shrub outside of the backyard patio predictably **grew** two feet after the installation of the advanced irrigation system.	plant	march
	The vase on the mantel in the long hall of the mansion suddenly **cracked** after the opera singer on the radio hit a very high note.	flower	tissue
	The doctor on the other side of the desk anxiously **moved** when the young couple started fighting over the right treatment.	patient	cabin
	The racket with the black handle and sharp new carrying case suddenly **broke** right after the game began at six o'clock sharp.	tennis	bottom
	The hand of the strong hardworking farmer with the brown freckles firmly **closed** around the iron hoe.	finger	minute
	The island in the Southern Hemisphere unfortunately **sank** before the scientists examined the native animals and insects.	ocean	event
	The bicycle from the consignment shop on Second Avenue quickly **rolled** down the hill when the happy rider finished homework on Friday.	wheels	prayer
Unergative	The surgeon with a brown felt fedora hat and matching coat eagerly **smiled** when the beautiful actress walked down the corridor to exam room three.	knife	drain
	The landlord of the building on Lexington Boulevard suddenly **screamed** when the newly signed lease flew away in the light evening breeze.	rent	pond
	The people in the live studio audience spontaneously **laughed** at the antics of the actors in the popular prime-time television situation comedy.	crowd	purse
	The fisherman from the south side of the peninsula happily **waved** as the helicopter circled above the sandy beach last Tuesday.	fish	pick

Type	Sentence	Related probe	Unrelated probe
	The roofer with a straw hat, three hammers, and a chisel apparently **cried** after the best hardware shop in town was closed by the Internal Revenue Service.	roof	beef
	The policeman from the choir of the New York City YMCA happily **sang** to his whole family in the eleventh family reunion in the family mansion.	gun	eye
	The lawyer with a sweet tooth and concerning tendency to gain weight spiritedly **jumped** when the Girl Scout turned the corner to deliver tasty cookies.	law	oil
	The senator with a conventional grey coat and red tie noisily **slept** in the upstairs guestroom after the fast-paced Scrabble tournament ended in the den.	Congress	entrance
	The aunt with the big green sport utility vehicle quickly **escaped** after the three unruly toddlers made a mess in the living room.	uncle	agent
	The plumber with a migraine headache and no medicine uncontrollably **winked** as the bartender mixed margaritas with lots of strawberries and salt.	pipes	socks
	The spider with the black fuzzy legs and a big red spot slowly **crawled** down the windowsill after the sparrows began to sing in the morning.	web	hut
	The producer with the very tiny Chihuahua restlessly **laughed** while the entertainer tap-danced across the stage in the Broadway revival of *The Phantom of the Opera*.	movie	bacon
	The librarian from the University of West Virginia usually **hesitates** before shelving the linguistics journals together with the psychology journals.	book	game
	The sailor with a tattoo of a girl on his right upper arm uncontrollably **smiled** when the street performer stumbled over a distinguished lady with purple hair.	boat	rain
	The chiropractor with a degree from a college in Minnesota involuntarily **trembled** when the assistant turned the air conditioner on full blast.	back	door
	The dentist from southwest Oklahoma City purposefully **shouted** when the assistant poured a full bottle of chloroform onto the linoleum floor.	teeth	chief
	The janitor with the orange silk trousers from Wisconsin spontaneously **waved** when a nice-looking woman with a floral dress entered the room with a charming smile.	broom	sauce
	The dog from the mountainous area of Boulder, Colorado, angrily **barked** at the mailman with the huge bag filled with interesting letters and postcards.	cat	bus

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Table 1

Mean priming effect (lexical decision time to unrelated minus related probes) by verb type and probe position (in ms)

	Probe Position 1	Probe Position 2	Probe Position 3
Nonalternating unaccusatives	57.6	18.3	63.1
Alternating unaccusatives	44.3	15.8	8.1
Unergatives	56.9	26.9	8.2

Table 2

Mean reaction time for unrelated probes according to verb type at each probe position (in ms)

	Probe Position 1	Probe Position 2	Probe Position 3
Nonalternating unaccusatives	672.9	655.8	680.6
Alternating unaccusatives	654.6	635.3	646.2
Unergatives	683.6	649.2	642.3