The vase fell (the vase): the online processing of unaccusatives

Naama Friedmann[1], Gina Taranto[2], Lewis P. Shapiro[3], and David Swinney[2]

[1] Tel Aviv University, [2] University of California San Diego, [3] San Diego State University

According to the Unaccusativity Hypothesis, unaccusative subjects are base generated at the object position, and move to the subject position. We examined this hypothesis using a Cross Modal Lexical Priming technique, which enables the examination of whether and when an antecedent is reactivated during the on-line processing of a sentence. We compared sentences with unergative verbs to sentences with unaccusatives, both alternating and non-alternating, 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 Unaccusativity Hypothesis.

1 **Introduction**

Mark Baker, in his 1983 paper remarked that "*All seemingly intransitive verbs are not created equal."* In this study we empirically test the theoretical claims regarding the difference between different intransitives, by testing whether there is an observable difference in the online processing of unaccusatives and unergatives. According to the Unaccusativity Hypothesis, there are two classes of intransitive verbs: unaccusatives and unergatives (Perlmutter 1978, Perlmutter and Postal 1984). Semantically, they differ in that the subject of unaccusative verbs, unlike the subject of unergatives, 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. Syntactically, the single argument of unaccusatives is a direct object, while in unergatives it is the subject. Thus,

---

Thanks to Nicoleta Bateman for running countless subjects in the Brain and Language Laboratory at UCSD. This research was supported by NIH-NIDCD grant DC00494 (Swinney, Shapiro) and by the Joint German-Israeli Research Program grant GR01791 (Friedmann). Address correspondence to: Naama Friedmann, Tel Aviv University, Tel Aviv 69978, Israel, e-mail: naamafr@post.tau.ac.il, http://www.tau.ac.il/~naamafr.

although superficially the sentences "*The leaf fell*" and "*The bird chirped*" both show NP-V word order, the first involves NP movement from object to subject position (1), while in the other the NP is base generated in the subject position (2).[1]

(1) The leaf$_i$ fell t_i

(2) The bird chirped

Since Burzio's (1986) incorporation of Perlmutter's Unaccusativity Hypothesis into transformational terms (see a survey of the development of this concept in Pullum 1991), 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, a recent paper by Rappaport-Hovav and Levin (2001) concludes: "*Our work calls even more seriously into question the existence of any evidence for the syntactic encoding of unaccusativity in English*" (p. 792). It is the aim of the current study to find out whether or not unaccusativity is syntactically encoded, and whether unaccusatives include an object at some stage.

Another question that is raised by theorists who accept the Unaccusativity Hypothesis, relates to the extent of this hypothesis, and specifically to whether alternating and non–alternating unaccusatives involve the same syntactic analysis. Alternating unaccusatives are those intransitive verbs whose subject may also appear as the direct object of a morphologically identical transitive verb, as illustrated by the alternating unaccusative *break* in (3). Subjects of non–alternating unaccusatives never appear as the direct object of a morphologically identical verb, an example is *vanish* in (4).

---

[1] Following Chierchia (1989), Reinhart (1997) and Reinhart and Siloni (in press), we assume that an operation labeled Reduction can operate in the lexicon on transitive entries to produce unaccusative verbs by reduction of the external argument. When the external argument is reduced, languages like English require the movement of the internal argument to subject position.

(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, which 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 projected in subject position at D-structure. Two arguments are brought for this claim. The first is that "normal" unaccusatives, such as *vanish*, do not have transitive counterparts that assign accusative case. Another argument comes from the *there*-construction diagnostics for unaccusative verbs in English: unaccusatives like *come* participate naturally in such constructions (5), but unergatives such as *shout* (6) do not. According to Haegeman and Belletti alternating unaccusatives resist this construction, as seen in (7), behaving in this respect like unergatives rather than unaccusatives.[2]

(5) There came three new sailors on board. (Haegeman 1994:335-85a)

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

(7) *There broke a vase.

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

[2] Notice, however, that some alternating unaccusatives can appear with 'there' - *There hung a picture on the wall,* and some non-alternating unaccusatives sound strange in this construction - *There expired some milk*. See Levin and Rappaport-Hovav (1999) who show that the restrictions on there-construction are very subtle and context-sensitive.

In the current study we compare the on-line processing of alternating unaccusatives and non-alternating unaccusatives, and compare them to unergative verbs, using a measure that is sensitive to reactivation of antecedent arguments - Cross Modal Lexical Priming. If indeed SV 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 unaccusatives but not in 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 the object position; we should not observe activation of the subject NP in the object position with unergative verbs.

