Verbs in spoken sentence processing

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CHAPTER 4. ARGUMENT STRUCTURE

1. ARGUMENTS AND ADJUNCTS

1.1. Introduction

The two experiments presented in the previous chapter showed that activation of the verb encountered in the matrix clause appeared to be bounded by this clause. As all verbs used in these experiments were (dominantly) two-place verbs, the final argument was always the Direct Object, which occurred at the end of the matrix clause. Therefore, deactivation of the verb at the final probe position could either have been caused by the clause boundary or by the fact that the dominant argument structure of the verb was complete. Experiment 3, described in section 3 of this chapter, was designed to tease these possibilities apart. The chapter starts with a (linguistic) introduction on argument and adjuncts (section 1) and how argument structure is reflected during on-line sentence processing (section 2).

1.2. Arguments

To understand a sentence, a reader or listener must determine the event being described in the sentence, the entities (persons or objects) that participate in the event, and the role these entities play. A sentence can be seen as organized into a set of arguments that ‘revolve around’ an event described by the predicate (the verb). For example, consider the verb \textit{fix}, as in the sentence:

\begin{equation}
\text{(1) Julia will fix the car.}
\end{equation}

The verb \textit{fix} defines the event being described (see also Chapter 5). The entities involved in the event are the two noun phrases (NPs): the Subject (\textit{Julia}) and the Direct Object (\textit{the car}). Verbs vary in terms of the number and type of arguments they allow. The argument structure of a verb gives information about the number of entities that are involved in the event. \textit{Fix} is a two-place predicate (or a \textit{transitive} verb), which requires two arguments (a Subject and a Direct Object) for a sentence to be well-formed. If \textit{fix} is contained in a sentence with only one argument (as in (2)), the sentence is ill-formed (incomplete). Thus, argument structure serves as a constraint on well-formedness. Other verb types are intransitive verbs, like \textit{skate},
requiring only a Subject, and *ditransitive* verbs like *give*, requiring three arguments (a Subject, a Direct Object and an Indirect Object), as in (3).

(2) *Julia will fix.
(3) Julia gave a present to John.

The *subcategorization frame* of a verb describes the type of syntactic categories that can be used to express the arguments of the verb. The verb *give* has two possible subcategorization frames: it can have two noun phrases (NPs) as internal arguments (see (4)) or an NP and a PP (Prepositional Phrase; as in (5)).

(4) Julia gave [John]NP [a present]NP.
(5) Julia gave [a present]NP [to John]PP.

Finally, the role played by each participant in the event is defined by the *thematic grid* of the verb. In standard linguistic analysis, each participant is said to play a distinct thematic (i.e., semantic) role. In (6), the Subject NP *Julia* is the Agent, the direct object NP *John* is the Patient. Thematic roles are independent of the syntactic (Subject versus Object) or argument (external versus internal argument) position they take in a sentence.

(6) Julia kisses John.

In summary, the verb *kiss* can be represented as follows:

(7) *kiss* argument-structure: (x, y) subcategorization frame: ( ___ NP NP) thematic grid: (Agent Patient)

1.3. *Adjuncts*

In many sentences, there are other constituents that are not part of the argument structure, but nevertheless contribute to the overall meaning of the sentence, for example by stating where, when, how, or why something happened. These constituents are called *adjuncts*. In (8), only *John* and *book* are arguments of the verbs *read*; all other phrases are adjuncts.

(8) In the afternoon John read a book about physics on a bench in the park.
The distinction between arguments and adjuncts is fuzzy. Clear cases of arguments are phrases that are obligatory, like the Direct Object of a transitive verb (*apple in Julia is eating an apple*). Adjuncts are always optional, but arguments can be optional as well. The main difference between arguments and adjuncts is that arguments are considered to be part of the lexical entry of a verb, whereas adjuncts have a less clear link to a particular verb. For example, the meaning of an argument PP is determined by the verb, whereas the meaning of an adjunct PP depends on the particular preposition (compare the meaning of *in* in (9) and (10)).

(9) John is interested in the Volvo.
(10) John is sleeping in the Volvo.

Structurally, arguments appear at a different level in the syntactic tree than adjuncts (arguments are sisters to the head of the verb phrase). A final difference is that, at least in English, arguments often appear closer to the head (verb) when both are present in the same sentence:

(11) Julia gave a present to John in the afternoon.
(12) * Julia gave a present in the afternoon to John.

