Chapter 9
Event End-Point Primes the Undergoer Argument: Neurobiological Bases of Event Structure Processing

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9.1 Introduction

The progress within neuroscience now allows probing the neural processing of language-related computations as they occur in the living brain. These in vivo investigations can assess how close linguistic theory has come to describing linguistic computations in the brain, uncover neural correlates of theoretically posited abstract linguistic features, and test language processing models. On the other hand, linguistic universals – the features that are consistently reported cross-linguistically – are likely to expose regularities inherent to human neural processing.

Verbal telicity belongs to a small set of semantic features which can affect the syntactic structure of the predicate, as well as the argument role assignment (Vendler 1967; Van Valin 2007; Dowty 1979). Telicity as an element of subatomic semantics is typically formulated as a reference to an end-point of an event within verbal semantics (e.g., *catch*, *fall*). Atelic verbs refer to activities or states, which are conceptualized as homogenous (*tease*, *sleep*).[1] From the point of view of semantics,

[1]Homogeneity and atelicity are not correlated in all theoretical frameworks. The early definitions of atelicity were based on homogeneity (Vendler 1967); however, such definitions did not define grain size of a single event, making difficult the treatment of semelfactives. (Krifka 1989) defined atelicity using the notion of cumulativity; some recent works also suggest treating atelicity as simply non-telicity. Homogeneity, however, remains the most intuitively simple explanation of what it means for a predicate to be atelic.

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B. Arsenijević et al. (eds.), *Studies in the Composition and Decomposition of Event Predicates*, Studies in Linguistics and Philosophy 93,
DOI 10.1007/978-94-007-5983-1_9,

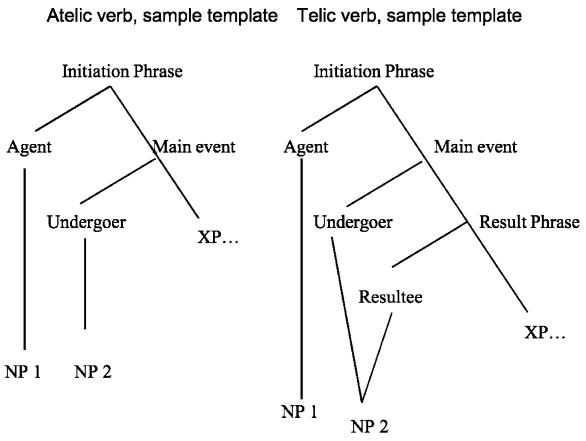

Fig. 9.1 Sample two-argument templates of atelic and telic verbs (cf. Ramchand 2008)

telic verbs provide a temporal reference point for further aspectual computations (Jackendoff 1991). Telic verbs also imply existence of an affected event participant.[2] They have been hypothesized to create a syntactic position for, and assign the thematic role of, the Patient argument, regardless of their transitivity status: intransitive/unaccusative, transitive, or ambitransitive (Tenny 1987; van Hout 2001).[3]

The linguistic behavior of telic verbs has long been of interest to syntacticians, who observed multiple correspondences between telicity (lexical aspect) of the verb, and syntactic structures it can be used in, exemplified by grammaticality of adverbial modification (Tenny 2000), aspectual coercion (Smith 1991), and argument structure alternations (Levin 1993; Ramchand 2008, etc.). Multiple theoretical proposals have been put forth to explain differences in syntactic behavior of verbs from distinct semantic classes; Fig. 9.1 illustrates one such proposal (after Ramchand 2008), linking verbal semantics with the presence of a Result Phrase in the syntactic template.

Early behavioral studies of subatomic event semantics, which indirectly measured the cognitive load induced by linguistic computation using reading and response times, had been driven by the question of whether the notion of

[2]Some languages, such as English or Dutch, require that the affected Patient is quantized in order for the VP to convey telic meaning. The use of bare mass nouns results in loss of telicity for the VP (cf. *I ate fish. – I ate the fish*.) The studies reviewed in this chapter all use quantized arguments.

[3]Multiple arguments exist as to whether to consider (a)telicity to be a feature of the verb, the full predicate (verb and its arguments – cf. Bott, Chap. 8 in this volume), or the entire sentence, (cf. Partee 2004); it is possible that the answer to this question is language-specific (cf. Malaia 2004). The present experiments avoided coercion and mismatch in telicity, as could be introduced by certain arguments or adjuncts: in the telic conditions, both the verb and the entire VP were telic. Additionally, the analysis of ERP waveforms was performed on the verb as well as all words within the VP, so as not to bias the results toward either theoretical framework.

telicity was purely semantic, or whether semantically telic verbs invoked specific syntactic structures during language processing. For example, Sanz (2000) used a cross-modal priming technique, and measured response times to semantic probes in sentences with telic and atelic verbs, showing re-activation of the Patient argument following telic verbs in Spanish (although not for English, possibly due to differential strategies used by the participants in the experiment). A 'word maze' experiment (O'Bryan 2003) used a type of extended grammaticality judgment to assess the effect of telicity on sentence comprehension: the participants were asked to build a grammatical sentence by sequentially choosing one of the two words on the screen (only one of the two words enabled the sentence to continue as grammatical). This experiment used four types of verbs: transitive telic (e.g. *accuse*), optionally transitive telic (e.g. *trip*), transitive atelic (e.g. *carry*), and optionally transitive atelic (e.g. *lecture*), in sentences containing Object reduced relative clauses (e.g. *The actress described by the writer left in a hurry*.). There was a significant reaction time advantage on the *by* for telic verbs, and an independent advantage for the second argument for transitive verbs (both telic and atelic), demonstrating independent effects of telicity and transitivity in this task. These results demonstrated that argument requirements of the verb, and the syntactic structure (or event template) that the verb invokes, are used independently for online sentence processing. Finally, a cross-modal priming study by (Friedmann et al. 2008) compared sentences with intransitive atelic (frequently also termed unergatives[4] in the linguistic literature) and intransitive telic (unaccusative[5]) English verbs, and found a priming effect for Subjects of intransitive telic verbs (unaccusatives), but not for intransitive atelic ones (unergatives).