1.1 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. For example, frequent words are accessed more rapidly than infrequent words (all other things being equal). Another factor that has been found to enhance lexical access 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 appears after an unrelated word. Thus, 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 1997). This phenomenon has been frequently used in psycholinguistic research to determine when during the course of auditory sentence processing word meanings are activated. When this technique is employed in the study of on-line processing of movement traces, the idea is the following: if reactivation of the antecedent occurs at the trace position, the reactivated item should prime a related word at that position. Thus, for example, in an auditorily presented object relative sentence (8) the visual target word "ballet" will be primed not only immediately after hearing the word "dancer" when it is first heard at the beginning of the sentence (point ①), but also at the trace position (point ②), where it is reactivated to interpret the sentence and assign the thematic role to the chain.

(8) The dancer① 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, Onifer, Prather, and Hirshkowitz 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 non-word) is visually displayed on a screen. The participant is asked to attend to the aurally presented sentence and to also make a lexical decision (word/non-word) 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, Canseco-Gonzalez, Zurif, and Grimshaw 1992, Love and Swinney 1996, Nicol and Swinney 1989, Swinney, Ford, Frauenfelder, and Bresnan 1988, Tanenhaus, Boland, Garnsey, and Carlson 1989, Tanenhaus, Carlson, and Seidenberg 1985, Tanenhaus, Stowe, and Carlson 1989, Zurif, Swinney, Prather, Wingfield, and Brownell 1995).

1.2 Cross Modal Lexical Priming and movement traces

In the last 15 years studies using CMLP have found ample evidence for the reactivation of the head of the antecedent NP at the trace position of Wh chains, mainly with relative clauses (Love and Swinney 1996, Nicol and Swinney 1989, Swinney, Ford, Frauenfelder, and Bresnan 1988, Swinney, Zurif, and Nicol 1989, Zurif, et al. 1993, 1995). Few CMLP studies have looked at the processing of NP movement. In one, however, Osterhout and Swinney (1993) tested reactivation in passives, using this technique. The participants in this study made lexical decisions about words (and non-words) that were presented at three locations after the verb during auditory sentence comprehension. Responses to words related to the subject were faster than responses to semantically unrelated words

during passive sentences, but not during active sentences, indicating that reactivation of the moved constituent occurs in passive sentences. However, compared to findings from wh-chains, the reactivation in passives occurred at a temporally delayed point, some 1000 ms after the verb (with only a non-significant trend for priming right after, and 500 ms after the verb). Other studies have also indicated reactivation 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) have reported re-access to the subject in passives, raising constructions and "tough" constructions, and Bever and Sanz (1997) reported re-access in unaccusatives in Spanish, using end-of-sentence probes (a methodology that can indicate reactivation but is limited with respect to being capable of detailing when exactly during the unfolding of the sentence the reactivation occurs).

In the current study we used CMLP to test another type of NP movement (A chain movement): unaccusatives. Our main aim was to test the theoretical claim that SV sentences with unaccusatives are derived by movement of the object to subject position, while SV sentences in unergatives do not include such movement. Again, if unaccusative subjects undergo movement from object position there should be reactivation of the subject in the trace position after an unaccusative verb, but not after an unergative verb. A second aim of this study was to compare the two types of unaccusative verbs: alternating and non-alternating, and see if they behave similarly with respect to reactivation after the verb. This was motivated both by the theoretical claims discussed earlier that alternating unaccusatives actually have their subjects base generated in subject position (Haegeman 1994, Belletti 1988), and following findings from neuropsychology of language indicating that individuals with Broca's aphasia behave differently on these two types of unaccusative in an off-line comprehension study: Piñango (1999) found that Broca's aphasics performed above chance in the comprehension of subject relative and subject cleft constructions on non-alternating unaccusatives, and at-chance on the alternating unaccusatives (the difference between the two types of unaccusatives was significant for one of the patients tested, but non-significant for the other).

2 **Method**

2.1 Participants

Participants were 120 undergraduates of 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 pre-tests of the materials are described with each pre-test 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 transitive verbs. 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: non-alternating unaccusative verbs, alternating unaccusative verbs, and unergative verbs.

