1. **Introduction**

Verbs have been recognized to play a central role in sentence processing since the inception of the field of psycholinguistics. That this should be so is an inevitable consequence of the fact that the verb is the core of a sentence: verbs express the event or activity that the sentence describes, the moment in time at which that event or activity takes place, and they provide the linkage of the possible persons or objects involved in the event. Thus, verbs (and all the information we implicitly understand when we ‘know’ a verb) provide a bridgework for nearly all aspects of sentential processing.

Because of this key role of verbs, accounts of sentence processing have long acknowledged a need for explicit details of verb activation and integration. From the earliest accounts of sentence perception (e.g., Fodor et al., 1968) to the most current accounts, studies revealing the properties of verbs have played increasingly important roles in informing comprehension processing models. While much research over the years has demonstrated that verb information plays a crucial role in sentence processing, there remains a surprising paucity of evidence detailing the precise nature of how and when such information is employed. For example, it is well established that when verbs are encountered during sentence comprehension, their argument structure configurations and thematic properties are immediately activated (Boland et al., 1990; Ferretti et al., 2001; Friederici & Frisch, 2000; Pickering & Branigan, 1998; Shapiro et al., 1987; Shapiro et al., 1989; Shapiro et al., 1991; Trueswell et al., 1993; Trueswell & Kim, 1998). However, only few details are known about the role of the verb throughout the ongoing integration of sentential material prior to final sentence interpretation.

The work presented in this dissertation focused on filling part of this void, with the specific goal of detailing the nature of activation of verbs throughout the process of sentence comprehension. More specifically, the pattern of verb activation during on-line spoken sentence comprehension in Dutch was mapped out for complex sentences consisting of at least two clauses. The effects of verb movement, argument structure, verb meaning and the clause boundary were considered. The present chapter will summarize the findings from seven Cross-Modal Lexical Priming (CMLP) experiments and relate them to these four topics (section 2). After this, an important issue will be discussed that was paid little attention to until now, namely, the question whether what was measured was in fact activation of the verb proper (section 3). The chapter ends with general conclusions.
2. SUMMARY AND INTERPRETATION OF THE RESULTS

To study the activation pattern of the main verb during on-line sentence processing, a great range of experimental sentences was constructed, which were variations on the same theme: matrix SVO clause – second clause, with a few exceptions. These sentences were presented in a CMLP paradigm. CMLP allows moment-by-moment activations in word meanings to be accurately tracked during ongoing spoken sentence comprehension. As the sentences are presented without interruption, and no secondary task is involved until the point of interest, there is relatively little interference with the ongoing process of comprehension. During the experimental sentences two types of probes were presented: verbs related to the matrix verb of the sentence and unrelated control verbs, matched to the related verbs for baseline lexical decision time and other relevant characteristics. If reaction times (RTs) to the related probes are significantly faster than RTs to the control probes, this is described as priming. This priming effect is classically held to be caused by the associative relationship between the verb that occurs in the sentence and the related probe, which facilitates its recognition in the lexical decision task. The fact that the matrix verb causes a priming effect at a certain point in the sentence is interpreted to indicate that the meaning of the verb was activated at this particular point.

2.1. Results

2.1.1 Introduction

In this section, a summary of the results will be given. For easy reference, the results are not presented per experiment, but an overview is provided for four important parts or points in the sentences: the position directly after the verb, the sentence part from the verb until the end of the main clause, the second clause and the position before the verb. After this overview, the remaining probe positions that do not fit within this division are discussed.

For easy reference, Figure 1 provides an overview of the experiments that probed for verb priming. The global sentence structure, the probe positions and the general findings can be read from this figure.
Figure 1. Overview of the verb experiments: Sentence structures (bars), results at each probe position (asterisks and hyphens) and verb activation patterns (lines).
2.1.2 Verb activation directly after the verb

A probe position directly after the verb was included in four of the experiments with word order SV(O) (Experiments 1, 2, 3, and 4) and in the verb-final experiment (Experiment 6). Directly after the verb, significant priming effects were found in four experiments (Experiments 1, 3, 4, and 6), but a null-effect was reported in Experiment 2. Post-hoc analyses and later experiments indicated that this lack of effect in Experiment 2 was due to the exact placement of the probe. If the probe is presented shortly after the offset of the verb, priming is reliably found.

In sum, the verb was consistently found to be activated directly after its occurrence (see Figure 2).