Overall, behavioral investigations demonstrated that telic verbs (as compared to atelic ones) prime (or re-activate) the Patient argument. However, it remains unclear at which point online comprehension is affected by verbal event structure, and whether the effect is driven by semantic or syntactic properties of the verb. ERP investigations of the timecourse of verbal telicity effects on online processing help answer a crucial question in language comprehension: how do humans associate arguments with thematic roles provided by the verb? Do syntactic and semantic cues interact continuously during comprehension to provide one with the understanding of "who did what to whom", or does the processing occur/progress sequentially? The answers to these questions are important both for the development of linguistic theories, and for the understanding of the brain network interactions, which are ultimately responsible for linguistic computations.

[4] *Unergatives* are a subset of atelic verbs: those with only one argument. Telic verbs with one argument are also termed *unaccusatives*. The neuro-psychological reality of this linguistic distinction is supported by neuroimaging evidence (Shetreet et al. 2010).

[5] While all one-argument telic verbs are unaccusatives, not all unaccusatives are necessarily telic: verbs such as *melt, cool, warm* can denote scalar events – e.g. "melt to some degree, but not completely".

The two studies reviewed here (Malaia et al. 2009, 2012) address these questions using evoked response potentials to sentences with reduced relative clauses using telic and atelic verbs. As prior behavioral work has shown that telic verbs activate specific syntactic (event structure) templates, we hypothesized that these templates would be used for integrating incoming information. The exact timing of integration, and ERP components elicited by such integration, would help answer the question of how prior syntactic information is used during online language processing. Sequential processing models (Bornkessel and Schlesewsky 2006; Friederici and Frisch 2000; Friederici et al. 1996) predict that computation of thematic role re-assignment would elicit left anterior negativity (LAN), while selection of the correct syntactic template from several possible ones (e.g. for ambitransitive verbs) would elicit early left anterior negativity (ELAN) on the NP following the verb. Parallel processing theories (Jackendoff 2007), on the other hand, suggest non-directional competition of multiple linguistic constraints (in this case, syntactic and semantic) in verbal working memory, allowing for earlier effects which can occur on any disambiguating word in the sentence. In the following section, we review existing ERP evidence for these theoretically predicted components, and review the rationale for selection of specific components and time windows for statistical analysis.

9.2 Predictions for ERP Waveforms

As both predictions and interpretations of observed components in ERP experiments necessarily rely on extant ERP literature, the hypothesized results centered on the following components of ERP waveform:

N100 is an exogenous component elicited by visual and auditory stimuli, and modulated by selective attention. Phrase structure violations have been shown to elicit increased amplitude in this early negative component (Neville et al. 1991). Spatial distribution of enhanced N100 over the cortical surface in language studies appears to depend on the nature of the stimulus and the task: visual word-category recognition tasks (Lai and Mangels 2007) elicit parieto-occipital distribution of this component, while auditory (Astheimer and Sanders 2009) and syntactic processing tasks (Yamada and Neville 2007; Neville et al. 1991) elicit more fronto-central localization. Additionally, both visual and auditory linguistic studies showed that the amplitude of N100 is modulated by attentional effort (Astheimer and Sanders 2009; Lai and Mangels 2007).[6]

P200 is an exogenous component elicited by the visual stimuli, modulated by attention, which likely indexes higher-order perceptual processing, such as

[6]N100 is distinct from early left anterior negativity (ELAN) in that ELAN occurs in response to violations of word-category/phrase structure, and its cortical distribution is more left-lateralised or bilateral. The stimuli for the studies under discussion did not contain the violations evoking ELAN.

top-down attentional preparation for an expected word. Increased negativity over this component has been interpreted as indexing an increase in the processing load, as it typically follows the onset of the critical word in ungrammatical sentences (Yamada and Neville 2007; Osterhout et al. 1994). Yamada and Neville (2007) related anterior distribution of this component to syntax-semantic interface processing triggered by the presence of semantic information. Their study demonstrated anterior increase in the negativity of P200 in response to ungrammaticality in English sentences, as compared to an even distribution of the same modulation in response to Jabberwocky sentences.

Late-onset negative components.[7] The family of ERP components occurring within this time interval includes a left-lateralized anterior negativity (LAN), Anterior Negativity, and the N400. Increased load on verbal working memory in grammatical sentences has been shown to elicit fronto-central and right-hemispheric distribution of negativity between 300 and 600 ms (Anterior Negativity) in the studies of gapping sentences in English (Kaan et al. 2004) and anaphor resolution in German (Streb et al. 2004). Discrepancies in morpho-syntactic information, and increased working memory load elicited left-hemispheric distribution of negativity over this interval (LAN) (Hagoort and Brown 2000; King and Kutas 1995; Osterhout and Mobley 1995). Finally, conflicts in thematic interpretation of the arguments (e.g. presence of two animate arguments before the verb, competing for the Agent role; cf. Frisch and Schlesewsky 2001), and semantic and pragmatic violations (Kutas and Hillyard 1984; Hagoort et al. 2004; Kutas and Hillyard 1980) are indexed by a posteriorly distributed N400 component.