The verbs were selected according to the following criteria and procedure: 15 verbs were initially selected for each 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 Kucera and Francis (1967) database. In order to balance overall frequency of verbs between the three verb-type groups, three verbs from each group were chosen to be repeated an additional time – making for 18 verbs appearing in each condition. (The mean frequencies of the alternating unaccusatives, non-alternating unaccusatives and the unergatives were 136.1, 126.9, and 83.5 respectively, which did not differ significantly, $F(2, 51) = 1.24$, $p = .30$). 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 possible argument structures. See the Appendix for a list of all verbs used in the experiment by verb type.

Non-alternating unaccusatives were identified based on 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 classified based on their behavior with respect to three diagnostics: existence of a morphologically identical predicate that takes a direct object (12), the ability to take a passive subject (13), and the 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 based on their behavior with respect to four diagnostics: ungrammaticality in the *there*-construction (15), ungrammaticality in the resultative construction (16), and the inability to occur with a reflexive pronoun (17) unless the reflexive pronoun is followed by a resultative (18). These diagnostics are illustrated below with the unergative verb *clap*.

(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.

All of the antecedents (heads of NP antecedent) were full NPs, and they were not proper names or pronouns. The antecedents used 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 pre-test involving 50 UCSD students who were all native speakers of English. Each of these participants wrote the first semantic associate they thought of for each subject NP; the most frequently provided response for each subject NP across these participants was chosen as the 'related' visual target probe.

The unrelated probes were chosen to be matched in number of letters, syllables, and frequency with each related probes, and then, most critically, a single 'unrelated' probe was chosen from among these candidates based on matched baseline reaction time for lexical decision. The baseline reaction time was determined by a study in which 54 participants (UCSD students participating for course credit) made lexical decisions via button press to each of several hundred visually presented words and non-words (equal numbers of each) which included the 'related' and potentially matched 'unrelated' items. The matched 'unrelated' probe was chosen from those tested based on a priori lexical decision times derived from this pre-test. The mean base lexical decision times 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 the 4 milliseconds. Each head of subject NP and each probe appeared only once per participant during the entire sentence list.

As seen in examples (19) - (21), 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 immediately at

the offset of the verb (at the trace). Probe Position 3 was 750 ms after the second probe position. This "downstream" positioning of the third probe was based on the findings of Osterhout and Swinney (1993) that reactivation of an NP trace took place downstream from the verb.[3]

(19) Non alternating 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.

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 a decay in activation from the initial appearance of the subject NP to take place. Given previous data indicating that 1.5 seconds or 3-5 syllables are typically required to detect decay in priming (Swinney 1979, Onifer and Swinney 1981, Love and Swinney 1996), 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, or to the related or the unrelated probes. In

[3] In typical gap filling experiments, a pre-gap position is often compared to a gap position, so that an argument can be made about *re*-activation rather than continuous activation from the filler. Because our design could only accommodate three probe positions – and we needed to test at the antecedent and at the trace, we chose a position after the trace as the third position rather than a pre-verb (gap) position. As it turns out, we did find decay and *re*activation – as the second probe position showed less priming effect than the first probe position, while the third probe position did show priming for the unaccusative verbs (see results section).

addition, padding of approximately 10 words (18 syllables) was added after the verb in order to avoid end-of-sentence effects, and to allow the responses to both the second and the third probe positions to be carried out while the sentence is still running (see., e.g., Balogh, et al, 1998).

2.3 Design

In order that no sentence would be heard more than once by the same participant, 6 scripts comprising identical experimental (54) and filler (40) sentences were created. The 3 probe positions and 2 probe types (related/unrelated) for each experimental sentence were then completely counterbalanced (equally distributed) across the 6 scripts. Each of the six scripts was presented to twenty participants, and the assignment of participant to script was 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 sound-proof testing booth in front of a computer monitor and a button response box. The sentences were presented over headphones via a digital tape recorder. During the temporal unfolding of each sentence, a visually-presented lexical decision probe appeared centrally (for 500ms) on the monitor. Subjects were required to attend carefully to the aurally-presented sentences and also to make a visual lexical decision whenever a letter string appears on the screen as quickly and accurately as possible by pressing one of two response keys (labeled WORD, NONWORD); Response times (RT) for this decision were recorded by the computer. In 20% of the trials subjects were asked a yes/no comprehension question about the sentence that they had just heard,

with the purpose of ensuring that the subjects 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 reactions times 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**

The main issue under investigation in this study was whether or not there is reactivation of the subject NP after the verb in unergatives and unaccusatives (of the two types). This was examined via the analysis of the priming pattern in the various Probe Positions for the different verb types. This was done by comparing priming effects within a verb type both between Probe Positions, as well as within a single Probe Position between verb types.