Figure 2. The activation of the matrix verb directly after its occurrence (see Figure 1 for a short explanation on how to read the figure)

2.1.3 Verb activation during the unfolding clause

Verb priming was checked for at positions 700 ms after the verb during the Direct Object (Experiment 1), 1500 ms after the verb during an Object Noun Phrase (NP) which was preceded by an adjunct (Experiment 2), 700 ms after the start of an adjunct which was preceded by an Object NP (which was approximately 2100 ms after the verb; Experiment 4), and, finally, at 1000 ms after an intransitive verb, during the adjunct (Experiment 3). Furthermore, probes were presented at the end of the main clause in three experiments (Experiments 2, 3 and 4). Finally, in Experiment 7, the end-of-clause probe position coincided with the verb probe position. At all these places, a significant effect of verb priming was found.

Figure 3. The activation of the matrix verb during the main clause

1 It should be noted, however, that in the 6th experiment the main verb appeared at the end of the clause. This means that other factors could have played a role in the priming effect found (e.g., the whole clause had already been processed, the probe was presented at the end of the clause).
In sum, activation of the verb meaning was present during the entire main clause, independent of sentence structure (Figure 3).

2.1.4 Verb activation and clause boundaries

Directly after the conjunction, no priming effect of the verb was reported in two experiments (Experiments 1 and 2). At 700 ms after the end of the matrix clause (150-200 ms after the conjunction; Experiments 3b and 6) and at 700 ms after the beginning of the second clause, no significant effects were found either. The latest probe position occurred at 1400 ms after the end of the main clause (approximately 900 ms after the conjunction, Experiment 3b) and no effect was found here.

In sum, there are no signals for activation of the verb during the entire second clause. As soon as a few hundred milliseconds after the end of the main clause (namely, after the conjunction), the stable activation effect found during this clause has died out, as is represented in Figure 4.

Figure 4. The activation of the matrix verb during the main and second clause

2.1.5 Priming before the verb

When only part of the Subject NP has been encountered, no priming effect of the (upcoming) verb is found (Experiment 3). Figure 5 is the final, complete picture, representing the general pattern that was found.

Figure 5. Overview of the activation of the matrix verb during a complex sentence consisting of a main and a second clause

2.1.6 Further probe positions

When an embedded Subject-relative clause was inserted within the main clause, strong priming effects were found 1000 ms after the first and 1000 ms after the second clause

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2 Although the results were less convincing at these points; the associated p-values clustered around p = .10.
boundary. A marginal priming effect of the matrix verb was reported at the end of the embedded clause, directly after the main verb of this clause (which was unrelated to both the related and control probe).

2.2. Reliability of the data

The general activation pattern for verbs that was found in the present experiments differs importantly from patterns that have been found before in CMLP experiments on wh- and NP movement (see Chapter 3). Although the most straightforward assumption is that this deviating pattern is related to the fact that verbs differ from nouns in many aspects, both the generalizability and specificity of the data had to be established before this conclusion can be drawn.

As can be read from the summaries above, most data points were measured at least in two different experiments, some even four or five times. Except for the first probe position, these replications revealed very similar results. Only the data on center-embeddings (Experiment 7) were not corroborated by further measurements. The generalizability of the effects was further assessed by a replication of the main findings – continued activation of the verb during the entire matrix clause – in Experiment 3, where a different verb type (intransitive verbs) was used and a new set of items was constructed.

The generalizability can be further corroborated with a cross-language comparison. If the same results are found for verbs in other languages, this confirms the hypothesis that the pattern found here applies to verbs in general. Preliminary findings for English are indeed similar to the ones presented in this dissertation: Once the verb meaning is active, it remains active for an extended period of time, even during adjuncts (L.P. Shapiro, personal communication, August 2006). For further evidence we have to rely on the weak evidence available in the literature (Basilico et al., 1995; Kaan et al., 2004; Shapiro et al., 2003; Wijnen & Kaan, 2001, Muckel, Urban, & Haertl, p.c., 2003; see Chapter 3, section 2.3).