As behavioral studies demonstrated priming of the Patient by telic verbs, which could lead to an increase in the cognitive load in the atelic condition due to comparative difficulty in phrase structure re-analysis, all of the temporal windows for these ERP components were examined in the two studies described below. Additionally, as previous research in electrophysiology has demonstrated that temporal and amplitude measures of ERPs differentiate neural functions of adults with normal and high language proficiencies (Weber-Fox et al. 2003), all participants were administered the Listening Grammar (LG) subtest of the Test of Adolescent and Adult Language, Third Ed. (TOAL-3, Hammill et al. 1994), and subsequently divided into two proficiency groups (Normal Proficiency, or NP, and High Proficiency, or HP). The task in this subtest consists of selecting two sentences closest in meaning from the three sentences read aloud to the participant, e.g.:

1. Jane did not make the grade because she didn't do her best.
2. Although Jane did her best, she did not make the grade.
3. If Jane didn't make the grade, it wasn't because she didn't try.

[7]We did not predict a P600 in our experiment, since this component is task-dependent. Also, P600 can indicate syntactic or semantic repair; with our stimuli, neither was necessary: all stimulus sentences were completely grammatical, and made sense.

The correct answers are B and C; as the sentences are presented one after another, the participants have to rely on verbal working memory for retrieval of exact sentence meaning. The results of the subtest are thus possibly indicative both of one's linguistic proficiency and verbal working memory capacity. The latter can serve as the predictor of the processing strategy the participant is likely to use for language processing (Budd et al. 1995; King and Kutas 1995).

9.3 Thematic Role Re-assignment Facilitated by Telic Verbs

The reduced Object relative clauses (RRCs, such as *The actress chaperoned by the writer left the ball early*) are often used to investigate effects of semantic variables (argument animacy, quantification, verbal telicity, etc.) on garden-path recovery and thematic role assignment (Just et al. 1996; King and Kutas 1995). During the processing of a typical sentence, the first argument encountered in the sentences is assumed to be the prototypical Agent and the Subject of the sentence (Wekerly and Kutas 1999; Kuperberg et al. 2007; Townsend and Bever 2001). When this assumption turns out to be incorrect, such as in garden-path sentences with RRCs, the comprehender has to quickly re-analyze thematic role assignment in order to proceed with sentence parsing (Townsend and Bever 2001).

Here we consolidate the results of two ERP experiments on neurocognitive processes underlying thematic role assignment by telic and atelic verbs (Malaia et al. 2009, 2012). The studies examined neurophysiological bases of telicity effects on thematic role re-assignment in reduced relative clauses. In order to control for the independent effect of argument structure, which prior behavioral studies have revealed, we restricted the stimuli to strictly transitive verbs in study 1, and ambitransitive verbs in study 2. The stimuli used for the two studies are presented in Table 9.1. Both verbs in RRCs in example 1 are obligatorily transitive, i.e. require two arguments to produce a grammatical sentence. Both verbs in RRCs in example 2 are optionally transitive, i.e. can form grammatical sentences with only one argument (cf. *The actress awakened at 5 am, or The actress worshipped alone*), as well as with two arguments.

In the first study, ERPs were recorded from 20 English speakers as they silently read sentences with reduced and unreduced Object relative clauses, in which the main verb (either telic or atelic) was obligatorily transitive, e.g., "The actress

Table 9.1 Examples of sentences with reduced relative clauses

Transitivity	Telicity	Sample sentence with a reduced relative clause
1. Obligatory	(a) Telic	The actress **spotted** by the writer left in a hurry.
	(b) Atelic	The actress **chaperoned** by the writer left in a hurry.
2. Optional	(a) Telic	The actress **awakened** by the writer left in a hurry.
	(b) Atelic	The actress **worshipped** by the writer left in a hurry.

(who was) *spotted/chaperoned* by the writer left in a hurry". Based on the linguistic theory of event structure (Ramchand 2008) and the parallel architecture processing theory (Jackendoff 2007), we hypothesized that the event template of telic verbs would activate the syntactic position for the Determiner Phrase (DP) containing the Patient argument (i.e. at the definite article *the*, the first word in the DP, since the Agent thematic role is borne by the entire DP), and facilitate re-assignment of thematic roles during syntactic processing, as compared to sentences with atelic verbs.