Our findings, which are elaborated below, were that priming occurred right after the head for all three verb types, and reactivation at Probe Position 3 occurred only for the unaccusative verbs (non-alternating and some of the alternating verbs), but not for the unergative verbs. The dependent variable that was 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 which took longer than 2000 ms to respond were discarded (2% of the data points). In addition, two participants had average reaction times that were more than 3 standard deviations above the mean for all participants and they were dropped from the

data analysis.[4] It was decided on a-priori grounds 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 sufficiently 'related' as to provide (the well-documented) immediate priming effect that could then be examined for reactivation. On these a priori grounds, 8 sentences (which distributed relatively evenly across verb types) were dropped from further analysis.

Following calculation of mean priming effect for each item for each condition for each subject, these data were submitted to inferential analysis with both items and with subjects as random variables. Both 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. (These are reported here for the items analysis, collapsing over subjects; the analysis collapsing across items reveals nearly identical results.)

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
Non alternating unaccusatives	57.6	18.3	63.1
Alternating unaccusatives	44.3	15.8	8.1
Unergatives	56.9	26.9	8.2

[4] Also, during the conduction of the experiment, some participants were discarded from the analysis on a priori decision-based grounds. These included participants who had more than 10% errors in lexical decision (including failure to respond within 2 seconds) (3 participants), participants who scored below 70% correct on the comprehension questions (1 participant), and participants who were not native monolingual English speakers (1 participant). In addition during some experimental runs computer or other hardware (sound) difficulties resulted in no data being collected (9 participants). For all of these cases, additional participants were run to replace them in the data analysis.

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 reaction times than the unrelated probes (657.1 ms, $F(1, 45) = 18.84$, $p < .0001$). A significant effect of relatedness was revealed also with an analysis of the data with subjects as the random variable ($F(1, 117) = 60.36$, $p < .0001$, mean related probes: 624.2 ms, mean unrelated probes: 655 ms).

Since our main interest was in whether there is *re*activation for each of the verb types, we ran preplanned (a priori) trend analyses for linear and quadratic contrasts. A linear trend would mean that there is a constant decrease in priming effect from Probe Position 1 to Probe Position 2 and to Probe Position 3, and this would mean that there is priming for the head of the subject NP, then this activation decays, and there is no reactivation of the subject at later point. A quadratic trend, on the other hand, indicates U-shaped activation pattern, suggesting that there is priming for the subject, then decay in activation, and then reactivation of the antecedent at probe position 3, which manifests in priming effect at Probe Position 1 and Probe Position 3. The analyses for each verb type, with items (sentences) as the random variable, yielded a significant quadratic trend for the non-alternating unaccusatives, indicating reactivation of the antecedent at Probe Position 3 ($F(1, 14) = 4.23$, $p = .05$), and no linear trend for the non-alternating unaccusatives. The unergatives and the alternating unaccusatives showed a linear trend and no quadratic trend, namely – 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 unergative, $F(1, 17) = 4.95$, $p = .04$ 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, $F(2, 214) = 3.74$, $p = .03$.

Preplanned contrasts for each of the verb types showed, like the analysis by items, a linear trend for the unergatives, $F(1, 107) = 4.05$, $p = .04$, and for the alternating unaccusatives, $F(1, 117) = 4.33$, $p = .04$, and no quadratic effect for either of them; for

the non-alternating unaccusatives there was a non-significant 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, which was done by one way ANOVAs 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 non-alternating unaccusatives and unergatives, $F(1, 107) = 5.13$, $p = .03$, and between alternating and non-alternating unaccusatives $F(1, 107) = 5.69$, $p = .02$. This supports the pattern of antecedent activation for the three verb types that can be seen in Table 1; reactivation occurs at the third Probe Position for non-alternating unaccusatives, but not for the other two verb types.

3.1 Analysis of RT for the unrelated probe as indication for processing load

To this point we have analyzed the priming effect at different positions of the sentences, and these analyses yielded a priming effect for (some of) the unaccusative verbs downstream from the verb, which was interpreted as reactivation of the antecedent. Still, the data lend themselves to an additional type of analysis. If we treat the RT for the unrelated probes as an indication for processing load (see Shapiro, Gordon, Hack, and Killackey 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 co-reference 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 to Probe Position 2 for both types of unaccusatives but not for the unergatives. At Probe Position 3 there was an *increase* of 24.8 ms for the non-alternating unaccusatives, an increase of 10.9 ms for the alternating unaccusatives, and a *decrease* of 6.9 ms for the unergatives. This difference between both types of unaccusatives and the unergatives was not significant on item analysis, $t(44) = 1.47$, $p = .14$; between the non-alternating unaccusatives and the unergatives, $t(26) = 1.74$ $p = .09$. Though these results

were not significant, they show a clear direction, and this can (carefully) be interpreted as an increased processing load for the unaccusatives at Probe Position 3 which resulted from gap filling (reactivation of the antecedent), while no such process occurred for sentences with unergative verbs.