Koenig, Mauner, and Bienvenue (2003) proposed two criteria that can be used to determine whether a certain constituent is an argument or an adjunct: semantic obligatoriness and semantic specificity. Semantic obligatoriness means, for example, that no reading event can exist without a person who performs the action (*John in (8)*) and without an object that undergoes the action (*book*). However, although semantic obligatoriness is necessary, it is not sufficient. Everyone will agree that reading must take place at a certain location. Nevertheless, event locations are the most prototypical examples of an adjunct. The specificity criterion restricts argument status to information that is specific for a certain verb, and is not generally used to describe other verbs. This applies readily to information about *where* and *when* the reading event took place: there are no specific criteria that a place or a moment in time needs to meet. Indeed, most events take place at a certain location, or at a certain time, and therefore, these phrases do not pass the test of semantic specificity. Using the two criteria in a rating study of 3900 English verbs, Koenig et al. (2003) found that event location and event time are properties that are required by 98 to 99 percent of all verbs, and thus can be considered typical adjuncts, whereas instruments, participant
locations and beneficiaries (Mary in John bought a book for Mary) were required in less than 15 percent of the verbs.

2. PROCESSING CONSEQUENCES

Two questions that will be answered in this section are: 1. Is the difference between arguments and adjuncts reflected in operations of the language processing system (parser)? and 2. Does the parser use the syntactic and semantic information present in a verb during sentence processing, and if so, when does this occur? The experimental evidence described is divided into three themes: studies on complexity effects, studies on violations and studies on integration of arguments.

2.1. Complexity effects

2.1.1 Arguments versus adjuncts

In a self-paced reading experiment, evidence was found for a preference for arguments over adjuncts (Clifton et al., 1991). All sentences included Prepositional Phrases (PPs) that could be attached as argument or adjunct to either the noun or the verb:

(13) The salesman tried to interest the man in a wallet during the storewide sale at Steigers. (verb attachment, argument)
(14) The man expressed his interest in a hurry during the storewide sale at Steigers. (verb attachment, adjunct)
(15) The man expressed his interest in a wallet during the storewide sale at Steigers. (noun attachment, argument)
(16) The salesman tried to interest the man in his fifties during the storewide sale at Steigers. (noun attachment, adjunct)

Reading times for the first segment after the PP were slower when the PP was an adjunct than when it was an argument. This effect was replicated in an eye-tracking experiment using the same materials, in which early effects (indicated by first-pass reading times) were found at the segment after the PP, and later effects (total reading time) were found both at the PP and at the segment after the PP.

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1 Event location was queried as follows: “Does the verb describe situations which include a location in which all participants must, can or cannot be located and in which the event as a whole takes place (e.g., the location in which the writing occurs in Marc wrote the address)?”, whereas participant locations included only locations in
A similar comparison between adjunct and argument PP was made in an experiment on sentence memory with amnesic patients (Shapiro, McNamara, Zurif, Lanzoni, & Cermak, 1992). The results indicated that sentences with pure transitive verbs followed by an adjunct PP yielded poorer performance in a sentence repetition task than sentences with a ditransitive verb, in which the PP was part of the argument structure.

In summary, these two experiments converge on the conclusion that the difference between adjuncts and arguments is indeed reflected during sentence processing: adjuncts are processed slower and remembered worse than arguments.

2.1.2 Verb types

An effect of the number of possible verb subcategorization frames was found in an early study testing problem solving (paraphrasing and anagram solution) (Fodor, Garrett, & Bever, 1968). Purely transitive verbs were easier to process than verbs that could take either an NP or a CP as argument. A later study replicated this effect in an on-line dual task paradigm (Clifton, Frazier, & Connine, 1984). Participants read simple sentences, one word at a time, which were interrupted by a complex secondary task (an LDT) in which a word or non-word appeared which was irrelevant to the sentence being read). The secondary task measured processing load in the immediate vicinity of the verb, which was always an optionally transitive verb. The sentence form used was either transitive (17) or intransitive (18), and the verbs had either an inherent transitive bias (a) or an intransitive bias, based on frequency of use (b).

(17)  
a. The babysitter read the * story to the sick child.  
b. The babysitter sang the * story to the sick child.

(18)  
a. The babysitter read to * the sick child.  
b. The babysitter sang to * the sick child.