Sixty stimulus sentences were constructed using obligatorily transitive verbs. Obligatory transitive verbs for the stimuli (30 telic and 30 atelic) were chosen based on (Levin 1993), and cross-referenced with examples of allowable usage from multiple dictionary sources. The sentences allowed the use of either telic or atelic verbs in the reduced relative clause, while remaining semantically plausible. The stimulus materials thus consisted of (a) 60 stimulus sentences with reduced relative clauses (RRCs), and (b) the same sentences but with the unreduced relative clauses (URCs). Noun-verb co-occurrences were assessed using the Pointwise Mutual Information measure (Recchia and Jones 2009), and were matched across verb type ($t(118) = 1.299$, $p > .05$), and argument order (first, second) in telic and atelic conditions ($t < 1$ in both cases). The stimulus verbs were compared for frequency in present and past forms using Kučera and Francis (1967) frequency tables; there was no effect of frequency for either present tense or past tense forms ($t < 1$). In addition, subjects were presented with 60 filler sentences with varying syntactic structures. Probe questions were constructed for all sentences in order to test for correct thematic role assignment, e.g. a sentence such as *The runner nominated by the coach won the race* was followed by a question *Did the runner nominate the coach?*. Stimulus sentences were presented word-by-word on a computer screen for 200 ms, with an interval of 315 ms between words. Sentence-final words appeared with a period. Each sentence was followed by a yes-no question. After the subject responded to the question, the prompt *Ready?* appeared on the screen, allowing the subject to pause before initiating the next trial.

EEG activity was recorded over the scalp using 32 Ag-Cl electrodes secured in an elastic cap (Quik-cap, Compumedics Neuroscan). Electrodes were positioned according to the criteria of the International 10–10 system (medial sites FZ, FCZ, CZ, CPZ, PZ, OZ; fronto-temporal lateral and mid-lateral sites F3/F4, F7/F8, FC3/FC4, FT7/FT8, C3/C4; parieto-occipital lateral and mid-lateral sites CP3/CP4, TP7/TP8, P7/P8, P3/P4, O1/O2). All electrode impedances were adjusted to 5 kOhms or less, and the electrical signals were amplified with a bandpass of .05 and 100 Hz, and digitized online (Neuroscan 4.0) at the rate of 500 Hz. Reference electrodes were placed over the left and right mastoids, and all scalp electrodes were re-referenced to the average of the left and right mastoid following the recording (Luck 2005). The eye movements and blinks were recorded using electrodes placed above and below the eye, and removed from the recorded data (7.7%). The 100 ms interval prior to onset served as the baseline for amplitude measurements of the ERPs.

Each ERP component was measured using a temporal window approximately centered around its peak in the grand averaged waveforms. The ERPs elicited by the verb in the relative clause, on the *by* following the verb, the article *the*, and

the Agent Noun were compared over three temporal windows. Thus, for the verb, the comparisons were made for negative peak amplitudes between 100 and 200 ms (N100), and positive peak amplitudes between 200 and 320 ms (P200) post word onset. For the preposition *by*, the respective windows were 85–185, and 185–315 ms post word onset. Mean amplitudes for the Anterior Negativity (AN) were measured between 360 and 600 ms for the verb, and between 385 and 585 ms for the preposition *by*. For the article *the*, the comparisons were made for negative peak amplitudes between 70 and 210 ms (N100), positive peak amplitudes between 210 and 330 ms (P200), and mean amplitudes between 370 and 630 ms (AN) following the onset of the definite article. For the Agent Noun, the comparisons were made for negative peak amplitudes between 115 and 215 ms (N100), positive peak amplitudes between 215 and 315 ms (P200), and mean amplitudes between 315 and 655 ms (AN) following the onset of the word. Statistical analyses included ERPs recorded at 26 scalp electrodes (medial sites FZ, FCZ, CZ, CPZ, PZ, OZ; fronto-temporal lateral and mid-lateral sites F3/F4, F7/F8, FC3/FC4, FT7/FT8, C3/C4; parieto-occipital lateral and mid-lateral sites CP3/CP4, TP7/TP8, P7/P8, P3/P4, O1/O2).

For lateral and mid-lateral sites, repeated-measures analysis of variance (ANOVA) was conducted to determine the effects of telicity (telic vs. atelic condition) separately with three factors (Telicity [telic, atelic], Hemisphere [left, right], and Anterior/Posterior [fronto-temporal, parieto-occipital]). For the analysis of the medial sites, analysis of variance included two factors (Telicity [telic, atelic], and Anterior/Posterior [fronto-central, parietal]). In cases where significant effects were found for interactions, a step-down ANOVA was performed to investigate whether the main effect was significant over a subset of electrode sites.

Telicity as an element of subatomic semantics is often formulated as a property of the verb referring to a change-of-state event (*catch*, *vanish*). Atelic verbs, on the other hand, refer to homogenous activities or states (*tease*, *sleep*). Telic, or change-of-state verbs infer existence of an affected event participant; thus telic verbs have been hypothesized to always assign the thematic role of the Patient, regardless of their transitivity status (intransitive/unaccusative, transitive, and ambitransitive) (Table 9.2).

In accordance with our predictions, ERPs in reduced relative clauses (RRCs) diverged on the definite article preceding the agent: the atelic condition was characterized by larger amplitude negativity at the N100 (Fig. 9.1). None of the reported interactions in unreduced relative clauses (URCs, e.g. *The actress who was chaperoned by the writer left the gala early*), which appeared significant at the full set of electrodes, had a significant effect over a subset of electrode sites; further data analysis demonstrated that significance of the interactions at the higher level was only due to the opposing direction of the effect over subsets of electrodes. The ERP waveforms elicited over the *by the* region in URCs are presented in Figs. 9.2 and 9.3.