3.2 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 the alternating unaccusative verb class was a result of variable behavior of various verbs in this class. This analysis revealed that *dried, sank, opened, bounced, froze,* and *grew* behaved exactly like the non-alternating unaccusatives, with priming at the antecedent, decay at Probe Position 2 and reactivation at Probe Position 3 (average priming effect of 42.0, -16.7, and 46.0 ms at Probe Positions 1, 2, and 3 respectively); whereas *closed, cooked, broke, rolled, spin*, *moved, cracked, swung* and *shut* showed decay from Probe Position 2 to Probe Position 3. Further analysis of these 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 (average priming effect of 57.9, 5.3, and -38.7 ms at Probe Positions 1, 2, and 3 respectively); *closed, cooked, broke, rolled, moved* and *spin* showed an unclear pattern of priming with either n-shaped (*closed, cooked, broke*) or no change in priming between two adjacent Probe Positions.

3.2.1 Alternating unaccusatives: further analyses and an interim discussion

At first blush the results with respect to alternating unaccusatives seem quite strange.[5] The first point that should be taken into account when thinking of the unruly reactivation behavior of the alternating unaccusative is that unlike the non-alternating unaccusatives, alternating unaccusatives in English are ambiguous between unaccusative and a transitive verb. When a parser meets an alternating unaccusative verb in English, it does not know

whether it is used in the sentence as a transitive or as an intransitive verb. Thus, patterns of reactivation can vary between sentences, between subjects and between verbs. It might be that when a parser encounters such transitive-unaccusative verbs, if it considers it initially as transitive, no reactivation is expected, and it is possible that in these cases reactivation would appear even further downstream, at a point where a transitive interpretation is ruled out. This could be examined in a follow-up priming study that will examine priming of antecedents of alternating unaccusatives at later positions in the sentence. Also, if indeed the reason for the varied behavior of the alternating unaccusatives was the identity of the transitive and the intransitive verb forms, it should be interesting to examine these verbs in languages like Hebrew, in which the transitive counterpart differs morphologically from the unaccusative (Borer in press, Reinhart 2000).

An additional direction of investigation that might shed light on the attested patterns is related to previous observations that unaccusativity can be linked to factors such as agentivity, aksionsart, or telicity (Dowty 1991, van Valin 1990, Wechsler 2001), or position along a continuum of unaccusativity (Sorace 2000). The hypothesis that emerges posits that those alternating unaccusatives that pattern like non-alternating unaccusatives (namely, that show reactivation at probe position 3) are most frequently found with subjects that are highly patientive, or bear more prototypically unaccusative properties, while those that pattern like unergatives (do not show reactivation) are most frequently found with subjects that can be interpreted as being volitionally engaged in the activity denoted by the verb, or otherwise show less prototypically unaccusative properties. Alternating verbs that did not show any coherent pattern are found with patientive and volitional subjects with equal frequency.[6]

---

[5] Until the 18th century, all scientists treated light as wave. Since Newton, scientists believed light was particles. In 1923, Louis-Victor de Broglie proposed that light has both particle- and wave-like characteristics.

[6] A question that arises here is are the properties involved in what Sorace (2000) terms gradient unaccusativity (i.e. change of location, change of state, continuation of pre-existing state, controlled/uncontrolled process) lexical properties of predicates, or can they vary depending on context? If unaccusativity is purely a lexical property, we would expect the sentences *The agile cowboy swung into the*

A preliminary search of the Brown Corpus is consistent with this hypothesis. In the case of alternating unaccusatives that pattern like non-alternating unaccusatives intransitive uses are frequently found with subjects that are what Dowty (1991) might call an affected object. An example with *sink* from the Brown Corpus is shown in (22), in which 'the entire platform' is affected by, and made to sink by 'ice build up on the aerator'.

(22) An extended cold spell caused ice to build up on the aerator which was mounted on a floating platform and caused the entire platform to *sink* lower in the water. (J70:1500-1520)

In contrast, those alternating unaccusatives that pattern like unergatives (namely *crack*, *shut*, and *swing*) are often found in the Brown Corpus with subjects that can be imagined to be volitionally engaged in the activity denoted by the verb. An illustration is provided with *swing* in (23).