The lexical decision probe was presented after the specifier (the) in the transitive sentences and after the preposition (to) in the intransitive sentences. At this point, the selected subcategorization frame is unambiguously clear. The results indicated that participants were faster on the LDT when the phrase following the verb matched its preferred argument frame (17a and 18b) than when sentence structure and verb preference did not match (17b and 18a). This result is taken as evidence that verb-specific information about the preferred subcategorization frame is employed very quickly during sentence processing.

which one, but not necessary all participants are (e.g., the notebook in Martha wrote down the address in her notebook) (p. 80).
Later studies, however, demonstrated that differences in processing load were caused by differences in the number of thematic grids associated with a verb, rather than by differences in subcategorization frames. Shapiro et al. conducted a series of experiments using a paradigm similar to the one used by Clifton et al. (1984), with the only difference that the sentences were presented aurally (Shapiro et al., 1987; Shapiro & Levine, 1990; Shapiro et al., 1991; Shapiro et al., 1993a; Shapiro et al., 1993b; Shapiro et al., 1989). The Cross-Modal Interference (CMI) paradigm is closely related to the CMLP paradigm, but the probe words are unrelated to any word in the sentence. If the probes are matched on important characteristics (like baseline reaction time, frequency, length, syllable structure), the differences in response time between different sentences or positions in the sentence are assumed to reflect the processing load at the particular point in time when the probe is presented. Shapiro et al. (1987) studied differences in processing load in relation to different types of verbs. They used sentences like (19) and presented the unrelated probe at the offset of the verb.

(19) The boy who was tall fixed [1] the toy yesterday.

The results demonstrated shorter reaction times for pure transitives (e.g., fix) than for optional ditransitives\(^2\) (e.g., lend). In addition, reaction times were shorter for two-complement verbs than for four-complement verbs. The two- and four-complement verbs could be used with either a direct object (NP) or a sentential complement (CP). The four-complement verbs (e.g., discover) had three possible sentential complements: a proposition, an exclamation, and an interrogative (20). The two-complement verbs (e.g., accept) only allowed a proposition complement (21).

(20) a. Mary discovered that the car was gone.
   b. Mary discovered what an idiot she was!
   c. Mary discovered why the car was gone.
(21) Mary accepted that the car was gone.

The authors concluded that the results show exhaustive activation of thematic information. Verbs with more possible participant roles generated a higher processing load, and thus were interpreted to be more complex, than verbs with fewer possible roles. In further studies it was found that thematic information has an effect regardless of context and sentence structure: effects were reported in constructions where the arguments had not

\(^2\) Optional ditransitives can be used both transitively and ditransitively, i.e., with either two or three arguments.
been encountered yet (in active sentences) as well as in constructions where all arguments already had been encountered, as in (22) (Shapiro et al., 1989).

(22) It was the garage where the car was fixed yesterday.

In the literature, many different ‘verb-complexity criteria’ are mentioned that are all based on the studies by Shapiro et al., for example ‘argument structure’ or ‘number of possible argument structures’ (e.g., Ben-Shachar et al., 2004). Although the results of the comparison of pure transitives versus optional ditransitives can be explained using these criteria, the fact that four-complement verbs were more complex than two-complement verbs cannot be explained in these terms. These latter results of Shapiro et al. (1987) demonstrated that the number of possible argument structures does not have an effect on processing load. As was explained before, argument structure is supposed to take into account only the number of arguments, irrespective of the syntactic or thematic form of the arguments. In Shapiro et al. (1987), differences in response times were reported for two- and four-complement verbs, which both have only one possible argument structure. Thus, argument structure cannot be the decisive factor. Similarly, the findings cannot be explained by the subcategorization frame, which takes into account the types of arguments a verb takes (e.g., NP, PP, CP). As mentioned above, the two- and four-complement verbs could both be used with either an NP (Direct Object) or a CP (sentential complement). The only complexity criterion that can be inferred from the Shapiro et al. study (1987) (and the only conclusion provided in the original article) is a criterion in terms of the number of possible thematic roles of a verb. Verbs that have more possible thematic roles are more complex than verbs with fewer possible roles.

Ahrens and Swinney (1995) disagree with Shapiro et al. (1987) on this conclusion. In an extensive study, using the same CMI paradigm, they directly compared the influence of the number of argument structures and the number of thematic roles. Their conclusion was that the differences in processing load were best explained by the number of thematic roles. However, only the number of thematic roles associated with the central sense of a verb had an effect. The authors state that “… information available immediately upon access is largely concerned with the verb’s meaning (the frame semantics – including the participant roles) and not the argument structures or the subcategorizational structures of the verb…” (p. 544). In a more recent study, a corpus analysis confirmed that the subcategorization probability of a verb differs by sense and that a sense-biasing sentence context immediately influences the subcategorization preference of a verb (Hare, McRae, & Elman, 2003).