As far as the specificity of the data is concerned, the most important alternative explanation to be excluded is that the pattern found is not specific to verbs, but can be explained by something inherent in the language or the type of sentences chosen. A possibility that has been suggested is that in Dutch all words are kept activated until the end of the clause, either because of the relative loose word order of the language (L.P. Shapiro & D.A. Swinney, personal communication, 2002) or because it is an SOV language (J.P. Koenig, personal communication, 2005). A comparison with German data seems relevant here, as German has an even less strict word order than Dutch and is also an SOV language. Unfortunately, the German experiments all used identity probes instead of related probes (e.g., Clahsen & Featherston, 1999; Featherston, 2001; Muckel & Pechmann, 2002), which results in some sort of basic activation level throughout the whole sentence. Only
interaction effects between probe positions are interpretable in this design. Also, German has specific characteristics (such as case marking) which makes it incomparable to Dutch.

Furthermore, a limitation in the present verb experiments was that sentence type was not manipulated (with Experiments 6 and 7 as exceptions, but these focused on slightly different questions and thus did not have probe positions similar to those in the experiments that showed continued activation). In theory, there might be something inherent to (Dutch) main clauses with word order SV(O), that results in maintained activation not only of verbs, but of all other elements.

Experiment 5 was designed to deal with these issues. In this experiment the same type of sentences and the same language was used, but nouns were studied instead of verbs. If nouns were found to remain activated for an extended period of time in the main clause, this would have been a clear reason to doubt the specificity of the data and look for other explanations than verb-related factors. If, on the other hand, the pattern found diverged importantly from the verb data, this would be an indication that we are after something interesting and verb-specific. The latter was the case. Nouns were found to be activated directly after their occurrence, however 1000 ms later this effect was clearly attenuated (compare Figure 6a and b). From the present data the exact pattern of deactivation cannot be deducted, but the most important conclusion for the current purpose can be drawn: verbs behave differently from nouns.

Figure 6. Overview of the activation pattern of verbs and nouns during a complex sentence consisting of a main and a second clause

2.3. Interpretation of the data

2.3.1 The data

The present findings all point to one important conclusion: the fact that verbs are different from nouns is reflected in one-line sentence processing. Verbs remain activated for a substantive period of time when encountered within a sentence. Only a clear signal that the main clause has finished dissipates the activation of the main verb. In this
dissertation, four main issues that could be of relevance for the activation pattern of verbs in Dutch complex sentences consisting of a main and a second clause were introduced: verb movement, argument structure, verb meaning and clause boundaries. In the remainder of this section, the data will (again) be mapped upon the data patterns predicted for each of this factors.

2.3.2 Verb movement

An important property of the sentences used in most of the present experiments is the fact that the word order in Dutch main clauses does not conform to the basic word order of the language, which is supposed to be SOV (Koster, 1975). The finite verb in Dutch main clauses is claimed to be displaced, or ‘moved’ from its base position at the end of the clause to second position.

It has been found repeatedly that in sentences with moved constituents, the meaning of this moved constituent (filler) is reactivated by the listener at its original position (gap). Gap-filling effects have been demonstrated for moved NPs (mainly wh-phrases) with a number of methodologies in English and in other languages such as German, Japanese, and Bulgarian (see, e.g., Bever & McElree, 1988; Clahsen & Featherston, 1999; Fiebach et al., 2003; Fiebach et al. 2001; Hickok, 1993; Love & Swinney, 1996; Muckel & Pechmann, 2004; Nagel et al., 1994; Nakano et al., 2002; Nicol & Swinney, 1989; Stamenov & Andonova, 1998; Stowe, 1986; Tanenhaus et al., 1989).

Several explanations have been put forward for this phenomenon. Swinney et al. (1988) provide a structural account: they suggest that listeners recover canonical word order, perhaps as a route to interpretation (Trace Reactivation Account, TRA). Others have suggested verb-centered, semantic accounts: the meaning of the moved Object is reactivated after the verb because a dependency relation is established between the verb and its dependents, that is, the arguments (Direct Association Hypothesis (DAH), Pickering & Barry, 1991). Two other lexical accounts were raised by Fodor (1989, 1995) and are called the Semantic Processing Account (SPA) and the Depth of Processing Account (DOP). These three accounts predict reactivation of a (moved) argument at two critical positions: after the subcategorizing verb (DAH and SPA) and at clause boundaries (SPA and DOP).

For the SVO sentences studied in the present experiments, the structural account of gap-filling would predict verb movement to be reflected as re-activation of the meaning of the main verb at its base position clause-finally (Figure 7a). A complicating factor is that theoretical linguists do not agree on the base position of the verb: if the final constituent is an adjunct; the gap might be before this adjunct but it could also be after the adjunct, at the end of the clause. Taking into account the assumption that the word order in the main clause is derived from the embedded clause (Koster, 1975; Zwart, 1993), evidence in favour
of the first position is the embedded clause construction in (1). Conversely, a similar construction is ungrammatical in (2). For this second example sentence to be grammatical, the main verb has to appear at the end of the embedded clause, after the adjunct (3).