As the ERP data analysis shows, the re-analysis of argument structure in garden-path-inducing RRCs with atelic verbs appears to produce a greater challenge in thematic role assignment as compared to the same process in RRCs with telic verbs. The processing data obtained for RRCs and URCs demonstrates that the syntactic

Table 9.2 Significant ANOVA results for various ERP measures taken on individual words

Word position	Effect	F (1, 19) =	p <	η_p^2 =
Sentences with Reduced Relative Clauses (RRCs)				
Verb in relative clause, e.g. *The actress spotted by* ...	T	5.169	.035	.214
N1 latency over lateral and mid-lateral sites				
the, e.g. *The actress spotted by the writer*...	T	6.633	.019	.259
N1 amplitude over midline sites	T × A	7.723	.012	.289
over anterior midline sites only	T	11.412	.003	.375
N1 amplitude over lateral and mid-lateral sites	T	4.370	.05	.187
P2 amplitude over midline sites	T × A	5.529	.030	.225
Anterior negativity over midline sites	T × A	9.46	.006	.333
over anterior midline sites only	T	4.740	.042	.200
Anterior negativity over lateral and mid-lateral sites	T × A	4.932	.039	.206
Sentences with Unreduced Relative Clauses (URCs)				
Verb in URC, e.g. *The actress who was spotted by* ...	T × A	5.388	.032	.230
Anterior negativity over lateral and mid-lateral sites				
Agent, e.g. *The actress who was spotted by the writer*...	T × A × H	12.160	.002	.390
N1 amplitude over lateral and mid-lateral sites				
P2 latency over lateral and mid-lateral sites	T × A × H	7.377	.014	.280

Note: Electrode subsets: midline [FZ, FCZ, CZ, CPZ, PZ, OZ]; midline anterior [FZ, FCZ, CZ]; midline posterior [CPZ, PZ, OZ]; anterior lateral and mid-lateral [F3/F4, F7/F8, FC3/FC4, FT7/FT8, C3/C4]; posterior lateral and mid-lateral [CP3/CP4, TP7/TP8, P7/P8, P3/P4, O1/O2]
T Telicity, *A* Anterior, *H* Hemisphere

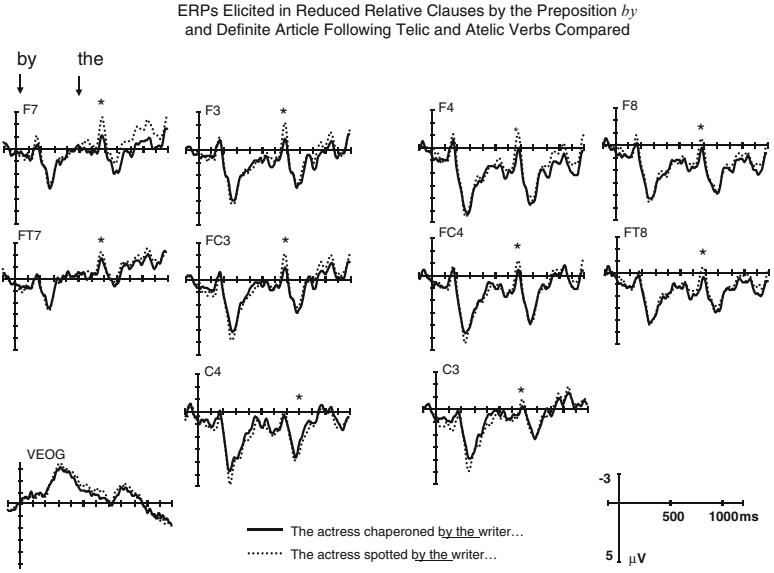

Fig. 9.2 ERPs elicited by the definite article in RRCs with telic and atelic verbs

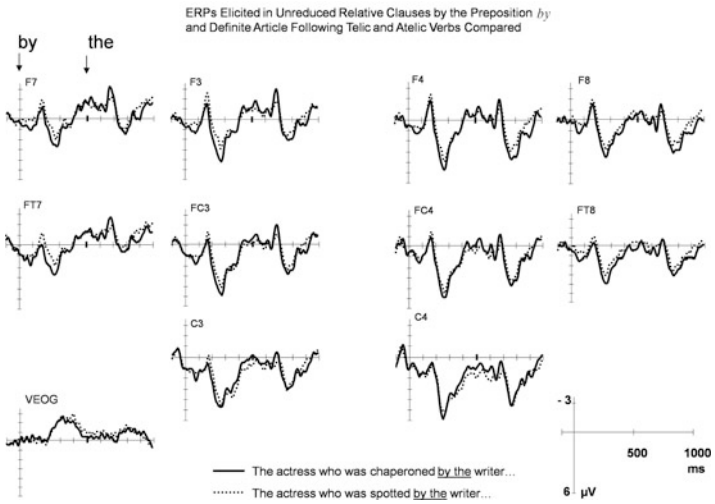

Fig. 9.3 ERPs elicited by the definite article in URCs with telic and atelic verbs

template activated by telic verbs is used for thematic role (re-)assignment in transitive clauses as soon as the head of DP (definite article *the*) is encountered. This effect is similar to the phenomenon of internal argument priming in unaccusative (i.e., intransitive telic) verbs (Friedmann et al. 2008). Since thematic role re-assignment begins on the head of DP, the article, rather than the Agent noun, it has to be attributed to prior activation of the Patient syntactic position (DP) by the telic event template, rather than to semantic or frequency effects. The current findings are consistent with previous results in language processing (Astheimer and Sanders 2009; Lai and Mangels 2007; Boddy and Weinberg 1981; Mehta et al. 2009) and indicate that modulations in attention with increased processing loads are quite rapid (∼150 ms). Taken together with previous findings, it appears that on-line adjustments to variations in language processing load may be mediated by changes in neuronal synchronization associated with attentional mechanisms.