The previous experiments all measured processing load to indicate that certain verb types are more complex than others. The fact that this complexity relates to argument structure (the number of different thematic roles that a verb entails) and that these effects
appear immediately after the verb is taken as evidence that the parser has immediate access to all (semantic and syntactic) information present in a verb. But what are the consequences of the availability of this information during sentence processing? How does this information help the parser? Is it used to determine whether the unfolding sentence is well-formed (section 2.2)? Is information from the verb used to process upcoming sentence constituents faster or better (section 2.3)? And does this occur both at the semantic and at the syntactic (structural) level?

2.2. Violations

There is evidence that verb-specific information is used immediately during sentence processing, to match incoming arguments with the requirements posed by the verb. For example, verbs were found to affect sensibility judgments in sentences where the plausibility of an argument for a transitive verb was manipulated (Boland, Tanenhaus, & Garnsey, 1990). Compare the following sentences:

(23) The cowboy signalled the horse to surrender to the authorities.
(24) The cowboy signalled the outlaw to surrender to the authorities.

Participants indicate that sentence (23) made no sense immediately at the embedded verb surrender, suggesting that selectional restriction information of this verb (only human beings can surrender) is used immediately during on-line sentence processing.

Trueswell, Tanenhaus, and Kello (1993) used a Cross-Modal Integration task to answer the question whether subcategorization information is accessed rapidly enough to affect the processing of a word immediately following the verb. They used a group of verbs that have two possible subcategorization frames, that is, the verbs could combine with either an NP or a CP. Auditory sentence fragments that ended with either an NP-biased verb (accept) or a CP-biased verb (insist) were presented. Immediately at the offset of the verb, the target word be or him appeared on the screen and participants had to read these words aloud as fast as possible. The pronoun be was a correct continuation of a sentence ending in a CP-biased verb, the pronoun him should be preferred after a NP-biased verb. A significant interaction was found between verb type and case of the target pronoun (whether be or him was used), indicating that naming times were slowed down when an illegal (or at

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3 The selectional restriction information of a verb details the semantic aspects of the thematic roles: some roles are preferably filled by members of particular semantic categories (e.g., an agent role is preferably filled by a lexical element specified as human/animate).
least not preferred) argument type followed the verb. These results suggest that subcategorization information is used immediately.

In an ERP study, Friederici and Frisch (2000) compared the effects of different types of information encoded in the verb. Participants read sentences containing a violation of the number of arguments (26), a violation of the grammatical type of the argument (direct versus indirect object) indicated by case marking (27), or a semantic violation concerning the thematic role (28). In (26), an intransitive verb is used in a transitive context, in (27) the verb visit selects for dative instead of accusative case marking of the argument (Indirect Object instead of Direct Object), and in (28) the selectional restriction information of the verb stain selects for an inanimate object instead of animate. In all sentences, the violation occurs at the second NP (the violinist).

(25) Heute besuchte (V) der Cousin (NOM) den Geiger (ACC) im Krankenhaus.
    Today visited (V) the cousin (NOM) the violinist (ACC) in the hospital.
(26) *Heute trödelte (V) der Cousin (NOM) den Geiger (ACC) am Aufzug.
    *Today dawdled (V) the cousin (NOM) the violinist (ACC) at the lift.
(27) *Heute besuchte (V) der Cousin (NOM) dem Geiger (DAT) im Krankenhaus.
    *Today visited (V) the cousin (NOM) the violinist (DAT) in the hospital.
(28) *Heute beizte (V) der Cousin (NOM) den Geiger (ACC) am Mittag.
    *Today stained (V) the cousin (NOM) the violinist (ACC) at noon.

The ERP patterns for each of the violation types differed, indicating that the different types of argument structure information which can be distinguished at a theoretical level, are reflected in psychological reality during on-line sentence processing. More precisely, the selectional restriction violations resulted in an N400 effect, typically related to semantic processing, whereas the type of argument violations produced a pattern related to syntactic processing (LAN-P600). The number-of-arguments violation showed a biphasic pattern, with an N400 followed by a P600 effect.

In conclusion, when an ‘illegal’ argument is encountered subsequent to the verb during sentence processing, the system immediately recognizes the error and the type of error (Friederici & Frisch, 2000).