(1) ..., omdat de domme gedetineerden vijftien rijke bejaarden beroven tijdens hun eerste proefverlof.  
..., because the stupid detainees fifteen rich seniors rob during their first parole.

(2) *..., omdat de kleine jongetjes de fanatieke voetbaltrainer imiteren elke zaterdagochtend weer.  
*..., because the little boys the fanatical soccer-coach imitate every Saturday-morning again.

(3) , omdat de kleine jongetjes de fanatieke voetbaltrainer elke zaterdagochtend weer imiteren.  
, because the little boys the fanatical soccer-coach every Saturday-morning again imitate.

The predictions for the semantic accounts are unknown, but taking into account the strong emphasis of all of these accounts on the relation between verb and argument, they would probably predict activation of the verb in the vicinity of its arguments (Figure 7b). The DOP and SPA would probably also predict activation at clause or sentence boundaries (Figure 7c).

Relevant data for the question whether verb movement is reflected in on-line sentence processing in Dutch can be abstracted from Experiments 1 and 2, where the main clause ended after the final argument, and from Experiments 3 and 4, where an adjunct intervened between the final argument and the end of the clause. Even without having to take a stance in the theoretical discussion on the base position of the verb in SVO-adjunct clauses, the results point to one direction: in Experiments 1 and 2 verb priming was demonstrated at all probe positions in between the verb and the supposed gap at the end of the clause, as well as at the gap itself (Figure 7d). If the adjunct is supposed to precede the gap, Experiments 3 and 4 show the same. If, on the other hand, the gap precedes the adjunct, Experiments 3 and 4 even show a pattern of extended activation after the gap, until the end of the clause. The pattern of verb activation after the occurrence of the verb, maintained at least until the gap, and maybe even longer, clearly deviates from the re-activation pattern discussed before for wh- and NP movement. Therefore, it is concluded that the verb gap does not play a role in the activation pattern of the verb: verbs are maintained activated until the end of the clause, independent of the position of the gap.

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3 Both sentences occur in Experiment 4.
Figure 7. Overview of the (predicted) activation pattern of verbs during a complex sentence consisting of a main and a second clause

For the sake of completeness, two alternative explanations are put forward here. First, the maintained verb activation pattern that was found can be attributed to the fact that the verb is kept activated until it is united with its base position (although this interpretation does not hold if the gap is assumed to be before the adjunct in S-V-O-adjunct clauses). Second, the pattern found might reflect a combination of maintained verb activation and gap-filling (Figure 7d + Figure 7a). Wijnen and Kaan (2001) made a reasonable case for a similar explanation in interpreting the data of their CMLP experiment on Dutch ellipsis.
constructions. Nevertheless, even if one of these alternative hypotheses turns out to be correct, the reason for verbs to be processed differently from nouns has to be sorted out. So, why do verbs remain activated during sentence processing whereas nouns do not?

2.3.3 Argument structure

Verb-argument structure has direct consequences for the sentence processing system. Influences of argument structure have been found at very early processing stages, using a variety of experimental techniques (Mecklinger, Schriefers, Steinhauer, & Friederici, 1995; Pickering & Branigan, 1998; Shapiro et al., 1987; Trueswell & Kim, 1998). These experiments have in common that they looked for effects of argument structure directly after the verb itself. However, it is not known what happens afterwards, during the ongoing sentence, for example, when the Direct Object is encountered and a theta role has to be assigned. The verb is critical to the assignment of thematic roles to the arguments. But is it the case that the verb remains active until its arguments are encountered in the sentence, to fulfill the requirement that all arguments are assigned a thematic role?

In Experiments 1 and 2, the final argument of the verb appears at the end of the main clause: all verbs were transitive verbs and all sentences ended with a Direct Object NP. In these experiments, activation of the verb was found up to and including this final argument. Relevant data for the question whether argument structure affects the activation pattern of the verb during on-line sentence processing is found in Experiments 3 and 4. In Experiment 4, the same verbs were used, but an adjunct intervened in between the Direct Object and the clause boundary. If the maintained activation of the verb in the first experiments were caused by argument structure (theta-role assignment), deactivation would be expected after the Direct Object NP in Experiment 4 (Figure 8a). This is not what was found: the verb was activated during the adjunct as well as at the end of the clause (Figure 8b).