9.4 Verbal Event Structure Used for Garden-Path Recovery

One peculiar aspect of the overt realization of thematic roles is that the Patient argument can appear in the surface syntactic structure of the sentence as either Subject or Object. If the verb is transitive, i.e. assigns two syntactically privileged argument roles (as in *Mary caught the ball*), the affected argument surfaces as an Object. If the verb is intransitive, i.e. only assigns one argument role (as in *Mary arrived*), the Patient surfaces as a Subject. Optionally transitive verbs, which can be used in sentences with one or two arguments (cf. *The baby awakened/The mother*

awakened the baby) alternate in assigning the affected argument to the Subject or Object position. Despite such variability in overt syntactic realization of thematic roles, comprehenders have no difficulty in correctly identifying the Agent and the Patient in each linguistic event.

It is, therefore, possible that argument structure (one vs. two arguments) is a more salient cue for thematic role assignment, as opposed to the syntactic structure activated by telic verbs. This hypothesis was tested in the second experiment, the methodology of which was identical to the first study. Twenty-two English speakers read sentences with an ambitransitive main verb, which was either telic or atelic, e.g., *The actress awakened/worshipped by the writer left in a hurry*. The participants were separated into groups according to whether their number of correct responses on the baseline (TOAL-3 LG subtest) was above or below the mean (29.7) for the entire group. The subjects were thus divided into Normal Proficiency (NP group, N = 12) and High proficiency (HP group, N = 10) responders. ERPs elicited by telic and atelic verbs, the preposition *by* introducing the second argument (Agent), and the second argument itself, e.g., *writer*, were compared. ERPs elicited in the atelic condition in high (HP) and normal (NP) proficiency groups were characterized by increased negativity, as compared to the telic condition. However, the two groups differed with regard to where in the sentence telicity information was utilized. In the HP group, the preposition *by* (the first word introducing the Agent argument) elicited differential processing in telic vs. atelic condition within 200 ms of word onset, which was sustained throughout the Anterior Negativity component (320–500 ms following the word onset) (Fig. 9.4). These results are consistent with a suggestion by Weber-Fox and Neville (2001) that participants with high linguistic proficiency have more reliance on closed-class words. In the NP group, however, the ERPs did not diverge until the Agent Noun itself; on the Agent Noun (Fig. 9.5), ERPs to atelic condition in this group were significantly more negative over N100 and P200 components (or N1-P2 complex).

This study demonstrated that ambitransitive telic verbs, as well as transitive ones, assign the Patient thematic role, thus facilitating parsing decisions in garden-path conditions. However, the exact timeline of thematic role re-assignment (on the *by* or on the Agent Noun) appears to be determined by the parsing strategy employed by the comprehender. A similar phenomenon, also attributed to strategic processing, has been observed in the behavioral investigation of telicity processing in Spanish (Sanz 2000), which employed a cross-modal priming paradigm. Based on the correlations between TOAL-3 (LG) scores of the participants and the strategy selected by each participant, we can assume that individual choice of strategy might be determined by one's syntactic proficiency (Pakulak and Neville 2010; Weber-Fox et al. 2003) or verbal working memory capacity, which is highly taxed in TOAL-3 LG tasks (Nakano et al. 2009; King and Kutas 1995).

An alternative analysis of these waveforms could be made using the long wave approach (Fig. 9.6): the overall slow frontal positive shift of the waveform in the telic condition can be interpreted as indexing higher ease of integration processes in the verbal working memory (cf. King and Kutas 1995).

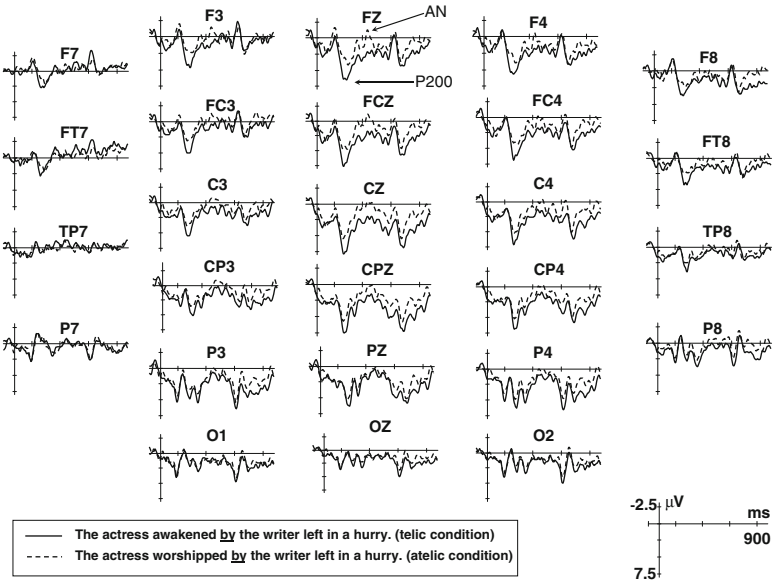

Fig. 9.4 ERPs elicited in the high proficiency group by the preposition *by*: relative clauses with telic and atelic verbs compared