2.3. Integrating correct arguments

What happens when regular, correct sentences are processed? The next sections show that the information available at the verb position helps to integrate upcoming information that matches the trajectory plotted by the verb, both at the semantic (2.3.1) and the syntactic level (2.3.2).
2.3.1 Priming of concrete lexical items

Schriefers, Friederici and Rose (1998) found that verbs prime common *patients*, both when presented in a word list and when presented in short phrases. Visually presented sentence fragments consisting of a personal pronoun, transitive verb and a definite article were followed by a noun target. Reaction times to this target were faster when it was related to the main verb (29) than when it was unrelated (30).

\[
\begin{align*}
(29) & \quad \text{Er schreibt den ... BRIEF} \\
& \quad \text{He writes the ... LETTER} \\
(30) & \quad \text{Er sieht den ... BRIEF} \\
& \quad \text{He sees the ... LETTER}
\end{align*}
\]

Similarly, priming for possible instruments (e.g., *knife*) was found a few words after the verb in a CMLP experiment with sentences like (31) (Swinney & Osterhout, 1990).

\[
(31) \quad \text{He cut the juicy meat * and began eating his dinner.}
\]

Ferretti, McRae and Hatherell (2001), finally, provided evidence for the activation of concrete thematic roles upon encountering a verb. Significant word-word priming effects were found from verbs to typical agents, patients and instruments (but not to locations), when a verb was presented for only 200 ms, followed by a mask of 50 ms. The priming effects for agents and patients were replicated at the sentence level: priming was found for good agents and good patients (32) compared to possible agents and patients (33) when they appeared in an appropriate syntactic environment (a), but not when they appeared in their atypical thematic role (b).

\[
\begin{align*}
(32) & \quad a. \text{She was arrested by the COP/CROOK.} \\
& \quad b. \text{She arrested the COP/CROOK.} \\
(33) & \quad a. \text{She was kissed by the COP/CROOK.} \\
& \quad b. \text{She kissed the COP/CROOK.}
\end{align*}
\]

Presumably, the priming effects reported in the previous studies are helpful during normal sentence processing: common patients are integrated into the sentence more easily, reducing the overall processing load for the parser. Using the visual world paradigm, Altmann and Kamide (1999) demonstrated that the verb does not only facilitate integration of upcoming information during on-line sentence processing, but that the verb can even help listeners or readers to generate expectations about what is to follow. In this study,
ARGUMENT STRUCTURE

participants listened to sentences and at the same time inspected a semi-realistic visual scene. Two sentences were directly compared:

(34) The boy will move the cake.
(35) The boy will eat the cake.

While listening to either of these sentences, participants were looking at a picture depicting a boy, a cake, a ball and various other toys. An eye-tracker attached to the participants’ heads kept track of where in the picture they were looking. Participants started looking at the cake after the onset of the spoken word cake in the move sentences (34), but did so before its onset in the eat sentences (35). These results were interpreted to suggest that information of the verb is used to restrict the domain of plausible arguments that are to follow the verb. The findings were extended by demonstrating that not only Direct Objects immediately following the verb, but also later occurring arguments (e.g., Goals) can be anticipated (Kamide et al., 2003).

2.3.2 Structural priming

Syntactic priming effects (priming of the syntactic structure of a sentence) have been found repeatedly for verbs with more than one possible argument structure in sentence production studies (e.g., Bock, 1986; Pickering & Branigan, 1998). However, subcategorization preferences of a verb presented for only 39 ms were found to influence further sentence processing as well (Trueswell & Kim, 1998). Participants were presented with temporarily ambiguous sentences like (36) in a self-paced word-by-word reading experiment. The temporary ambiguity arose from the fact that the main verb (accepted) could take either an noun phrase (NP) or a complementizer phrase (CP) as its argument, so the word after the verb could be either a Direct Object or the Subject NP of a new clause. With these types of sentences, longer reaction times are typically found at the disambiguating word in the CP-reading (could) as compared to the NP-reading. This effect is called the ‘garden-path’ effect, because it is assumed that participants first interpret the sentence as an NP-sentence, and thus are led down the garden-path.

(36) The talented photographer accepted the fire could not have been prevented.

Just before the main verb appeared on the screen, a verb with either an NP-preference (e.g., obtained) or a CP-preference (e.g., realized) was briefly presented. Participants reported that they did not to see this fast prime. The results indicated that after priming with a CP-preferred verb, participants were much less ‘garden-pathed’, indicating that the CP-structure was primed by the presented verb.
2.4. **Summary**

In syntactic theory, an important distinction is made between arguments and adjuncts. This distinction is reflected in processing studies, where arguments were found to be processed faster or better than adjuncts. It is also well-established that verb-argument structure has immediate consequences for the processing system. Influences of argument structure have been found at very early stages, using a variety of experimental techniques. Studies tapping into the processing load of particular verbs found evidence for the immediate activation of the number of possible thematic roles. Furthermore, violations of argument structure as well as thematic role structure are noticed immediately and both syntactic and semantic priming effects are found immediately during on-line sentence processing.