**Figure 8.** Overview of the (predicted) activation pattern of verbs during a complex sentence consisting of a main and a second clause

a. ARGUMENT STRUCTURE HYPOTHESIS

![Argument Structure Hypothesis]

b. EXPERIMENT 4

![Experiment 4]
Experiment 3 serves as a second check: sentences were similar to Experiment 1, but in this case the verb was intransitive, and thus the constituent that followed it was not a Direct Object but an adjunct. Therefore, if the verb would remain activated until its final argument, no priming effects were to be expected after the verb (Figure 9a). Contrary to this prediction, the results showed continued activation during the entire main clause (Figure 9b).

Figure 9. Overview of the (predicted) activation pattern of verbs during a complex sentence consisting of a main and a second clause

Taking these two experiments together, it seems safe to conclude that there were no direct effects of argument structure on the activation pattern associated with the matrix verb.

2.3.4 Verb meaning

The verb is the main determinant of the event that a sentence describes, but verbs are more polysemous than nouns (verbs have more different word senses than nouns: Fellbaum, 1993; Gentner, 1981b) and verb meanings are flexible and adjustable (Bencini & Goldberg, 2000; Gentner, 1981a, b; Gentner & France, 1988). The meaning of a verb and, since verb and sentence meaning are highly intermingled (Chafe, 1970), the meaning of the entire sentence is dependent on the syntactic structure of the sentence and on the other words (mainly nouns) used in a sentence. According to the underspecification hypothesis (Frisson & Pickering, 1999, 2001; Pickering & Frisson, 2001), verb interpretation is delayed and can be regarded as a process of zooming in on the appropriate sense of the verb on the basis of information in the context.

Two issues can be abstracted from this hypothesis: first, the meaning of the verb is underspecified when it is encountered; second, during the unfolding sentence, the sentence
processor will zoom in to the final, and most detailed meaning on the basis of the information present in the sentence.

2.3.4.1 Activation of the verb immediately after its occurrence

As far as the first point is concerned, the degree of underspecification or ‘vagueness’ of the verb can be dependent on a range of factors, for example, the verb itself (is it a general verb, is it ambiguous, or does it have multiple senses?), or the information that has been processed before the verb is encountered (in the present study, this was the Subject NP). In the present experiments, these factors were not manipulated directly.

However, the failure to find an effect directly after the verb in Experiment 2 was explained by timing issues (Chapter 3), which were related to the underspecification hypothesis in Chapter 5. In those sentences where the probes were presented at the onset of the word following the verb, priming was found, whereas this was not the case in the sentences where the probes were presented slightly earlier. When the verb is encountered as part of a sentence, its meaning may remain underspecified for a while. However, after a short delay stable priming can be found. The duration of this delay will differ (depending on, for example, the sentence context preceding the verb and the verb itself).

The hypothesis that the immediacy of the priming effect depends on the amount of information available from the preceding constituent (the Subject NP in our sentences) was tested in a post-hoc off-line test. In this test, participants rated how much the Subject NP added to the interpretation of the verb meaning, for each experimental sentence. A marginally significant relation was found between this measure and the degree of priming at the verb probe position. It seems worthwhile to explore this effect empirically.

Extra evidence in favour of this hypothesis comes from Experiment 7, where the verb appeared at the end of the main clause, and a Subject NP, modal verb, Object NP and adjunct preceded it. In this experiment, a significant priming effect was found directly after the verb, even though the probes were presented at its offset, and not with a slight delay, as was done in all experiments except for the first two.

2.3.4.2 Meaning of the verb during the unfolding sentence

With regard to the trajectory to full specification of verb meaning, the underspecification hypothesis states that evidence from the remainder of the sentence is used to focus on a more specific interpretation of the verb. Since CMLP inherently cannot examine relative priming levels\(^4\), a gradual increase in the specification of verb meaning could not result in a similar gradual increase in the amount of verb priming. Nevertheless,
the maintained priming of the verb in the present experiments is considered to be a reflection of the verb specification process. This means that specification continues throughout the entire clause ‘lead’ by the main verb and that, in this respect, there is no difference in the way arguments and adjuncts are processed.