(23) Pat *swung* into the saddle, yet still he delayed, his brows puckered. (N14:1060-1070)

Finally, in the case of those alternating intransitives that show inconsistent pattern of reactivation, initial survey suggests that their subjects are equally likely to have either a patientive or a volitional, agentive subject. Thus, our preliminary conclusion is that there are identifiable sub-classes within the class of alternating unaccusatives, though more evidence in support of this conclusion is necessary.[7]

---

saddle and *The tasty bait swung at the end of the fishing line* to show the same reactivation pattern. If unaccusativity is susceptible to contextual influence (at least at a point 750ms after the verb), we expect different reactivation patterns.

[7] An interesting minimal triple in this respect are the alternating intransitives *open*, which in our study patterned like the non-alternating unaccusatives, *shut*, which patterned like unergative intransitives, and *close*, which showed unruly behavior. The meanings of these verbs are similar to the extent that they each involve a change of state. Real-world knowledge suggests that the changes of state described by each of these predicates could be the result of either controlled or uncontrolled processes. Further research may determine that in spite of real-world possibilities, the lexical semantics of intransitive *open* are suggestive of an uncontrolled process, the lexical semantics of intransitive *shut* are suggestive of a controlled process, and the lexical semantics of *close* are un- or under-specified for 'control of process'.

4 **Discussion**

The main findings of the current study are that the processing of sentences with unaccusative verbs includes reactivation of the subject antecedent after the verb, while in sentences with unergative verbs such a reactivation is not evinced. The reactivation pattern of the unaccusative subject NPs is similar to the activation pattern found in another NP movement structure – passives – in that the reactivation does not occur immediately at the trace position, but rather a short time following it. The alternating unaccusatives showed a mixed pattern of reactivation with some verbs patterning with the (non-alternating) unaccusatives and some verbs patterning with the unergatives, a finding that can be ascribed to some sub-classification of the alternating verbs or to the fact that the alternating unaccusatives are formally identical to transitive verbs and the parser cannot know at an early point which of the possibilities applies to the processed sentence.

The findings have several implications. First, they indicate that SV sentences with unaccusative and unergative verbs are processed differently and that the subject is reactivated after the verb in unaccusative, but not in unergative verbs, thus supporting the Unaccusativity Hypothesis and analyses that argue for movement in unaccusatives from object to subject position (see also Bever and Sanz 1997).

A second implication of the findings is that the reactivation following a verb here and in other CMLP studies is *not* a result of a reactivation of all the arguments of the verb when the verb is encountered as some have claimed (Nicol 1993, see Walenski 2002, for a review and discussion). If this were the case, then we would have expected reactivation of the subject also in the sentences with unergative verbs, contrary to the findings of the current study.

Another point that is raised by the current results, taken together with previous findings regarding activation patterns in on-line 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. While 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 movement of NPs: A-movement (or NP movement to subject position) and A-bar-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. However, we would like to suggest that this might be due not to the different chain types but rather to the availability of cues for the existence of movement in the sentence. Consider the types of wh-movement chains that have been studied using the CMLP task: wh-questions and relative clauses. In both there is an explicit cue early in the sentence for the existence of a trace downstream – in questions it is the wh-word, 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 only realizes that reactivation is required when presented with the verb. This difference might be the cause for 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]

This sort of analysis is supported by a study that compared relative clauses with and without the complementizer "who". The findings were that when the (optional) relativizer was omitted in English object relative constructions (which include wh-movement), re-activation of the direct object appears to be delayed by at least 300 milliseconds (Swinney and Osterhout 1989).

---

[8] An interesting prediction is that if the reason for the late activation in NP movement is the lack of cue, then if an early cue would be available in an NP-movement structure, no delay in priming is 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 structure 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 only possible on internal arguments. This case marking would be the early cue for displacement, and should yield an activation at the gap if the late priming results from lack of cue for movement.

Another point which relates to visibility considerations is our findings with regard to the alternating unaccusatives. It might very well be that the finding that some of these verbs showed reactivation 750 ms after the verb and some did not (unlike the non-alternating unaccusative, which uniformly showed reactivation), relates to the fact that even when the alternating verb is encountered, it is not clear whether reactivation would be required, because it might be transitive and hence not require reactivation, or unaccusative, in which case a trace and reactivation would be required.