2.5. **Implications for the present study**

Experiments 1 and 2 showed a maintained verb priming effect until the end of the matrix clause, which was absent in the second clause. This might be in line with hypotheses centering on argument structure, assuming for example that a verb remains active to assign thematic roles. As all verbs that were used in the experiments were (dominantly) two-place verbs, the final argument was always the Direct Object, which occurred at the end of the matrix clause. Therefore, deactivation of the verb at the final probe position can be either related to the clause boundary or to the fact that the (dominant) argument structure of the verb is complete. Experiment 3 was designed to tease these possibilities apart. All verbs used in the present experiment were intransitive verbs (verbs with only an external argument and no internal arguments). If argument structure is of importance, continued activation of an intransitive verb is predicted only in sentence constructions where the subject follows the verb, so for example in a sentence like (37) and not in any other constructions, for example (38).

(37) **adjunct-V-S-adjunct:**
Elke zondagmorgen fietsen de vrolijk giechelende pubers in het wonderschone groene park, omdat ...

*Every Sunday-morning bike the cheerfully giggling adolescents in the wonderful green park, because...*

(38) **S-V-adjunct:**
De vrolijk giechelende pubers fietsen in het wonderschone groene park, omdat ....

*The cheerfully giggling adolescents bike in the wonderful green park, because ...*
3. **EXPERIMENT 3: INTRANSITIVE VERBS**

3.1. **Introduction**

The present experiment was designed as a direct test for the influence of argument structure on verb activation in Dutch matrix clauses. If no priming of intransitive verbs is found after their occurrence in S-V-adjunct sentences, this is a strong indication that argument structure affects the duration of verb activation.

However, a replication of the priming pattern found in Experiments 1 and 2, where transitive verbs were used, would rule out the explanation that verbs remain activated to be linked to their arguments (e.g., for theta role assignment). In addition, a replication of the findings of Experiments 1 and 2 would show that the previous data generalize to other verbs, sentences and probes.

3.2. **Methods**

3.2.1 Participants

Fifty-one students of the University of Groningen took part in the experiment. Three participants were excluded post-hoc (one person failed the comprehension question criterion of 67% correct answers, the other persons were excluded because their mean and/or SD of the RTs exceeded the overall mean and SD RTs by more than 2.5 SD). No participants made more than 10% errors on the Lexical Decision Task.

The remaining 48 participants (1 male, 47 female) were all right-handed (2 ambidextrous) native Dutch speakers (5 were raised bilingually Dutch-Frisian) with a mean age of 20.8 (range 18-29 years), self-reported normal or corrected-to-normal vision and hearing, no dyslexia or other reading problems and no history of neurological disorders or long periods of unconsciousness. The original 51 participants were randomly assigned to two groups, resulting in 18, 14 and 16 participants per group respectively for the remaining 48 participants.

3.2.2 Materials

Seventy-two verbs were selected that cannot occur with a Direct Object NP (i.e., strictly intransitive verbs). In an association test, these verbs were presented to 28 participants who were instructed to write down the first one or two verbs that came to mind for each item. Intransitive verbs to be used in the sentences and related verb probes were chosen based on having an association quotient of 30% or higher across participants.

A variant of the switched probe design was used in this experiment. In the switched probe design the related probe for a particular sentence is used as control probe for
another sentence (see also Chapter 2, section 5). In the variant used here, the related and control probes are matched per pair. Therefore, a further criterion for the related probes was that they could be matched with another related probe on baseline lexical decision reaction time. A list of 250 verbs was presented to 20 right-handed participants in an Unprimed List Lexical Decision Task. Based on the RTs averaged across participants, a final list of 18 probe pairs was constructed, matched as closely as possible on RT, frequency, length in letters and syllables and argument structure (see Table 1). Differences were not significant in paired t-tests ($t_1$ and $t_2 < 1.3$, p’s > .2).

<table>
<thead>
<tr>
<th>Set 1 (n=18)</th>
<th>Set 2 (n=18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Baseline RT</td>
<td>586.5</td>
</tr>
<tr>
<td>Frequency (logarithmic)</td>
<td>1.79</td>
</tr>
<tr>
<td>Number of letters</td>
<td>6.6</td>
</tr>
<tr>
<td>Number of syllables</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Since each verb of a related – control probe pair was linked to an intransitive verb prime (to which it was associatively related), each pair was consequently linked to two experimental sentences. The pairs were selected in such a way that the probe that was related to the intransitive verb in sentence 1, was unrelated to the intransitive verb in sentence 2 and vice versa. Thus, a design was created in which related and control probes were matched per pair (as in Experiments 1 and 2), but the complete list of related and control verbs was matched perfectly as well, as they consisted of the same 36 verbs. The main advantage of this design is a reduction in variability between items, and therefore more power in the item-analyses.