In the literature, arguments have often been the major sentence constituents put forward to influence verb meaning (e.g., Bencini & Goldberg, 2000; Gentner, 1981a; Kersten, 1998; Kersten, 2003; Pickering & Frisson, 2001). Nonetheless, it is clear that information about where, when, and why something happened, information often carried by adjuncts, is essential to interpret the event described by a verb, and thus, according to the underspecification hypothesis, to interpret the full meaning of the verb itself. Therefore, it is not surprising that verbs continue to be activated in their clauses beyond saturation of their arguments alone. The current data suggest that adjunctive information may play a much more important role in sentence processing than has been considered before. Frisson and Pickering (2001) indeed chose a more ‘relaxed’ interpretation of the underspecification hypothesis, not referring to any sentential elements in particular, but stating that further specification can take place as long as it is necessary: “...as long as there is no semantic ‘clash’ between the activated underspecified meaning and the ongoing context, sentential processing can continue and specification of meaning can occur when more information has been processed ...” (Frisson & Pickering, 2001, p. 165). Also, many verbs have more than one possible argument structure. The general flexibility of transitivity and argument structure, makes it functional for a verb not to stop being open to other options too soon.

2.3.5 Clause boundaries

With respect to the end point of verb priming, Experiments 7a and 7b indicate that it is not the clause boundary per se that triggers it. Rather, the verb seems to be closely linked to ‘its’ clause. When the main clause is temporarily interrupted, the verb continues to exert influence, probably to maintain associated with its event. Only when the main clause is definitely finished, priming of the verb ends. In this way, all information present in a clause can be linked to the verb. However, when a new clause starts, a new verb appears or is expected that takes over this role.

In this dissertation it is proposed that the meaning of a verb is continuously specified during the unfolding event, based on all components that play a role in describing the event (both arguments and adjuncts). This process only stops when a clause boundary signals that a new event is being described. Or: the clause is ‘the unit around a lexical verb, containing

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4 CMLP patterns are often cast as existence-proofs; either priming is found, or not. To find out more about underspecification, one would probably need to select the related probes in such a way that they are more or less related to the ‘specified’ meaning of the verb (see e.g., (Gentner, 1981a).
all the bits that the verb requires as well as any optional bits the speaker has chosen to include...’ (Börjars & Burrige, 2001, p. 212).

3. **Verb Activation or Priming by the Event Structure?**

3.1. *An alternative interpretation: Event memory*

One issue has been paid little attention to until now: *What exactly did we measure?* In previous CMLP studies focusing on nouns, the assumption has been that priming of the noun can be directly linked to activation of the noun: only when the meaning of the noun is active can it cause a (lexical/semantic/associative) priming effect in the CMLP paradigm. Results from CMLP experiments have been typically interpreted to reflect the activation of a singular word during ongoing sentence processing. In studies on lexical ambiguities, the question has been when exactly the two different meanings of an ambiguous word are active (Love & Swinney, 1998; Onifer & Swinney, 1981; Swinney, 1979; Swinney & Prather, 1989) and in gap-filling experiments the meaning of the moved constituent (a noun in most cases) has been shown to be re-activated at its original position (Balogh et al., 1998; Clahsen & Featherston, 1999; Love & Swinney, 1996; Love & Swinney, 1998; Nagel et al., 1994; Nicol, 1993; Nicol & Swinney, 1989; Nicol et al., 1994; Osterhout & Swinney, 1993).

But can we reason along the same lines with respect to verbs? According to the event memory account (Ferretti et al., 2001; McRae, Ferretti, & Amyote, 1997; McRae, Hare, Elman, & Ferretti, 2005), verbs are represented in memory as part of a generalized event. Thus, verbs provide access to the generalized situation structure corresponding to the event to which they refer. Priming occurs when a target overlaps substantially with the constructed event space. Generalized event structures include information about the activity (the verb), but participants (arguments), and time and location (i.e., adjuncts) are taken into account as well. It is assumed that all components playing a role in the event can provide access to event memory. The verb itself is a strong information carrier for event structure and thus should quickly activate a general situation structure or general event knowledge. When the target verb substantially overlaps with the predicted event space, priming occurs.

Unfortunately, the theory of Ferretti et al. (2001, 2005) is based on word-word priming experiments solely. Therefore, the interaction of different event components (e.g., arguments and adjuncts) and the unfolding of the processes in time are unclear. It can be assumed that in sentence processing, different components are used to form a combined event space, which can be more specific than the generalized events based upon only one information source (the verb in isolation). During SVO sentence processing, after the verb has been encountered the event will be further specified by information present in the
argument and the adjunct. Facilitation of responses to a target verb at any point during the sentence is supposed to occur when this target verb overlaps substantially with the event space as it is constructed until the particular point in time. So, according to this view, if priming occurs, this means that the event that the verb denotes is activated.