To conclude, following this study we can confidently conclude that unaccusatives (non-alternating, and some of the alternating) show reactivation of the subject after the verb, and unergatives do not, thus supporting an analysis of unaccusative subjects as base generated in an object position.

References

Baker, Mark. 1983. Objects, themes, and lexical rules in Italian. In Papers in lexical-functional grammar, ed. L. Levin, M. Rappaport-Hovav and A. Zaenen, 1-46. Bloomington: Indiana University Linguistics Club.

Balogh, Jennifer, Edgar Zurif, Penny Prather, David Swinney, and Lisa Finkel. 1998. Gap-filling and end-of-sentence effects in real-time language processing: Implications for modeling sentence comprehension in aphasia. Brain and Language 61: 169-182.

Belletti, Adriana. 1988. The case of unaccusatives. Linguistic Inquiry 19: 1-34.

Bever, Thomas G., and Brian McElree. 1988. Empty categories access their antecedents during comprehension. Linguistic Inquiry 19: 35-45.

Bever, Thomas G., and Montserrat Sanz. 1997. Empty Categories Access Their Antecedents during Comprehension: Unaccusatives in Spanish. Linguistic Inquiry 28: 69-91.

Borer, Hagit. In press. The Grammar Machine. in The unaccusative puzzle: Studies on the syntax-lexicon interface, ed. A. Alexiadou, E. E. Anagnostopoulou and M. Everaert. Oxford: Oxford University Press.

Burzio, Luigi. 1986. Italian Syntax. A Government-Binding Approach. Dordrecht: Reidel.

Chierchia, Gennaro. 1989. A semantic for unaccusatives and its syntactic consequences. Ms., Cornell University.

Dowty, David. 1991. Thematic proto-roles and argument selection. Language 67: 547-619.

Fodor, Janet D. 1993. Processing empty categories: A question of visibility. In Cognitive models of speech processing: the second Sperlonga meeting, ed. G. Altmann and R. Shillcock, 351-400. Hillsdale, N.J.: Erlbaum.

Haegeman, Liliane. 1994. Introduction to Government and Binding theory, 2nd ed. Oxford: Blackwell.

Hickok, Gregory, Enriqueta Canseco-Gonzalez, Edgar Zurif, and Jane Grimshaw. 1992. Modularity in locating wh-gaps. Journal of Psycholinguistic Research 21: 545–561.

Kučera, Henry, and W. Nelson Francis. 1967. Computational analysis of present-day American English. Providence, RI: Brown University Press.

Levin, Beth A., and Malka Rappaport-Hovav. 1995. Unaccusativity. Cambridge, Mass: MIT Press.

Love, Tracy, and David Swinney. 1996. Co-reference processing and levels of analysis in object-relative constructions: Demonstration of antecedent reactivation with the cross-modal priming paradigm. Journal of Psycholinguistic Research 25: 5-24.

McElree, Brian, and Thomas G. Bever. 1989. The psychological reality of linguistically defined gaps. Journal of Psycholinguistic Research 18: 21-35.

Meyer, David, Roger Schvaneveldt, and Margaret Ruddy. 1975. Loci of contextual effects on visual word recognition. In Attention and performance, Vol. V. ed. P. Rabbit and S. Dornic, 98-118. New York: Academic Press.

Napoli, Donna Jo. 1988. Review article: Italian syntax: A Government-Binding approach. Language 64: 130-142.

Neely, James H. 1977. Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. Journal of Experimental Psychology: General 106: 226–254.

Nicol, Janet. 1993. Reconsidering reactivation. In Cognitive models of speech processing, ed. G. Altmann and R. Shillcock, 321-350. Hillsdale, N.J.: Erlbaum.

Nicol, Janet, and David Swinney. 1989. The role of structure in coreference assignment during sentence comprehension. Journal of Psycholinguistic Research 18: 5-19.

Osterhout, Lee, and David A. Swinney. 1993. On the temporal course of gap-filling during comprehension of verbal passives. Journal of Psycholinguistic Research 22: 273-286.

Perlmutter, David, M. 1978. Impersonal passives and the Unaccusative Hypothesis. In Proceedings of the fourth annual meeting of the Berkeley Linguistic Society, ed. J. Jaeger et al., 159-189. University of California, Berkeley.

Perlmutter, David. M., and Paul M. Postal. 1984. The 1-advancement exclusiveness hypothesis. In Studies in relational grammar 2, ed. D. Perlmutter and C. Rosen, 81–126. Chicago: University of Chicago Press.