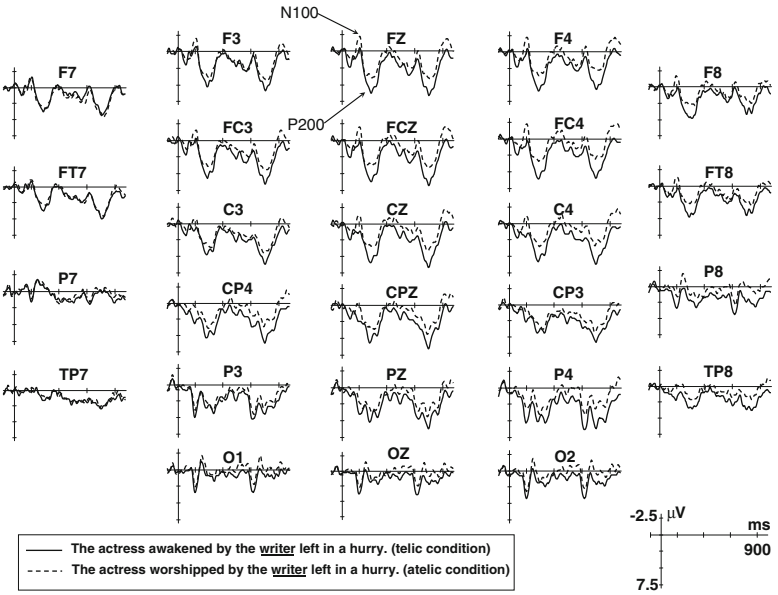

Fig. 9.5 Agent noun: ERPs elicited in the normal proficiency group by the relative clauses with telic and atelic verbs compared

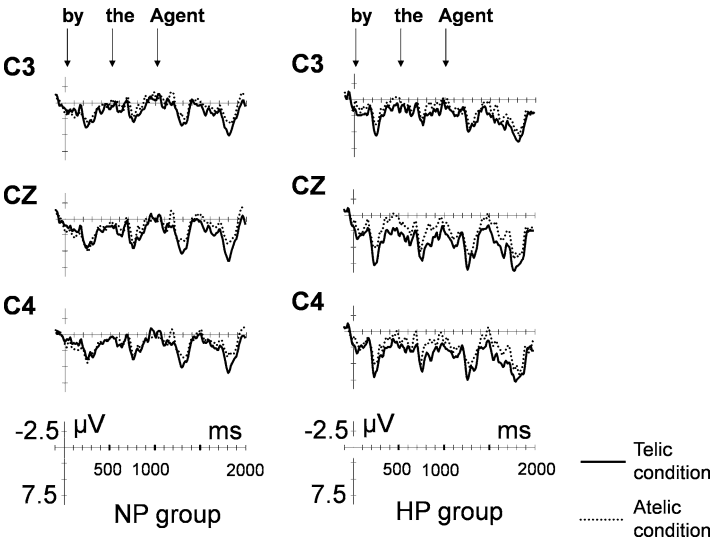

Fig. 9.6 Long epoch comparison of the High Proficiency (HP) and the Normal Proficiency (NP) groups

9.5 Linguistic Analysis

The comparative changes in event and argument structure in telic and atelic verbs undergoing intransitive-transitive frame alternations (Study 1) are illustrated in the following figures. Figure 9.7a, b provide a schematic representation of changes in argument role structure during thematic role re-assignment. As can be seen in Fig. 9.7a, the event template of telic verbs, which semantically signals that there will be an Undergoer/Resultee (possible forms of the Patient thematic role), activates the syntactic position for the Undergoer/Resultee, facilitating re-assignment of that thematic role to the first NP in the sentence when the second argument is encountered. The atelic verb template, lacking a semantic Resultee, does not activate the syntactic position for Undergoer(/Resultee). Thus, although in both conditions the Agent role is initially assigned to the first argument, the re-assignment of the Agent and Undergoer roles between the subject and the object of the reduced relative clauses with atelic verbs does not show the benefit of structural activation through the event structure template.

In the case of ambitransitive verbs (Study 2), when the second argument is introduced by the *by* construction, it is added to the existing verbal phrase frame as an external Agent, and does not necessitate re-assignment of thematic roles in telic condition (Fig. 9.8a). Atelic verbs, on the other hand, initially assign both Agent and Undergoer roles to the first argument, which results in necessary thematic role re-assignment when the second argument is added (Fig. 9.8b). Re-assignment of