It will be clear that the event approach is not incompatible with the underspecification hypothesis discussed above. Although the definitions used may vary, the general way to deal with the issues at hand is comparable. Both the event memory account and the underspecification account emphasize the way in which a verb is intertwined with the other sentential elements. Both make comparable predictions with respect to the priming pattern found in our experiments. Whether the priming effect measured reflects generalized event representations or verb meanings specified by the current sentence context remains to be investigated.

3.2. Effective context

Related to the previous discussion is the recent suggestion by Norris et al. (2006) that priming in the CMLP paradigm does not reflect the activation of individual word-meaning representations. Rather, they state that the CMLP paradigm is particularly suited to tap into the ongoing construction of a conceptual interpretation of an utterance. The authors used the CMLP task to study priming of words of different categories (verbs, nouns, adjectives, etc.) as well as embedded words (date in sedate) at different positions in a sentence. Although priming effects for the words were found in random word lists, these effects could not be replicated in five out of six experiments where the prime words were integrated in a sentence.

Some characteristics of the sentences and the task used by Norris et al. (2006) seem to be relevant here: in the cases where no priming was found, a neutral intonation was used, that is, sentences were spoken in a ‘matter-of-fact fashion’, with no contrastive accents, and the control task (used to ensure that participants pay attention to the spoken sentences) was either a recognition task, where complete sentences had to be recognized at the end of the experiment, or a sentence repetition task. These factors taken together can be argued not to encourage deep semantic processing of each individual word in the sentence (see also Ferreira et al., 2002; Sanford & Sturt, 2000).

The only CMLP experiment of Norris et al. (2006) in which priming was found when sentences were presented uninterruptedly employed contrastive stress on one of the words in the sentence instead of the neutral intonation used in the other experiments. The authors assume that this prosody manipulation stimulated fuller processing of the meaning of the sentence. Listeners were encouraged to incorporate a richer (more detailed) word meaning
representation into the representation of the sentence and thus to process the prime words more deeply. This resulted in significant priming effects.

Importantly, the design and the procedure in the experiments presented in this dissertation were such that deep semantic processing of the sentences was encouraged: intonation was natural instead of neutral, the sentences were rich in information (content words, adjectives), interesting filler sentences were inserted to keep attention focused to the task, and comprehension questions forced the participants to pay attention to the contents of all sentences (as it could not be predicted when a question would be asked)\(^5\) and all information in the sentences (as questions focused on factual aspects of different parts of the sentences). For these reasons, associative priming would be expected to occur for words embedded in these sentences. Also, our prime and probe words were all verbs. Presumably this enhances the chances to find associative priming effects, as it has been shown that during sentence processing more attention is being paid to verbs than to other word classes (Rayner, 1977), and verbs are more likely to be related to the overall interpretation of the sentence (Bencini & Goldberg, 2000; Gentner, 1981a; Kersten, 1998; Kersten, 2003). These points all suggest that the chances to measure associative priming effects from the verb are optimal in our experiment.

Williams (1988) used the term effective context to explain differences in priming effects in word lists and in sentences. When isolated words are presented, the only available context that can cause priming effects is the prime word itself (or words that were presented earlier). Thus, in a word list, the effective context is the prime word preceding the target, and therefore, priming always occurs in these situations. In a sentence, on the other hand, the listener is focused on a sentence-level interpretation instead of the level of individual words. Therefore, in a sentence, the effective context is the propositional representation of the sentence. Only if the associatively related target is relevant to this propositional representation, the target will be primed.

Most of the data presented in this dissertation are not contrary to this account. For probes presented directly after the verb, the effective context consists of the Subject Noun Phrase and the verb itself, so it seems to make sense that priming is found here. For probes presented later during the main clause, the representation of the sentence built up thus far would be the effective context and clearly the matrix verb plays an important role in this representation, again verb priming effects can be justified this way as well. It is, however,

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\(^5\) Informal discussions with participants yielded that some of them used all information possible (both relevant and irrelevant) to predict when a question could occur. For this reason, in all experiments except for Experiment 1, comprehension questions were asked about two consecutive sentences at least once (otherwise, participants reported to allow an attention ‘dip’ for the first couple of sentences occurring directly after a question).
unclear what predictions the effective context account would make for the probe positions in the second clause.