Piñango, Maria Mercedes. 1999. Syntactic and semantic operations and their neurological underpinnings. Doctoral dissertation, Brandeis University. Waltham, MA.

Pullum, Geoffrey K. 1991. The great Eskimo hoax and other irreverent essays on the study of language. Chicago: University of Chicago Press.

Rappaport-Hovav, Malka, and Beth Levin. 2001. An event structure account of English resultatives. Language 77: 766-797.

Reinhart, Tanya. 1997. Syntactic effects of lexical operations: reflexives and unaccusatives. In OTS working papers in linguistics. University of Utrecht.

Reinhart, Tanya. 2000. The theta system: Syntactic realization of verbal concepts. OTS working papers in linguistics (00,01/TL).

Reinhart, Tanya, and Tal Siloni. (in press). Against the unaccusative analysis of reflexives. In Studies in Unaccusativity: the Syntax-Lexicon Interface.

Shapiro, Lewis P., Betty Gordon, Nancy Hack, and Jennifer Killackey. 1993. Verb argument structure processing in complex sentences in Broca's and Wernicke's aphasia. Brain and Language 45: 423-447.

Shapiro, Lewis P., Nicholas H. Nagel, and Beth A. Levine. 1993. Preferences for a verb's complements and their use in sentence processing. Journal of Memory and Language 32: 96-114.

Shapiro, Lewis P., Edgar, Zurif, and Jane Grimshaw. 1987. Sentence processing and the mental representation of verbs. Cognition 27: 219-246.

Shapiro, Lewis P., Edgar Zurif, and Jane Grimshaw. 1989. Verb processing during sentence comprehension: Contextual impenetrability. Journal of Psycholinguistic Research 18: 223-243.

Sorace, Antonella. 2000. Gradients in Auxiliary Selection with Intransitive Verbs Language 76: 859-890.

Swinney, David, Marilyn Ford, Ulrich H. Frauenfelder, and Joan Bresnan. 1988. On the temporal course of gap-filling and antecedent assignment during sentence comprehension. Unpublished MS.

Swinney, David, William Onifer, Penny Prather, and Max Hirshkowitz. 1979. Semantic facilitation across sensory modalities in the processing of individual words and sentences. Memory and Cognition 7: 159–165.

Swinney, David, and Lee Osterhout. 1989. Inferential elaboration during language comprehension. Paper presented at the Annual Meeting of the Psychonomic Society, Atlanta.

Swinney, David, Edgar Zurif, and Janet Nicol. 1989. The effects of focal brain damage on sentence processing: An examination of the neurological organization of a mental module. Journal of Cognitive Neuroscience 1: 25-37.

Tanenhaus, Michael K., Julie Boland, Susan M. Garnsey, and Greg M. Carlson. 1989. Lexical structure in parsing long-distance dependencies. Journal of Psycholinguistic Research 18: 37–50.

Tanenhaus, Michael K., Greg Carlson, and Mark Seidenberg. 1985. Do listeners compute linguistic representations? In Natural language parsing: Psycholinguistic, theoretical, and computational perspectives, ed. A. Zwicky, L. Kartunnen, and D. Dowty, 359-408. London and New York: Cambridge University Press.

Tanenhaus, Michael K., Laurie A. Stowe, and Greg Carlson. 1989. The interaction of lexical expectation and pragmatics in parsing filler–gap constructions. In Proceedings of the Seventh Annual Cognitive Science Society Meeting, 361–365.

Van Valin, Robert. 1990. Semantic parameters of split intransitivity. Language 66: 221-260.

Walenski, Matthew S. 2002. Relating parsers and grammars: On the structure and real-time comprehension of English infinitival complements. Doctoral dissertation, UCSD, San Diego, CA.

Wechsler, Stephen. 2001. An analysis of English resultatives under the event-argument homomorphism model of telicity. Proceedings of the 3rd Workshop on Text Structure. University of Texas, Austin, Oct 13-15.

Zurif, Edgar, David Swinney, Penny Prather, J. Solomon, and C. Bushell. 1993. An on-line analysis of syntactic processing in Broca's and Wernicke's aphasia. Brain and Language 45: 448-464.

Zurif, Edgar, David Swinney, Penny Prather, Arthur Wingfield, and Hiram Brownell. 1995. The allocation of memory resources during sentence comprehension: evidence from the elderly. Journal of Psycholinguistic Research 24: 165-182.

Appendix: Verbs that Were Used in the Experiment

Unergative	Non-alternating unaccusative	Alternating unaccusative
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