Thirty-six experimental sentences were composed according to the following criteria: the Subject NP, consisting of 11-13 syllables, was followed by an intransitive verb in third person plural and an adjunct (Prepositional Phrase) of 11-13 syllables. The second clause was not subject to any restrictions.


ETEN (EAT) – LEVEN (LIVE)
De twee veelbelovende toneelspilers sterven aan het einde van het geveelbelovende toneelspel, maar de volgende dag staan ze weer springlevend op de planken.

The two promising actors die at the end of the violent play, but the next day stand they again alive on the boards (= appear on stage).

LEVEN (LIVE) – ETEN (EAT)

The probes were presented at three probe positions. Probe position 1 functioned as a control position at which no priming was expected and was placed 1000 ms after the onset of the sentence (which is for each sentence at least 700 ms before the matrix verb). Probe position 2 was meant to measure direct priming of the verb and was placed slightly later than in Experiment 2: at the onset of the first word following the verb, and if this point could not be measured adequately (e.g., due to coarticulation), at the onset of the first vowel of this word. This was done to correct for the problem discovered in Experiment 2 with this probe position, and allowed a direct test of the timing hypothesis concerning the source of that effect. Probe position 3 was the primary point of interest in this experiment, namely the test case for effects of argument structure. It was placed 1000 ms after probe position 2 and always at least 700 ms before the end of the clause. If priming is found at this position, the argument structure hypothesis can be rejected. Alternatively, if no effect is found here, this would be an indication that argument structure affects the activation pattern of the matrix verb in Dutch clauses.

Filler sentences were composed, of which 36 sentences had a structure similar to the experimental sentences (20 employed intransitive verbs, 16 transitives) and were combined with non-word probes, and ten had varying structures and were combined with both word probes (five) and non-word probes (five). Thus, the word:non-word ratio was 1:1. Probe placement was varied across the filler sentences.

The sentences were presented in combination with 50 sentences from another experiment with different sentence types and transitive verbs, resulting in a total of 132 sentences per session. In total, 30 comprehension questions were asked throughout the experiment, to encourage participants to pay attention to the sentences. Participants answering less than 67% of these questions correctly were excluded from the final analyses.

3.2.3 Design

Both probe position and probe type were within-subject factors. Each participant was presented with probes at all three probe positions. Furthermore, each participant was presented with each experimental sentence twice: once in combination with the related and once in combination with the ‘control’ probe. Per sentence, the probes were presented at the same probe position, to make a direct paired comparison within participants and within
items possible. The design was such that not only each experimental sentence, but also each experimental probe was encountered twice: once as a related probe and once as a control probe. Per session, participants were never confronted with the same sentence or the same probe more than once.

3.2.4 Procedure

The procedure was largely the same as in Experiments 1 and 2. Participants were tested in two sessions at least two weeks apart. Each test session was divided into seven blocks: three practice blocks (one block with ten lexical decision probes only (five words and five non-words) and two times the same CMLP block consisting of ten filler sentences and three comprehension questions) and four experimental blocks (consisting of 32 to 34 sentences and six to eight comprehension questions each). The participants could determine the length of the breaks in between the blocks themselves. Each experimental session (instructions and breaks included) lasted approximately 40 minutes.

3.3. Results

Reaction times for experimental items were collapsed across items and across subjects and repeated-measures analyses of variance were performed on means calculated for each. Probe position ([1],[2], [3]) and probe type (related and control) were within-subjects factors. A priori planned comparisons were made between related and control items for each probe position (paired samples t-tests, one-tailed) and between probe positions that followed each other in the unfolding sentence (F₁ and F₂ interaction effects).

Error rates were low (2.7%). Due to an error in the original scripts⁴, 5.5% of the data had to be excluded. The exclusion of errors, script errors and outliers (all values deviating from the subject and item mean for the particular data point with more than 2.5 SD were excluded) resulted in a total data loss of 9.3%.

The mean RTs for all probe positions and probe types are presented in Table 2. The ANOVAs revealed no effect of probe position but a significant main effect of probe type (priming effect) in the subject-analysis (F₁ (1,47) = 13.40, p = .001), which was marginally significant in the item-analysis (F₂ (1,32) = 3.86, p = .058). The interaction between probe position and probe type was significant in the item-analysis (F₂ (2,64) = 3.68, p = .031), and marginally significant in the subject-analysis (F₁ (2,94) = 2.65, p = .076).