3.3. Implications

Both the theoretically oriented discussion in section 3.1, where an event memory account was proposed as an alternative explanation for the data, and the methodological discussion in section 3.2, where the sensitivity of the CMLP paradigm for sentence-level effects was the issue, suggest that the effects found cannot be automatically attributed to activation of the verb proper. And although both issues might seem to approach the ‘problem’ at another level, we suggest that both can be traced back to where this dissertation started: the special role of verbs during sentence processing.

From the data presented in this dissertation it is clear that the verb plays a very important role and that even at points later in a clause its presence can be clearly measured. Because the related probes that were used were related to the verb, priming effects during the whole clause show that either the verb itself is maintained activated (lexical priming account), that the verb contributes significantly to the overall sentence meaning (effective context account), or that verbs that are related to the matrix verb also relate to the event being described in the sentence (event memory account). The latter distinction in particular may well turn out to be impossible to disentangle experimentally.

When the lexical activation account is then linked again to the underspecification hypothesis, which was introduced as an explanation for the continued activation of the verb throughout the entire clause, all accounts lead to the same underlying issue: the meaning of the verb does not exist without the meaning of the whole sentence. In the present experiments, the meaning of the verb and the meaning of the clause are intermingled and cannot be teased apart.

3.4. Integrative account

Vasishth (2003a,b) describes an account in which incremental processing is combined with activation and decay of sentential elements. The account assumes that possible sentence structures are retrieved from long-term memory when sufficient linguistic information is available. Each structure has an initial activation level that increases with repeated access but decays over time. When new sentential information is encountered, the previously predicted sentence structure is retrieved and the element is integrated. This leads to an increased activation level. At the same time, arguments are assumed to decay after having been encountered, but to be retrieved at verbs subcategorizing for them.
The attractive part of this account for the current discussion is that it combines activation and decay of individual sentential elements with incremental processing of the entire sentence structure. However, the fact that it is focused on structure more than on meaning makes that it maps less directly to the story presented in this dissertation.

The most important lesson that can be learned from this account is that the results that were reported in this dissertation do not necessarily need to be attributed to either a lexical priming effect of the verb or a more general event or sentence priming effect. It might well be the case that both processes take place at the same time, and maybe even reinforce each other. According to Vasishth (2003a,b) relevant new incoming information results in reactivation of the predicted sentence structure. This can be linked to the underspecification hypothesis, where the meaning of the verb is supposed to become more specified with every bit of relevant new information being encountered (Frisson & Pickering, 1999, 2001; Pickering & Frisson, 2001). Although in isolation the activation of the verb would decay fairly rapidly, in our sentence contexts new information specifying the meaning of the verb occurs relatively soon. This new information boosts the activation level of the verb when used to specify the meaning of the verb. Apart from this process, an overall sentence meaning is incrementally built, resulting in an event space (Ferretti et al., 2001; McRae et al., 2005).

Thus, the current data may reflect both activation of the verb and activation of the event that the verb denotes. Priming effects can reflect both activation of the verb itself, which is being specified during the entire clause of which it forms the core, and activation of the event being described, which stops when a new clause signals that a new event will be described.

4. CONCLUSION

This dissertation reports on a series of CMLP experiments exploring the activation of matrix verbs in on-line processing of Dutch main sentences with verb-second clause structure. Despite some unresolved issues discussed above, the main findings are consistent. It was found that priming emerges rapidly after the verb has been encountered and persists until the end of the main clause. This effect is independent of whether listeners are processing arguments or adjuncts of the matrix verb. Also, if the main clause is interrupted by an embedded clause, the effect continues during the continuation of the main clause. The priming effect only disappears when a new clause is entered after the closure of the main clause. This pattern of verb activation differs importantly from the pattern found for nouns: whereas a similar semantic priming effect was found immediately following the noun, this effect diminished before the end of the clause.
This difference in verb and noun processing is suggested to reflect important inherent differences between verbs and nouns. Verb information has a special status in the sentence: the verb is essential for the computation of the meaning of the sentence and the sentence is indispensable for the computation of the meaning of the verb (the event). Therefore, it is important that verb information is available during the sentence part of which it forms the core. This allows continuous linking of the verb to sentential elements like arguments and adjuncts and an incremental process of refinement of the meaning of the verb and of the message that the sentence conveys. Only when the clause that the verb ‘governs’ ends do these processes come to an end as well.