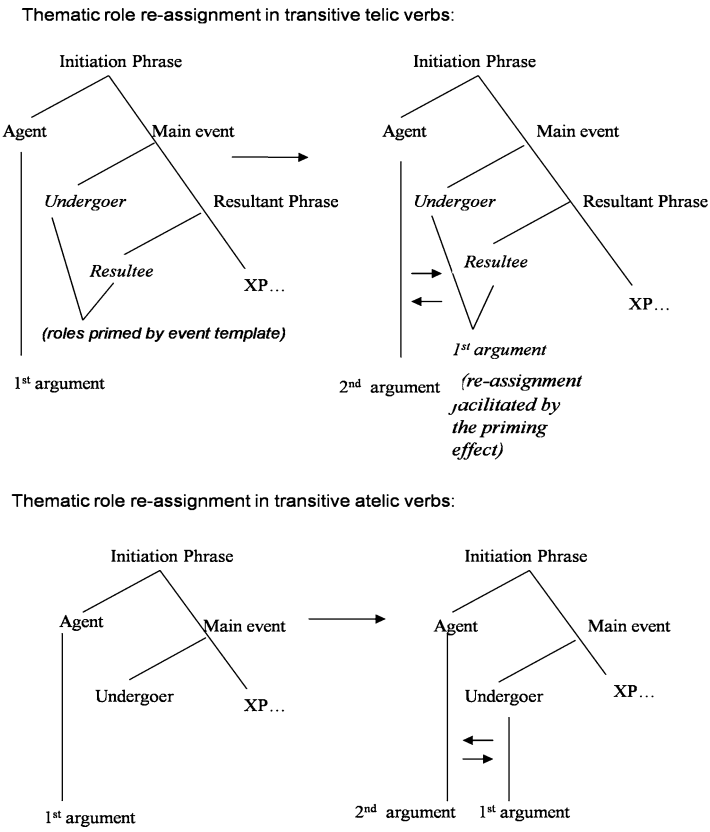

Fig. 9.7 Reanalysis of transitive verbs during garden-path recovery

Agent and Undergoer roles between the subject and the object of the reduced relative clause thus appears to be a process which elicits more negative ERPs as compared to simple addition of an extra argument in a vacant thematic role.

9.6 Conclusion

Early psycholinguistic research on event structure processing provided behavioral data indicating that the type of event denoted by the verb affected processing load (as evidenced by multimodal paradigms), and processing speed (response times). The ERP studies now indicate that integration of word-class information with information about the preceding verb's telicity occurs as early as 150 ms post-onset of visual word stimulus. Similar recognition timecourses have also been observed for grammatically relevant semantics features, such as animacy (cf. Boddy 1981).

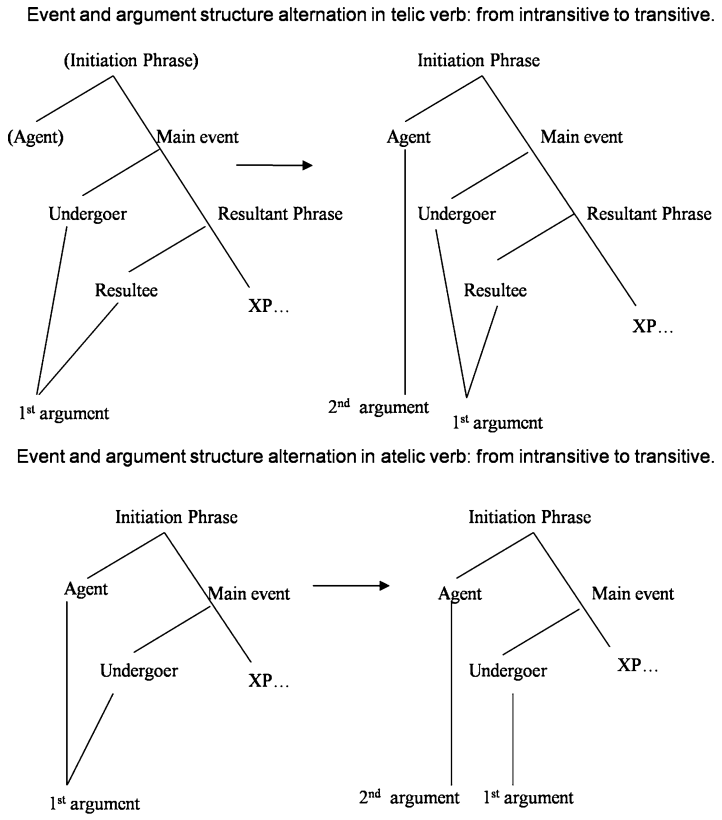

Fig. 9.8 Reanalysis of ambitransitive verbs during garden-path recovery

Our data is also consistent with behavioral and neuroimaging studies of intransitive telic (unaccusative) and intransitive atelic (unergative) verbs (Friedmann et al. 2008; Shetreet et al. 2010), which suggest that the Subject of telic verbs is base-generated in the internal argument position (the Patient, or the Undergoer).

The neurophysiological data from the two reviewed studies demonstrates that telic verbs activate an event structure template with an obligatory internal argument, which serves as a salient cue for thematic role assignment during online linguistic computations. The data from the two experiments shows that priming of the Patient by telic verbs is indexed by neurocognitive processes related to attention and cognitive load, while the syntactic structure evoked by telic verbs is utilized simultaneously with word-category assessment. In sentences with strong garden-path effect (study 2, optionally transitive verbs), individual choice of processing strategy also appears to depend on verbal working memory capacity. In all conditions, however, the effect of verbal event structure appears downstream, at the point of processing which necessitates (or questions) correct thematic role assignment. The results are consistent with the theoretical accounts of event structure, which integrate thematic

roles as structural positions within an event-argument structure complex (Ramchand 2008) and parallel processing theories (Jackendoff 2007). The reported results are somewhat less consistent with sequential processing theories, as they would seem to predict somewhat later differential ERP components indicative of re-linking of thematic roles. However, further investigation into the interaction of grammatically relevant semantic features of arguments (e.g. definiteness, animacy, Case, etc.) and verbal templates, as well as refinement of theoretical models of language processing based on neural data, might help reconcile the differences between theoretical and empirical findings.

While the opportunity to probe online linguistic processing creates a challenge for current theories to produce testable hypotheses about the language mechanisms with plausible neural realizations, it also enables more rapid progress in the field by revealing computational properties of the brain with regard to language, and other domains of higher-order cognition.

Acknowledgments This work was partially supported by NIH grant DC005241 and NSF 0345314 to Ronnie Wilbur.

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