Planned comparisons indicated that the priming effect was only significant at the last two probe positions (probe position [2]: t₁ (47) = 2.45, p = .009; t₂ (33) = 2.54, p = .008;

⁴ For three experimental sentences, some participants were not presented with the correct match of probes in the first and second session.
probe position [3]: \(t_1 (47) = 4.28, p < .001; t_2 (33) = 2.63, p = .007\), and not at the first, control, probe position, which was presented before the verb was encountered \(t_1 (47) = .03, p > .4; t_2 (33) = -.25, p > .4\). The interaction between probe positions [1] and [2] was marginally significant \(F_1 (1,47) = 2.45, p = .124; F_2 (1,32) = 3.52, p = .070\). The interaction between probe positions [2] and [3] was not significant (both Fs < 1).

**Table 2.** Mean (and SD) reaction times (in ms) to related and control probes for each probe position in Experiment 3.

<table>
<thead>
<tr>
<th>Probe Type</th>
<th>Probe Position</th>
<th>[1]</th>
<th>[2]</th>
<th>[3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td>648</td>
<td>657</td>
<td>656</td>
</tr>
<tr>
<td>Related</td>
<td></td>
<td>648</td>
<td>638</td>
<td>631</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td>0</td>
<td>20</td>
<td>26</td>
</tr>
</tbody>
</table>

**p<.01 (paired samples t-test, subject-analyses, 1-tailed)

De hoge politie\[1\]functionarissen ontbijten \[2\] in de rustige inter\[3\]city naar Den Haag, terwijl ze alle stukken nog eens doornemen.  
*The senior police\[1\]officers are-having-breakfast \[2\] in the quiet inter\[3\]city-train to The Hague, while they all paperwork again once go over.*

### 3.4. Discussion

The present experiment was designed to test whether argument structure could be a possible explanatory factor for the continued verb activation found throughout Dutch matrix clauses in Experiments 1 and 2 (Chapter 3). The result at probe position [3] indicates that in SV matrix clauses, intransitive verbs demonstrate the same continuous priming pattern as was found for transitives (i.e., significant priming 1000 ms after the verb). In the case of intransitive verbs the only argument that the verb ‘needs’ (the external argument) *precedes* the verb (at least in the types of sentences used here) and thus, no arguments are to be expected after the verb. Therefore, the maintained priming effect found in this experiment cannot be related to argument structure. The Argument Structure Hypothesis as put forward in the previous chapter can thus be rejected. Also, the interpretation of the lexical accounts (DAH, DOP, SPA) that was proposed in the previous chapter (to predict verb activation in the vicinity of an argument) is not in line with the present data.

The null effect at probe position [1] is essential, as it indicates that the effects found later in the sentence are not caused by inherent differences between the related and control probes. The stable priming effects at probe position [2] confirm the hypothesis offered in
the discussion of Experiment 2 concerning the lack of effect at the verb probe position in that study, namely that the probes were presented too early. A slightly later placement of the probes in this study revealed significant priming after the verb. In conclusion, the present experiment shows that the results of Experiments 1 and 2 generalize to different verbs and even different verb types, supporting the generality of the pattern of continued verb activation throughout a Dutch matrix clause. We are thus left with the following issue: why do verbs remain active throughout the temporal unfolding of the clause, even when all arguments have been encountered? This cannot be explained by some simple claim that verbs are activated endlessly; Experiments 1 and 2 demonstrated that immediately upon encountering evidence of a new clause, the activation of the verb associated with the prior clause was terminated. Continued activation of a verb throughout a clause may be a critical aspect of sentence processing, in that not only arguments, but also other information present in the clause is critical to the interpretation of the conceptual information conveyed by the clause (and hence linked to the clausal verb in some fashion). It may thus turn out that in addition to information present in the argument structure of a verb, adjunctive information plays an important role in processing verbs as well. Indeed, information about where, when, how, and why something happened (information often conveyed by adjuncts), can be very important for the interpretation of the event described in the sentence. Thus, it may not be surprising that verbs continue to be activated in their clauses beyond saturation of their arguments alone. In Chapter 5 the semantic aspects of verbs and sentences containing these verbs will be further considered. Chapter 6 focuses on the effects of the clause boundary on the pattern of verb activation.

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5 However, note that other primes, probes and sentences were used in the current experiment. The reader is referred to Experiment 4 for further evidence in favor of the ‘probe placement hypothesis’.