1. VERB MEANING AND SENTENCE PROCESSING

1.1. Introduction

In the literature, people have come up with quite a range of explanations for why verbs are difficult to remember, to learn and more vulnerable to ‘lose’ in language impairment (see Chapter 1). The present chapter describes some intrinsic semantic difference between verbs and nouns, especially when presented as part of a sentence (section 1). The effects of semantically or propositionally relevant, but syntactically non-obligatory, sentential elements on verb activation are studied in Experiment 4 (section 2). In Experiment 5 (section 3) it is shown that the activation pattern found in the experiments discussed so far is a verb-specific pattern.

1.2. Verbs in language acquisition

A difference between nouns and verbs that most people know intuitively is the way in which the lexical form of the words is matched to the ‘real world’. Although this word-world mapping is not one-to-one for nouns, with verbs it gets even more complex. Many researchers have acknowledged this difference between nouns and verbs and hypothesized that it is the main reason for verbs to be acquired later and at a slower rate in children developing language (e.g., Gennet, 1978; Gleitman, 1994; Marshall, 2003).

Gleitman (1994) came up with a number of arguments why verbs cannot be learned in the same way as nouns, that is, by matching the speech of more experienced speakers (mostly caretakers) to objects in the real world. Events are interpretable from different perspectives, and different verbs can be used to describe the same event. A clear example is the case of paired verbs that describe single events, like buy and sell and flee and chase. Related, the ‘subset problem’ indicates that, dependent on the level of specificity that the speaker chooses, a different verb is selected, for example, compare give and sell. Also, many verbs do not refer to the observable world at all (e.g., understand and hope). Gleitman (1994) therefore proposes that additional information is used when learning verbs, that is, information derived from the linguistic (syntactic) environment in which a word occurs in speech (see also (Marshall, 2003). She calls this syntactic bootstrapping (as opposed to semantic bootstrapping, e.g., (Pinker, 1984)) and describes it as sentence-to-world mapping (instead of word-to-world mapping).
Indeed, it has been found repeatedly that an overlap in subcategorization frames of verbs is a powerful predictor of semantic similarities (e.g., Bencini & Goldberg, 2000; McKoon & MacFarland, 2002). For example, mental verbs (like think) take sentential complements and transfer verbs (like give) often require three Noun Phrases. So verbs do not stand alone, but are highly dependent on the syntactic environment in which they occur (see also Chapter 4). Even children seem to acknowledge this and use it when learning new verbs.

1.3. Verb meaning and sentence meaning

In Chapter 1, a sentence sorting experiment by Healy and Miller (1970) was discussed, which revealed that the meaning of the verb is the best predictor of overall sentence meaning. However, the fact that the verb is inextricably bound up with the number and types of arguments described in the event (see Chapter 4) suggests that this might be an oversimplification. In line with this, a more recent study by Bencini and Goldberg (2000) indicated that the pattern gets more complicated when argument structure is taken into account. The authors point to the fact that the same verb can occur in many different argument structure configurations. Although each verb has a preferred or dominant argument structure, a variety of event types can be expressed using the same verb. For example kick, a prototypical transitive verb (Julia kicked the ball) can occur in many more argument structure configurations, each denoting a particular event type (examples adapted from Bencini & Goldberg, 2000, p. 641):

(1) Julia kicked him black and blue (caused change of state)
(2) Julia kicked the football into the stadium (caused motion)
(3) Julia kicked at the football (attempted action)
(4) Julia kicked him the football (transfer)
(5) Julia kicked her way out of the operating room (motion of the Subject referent)

In a paradigm similar to the one used by Healy and Miller (1970), participants had to sort sixteen sentences, obtained by crossing four verbs (throw, get, slice, take) with four sentence constructions (transitive: Barbara sliced the bread, ditransitive: Jennifer sliced Terry an apple, resultative: Meg sliced the ham onto the plate, and caused-motion: Nancy sliced the tire open). The authors conclude that their results indicate that people see both the verb itself and the structure in which it occurs as relevant for establishing meaning.

Two possible mechanisms are proposed to describe the way in which verb meaning and sentence structure interact. In the multiple-sense view, a verb has different meaning senses and each sense is associated with a unique argument structure. According to the
constructional approach, on the other hand, both argument structure and verb meaning contribute directly and independently to the overall meaning of a sentence. Thus, in many cases, the sentence structure in which a verb appears reveals important information that is not automatically obvious from the verb itself. When presented as part of a sentence, the main verb itself does not reveal which one of its multiple senses is relevant in the particular sentence. Only when a considerable part or maybe the entire sentence structure is discerned can the associated meaning be deduced. Similarly, Kersten (1998) states that where motion events are concerned, the verb only describes certain aspects of the motion. Words from other word classes, like nouns, prepositions, verb particles and adverbs, have to be taken into account to get the complete picture.

The study by Bencini and Goldberg (2000) reveals two important characteristics of verbs that distinguish them from nouns: 1. verbs are more polysemous than nouns (have more different senses) and 2. the meaning of a verb is more dependent on the overall sentence than the meaning of a noun. Verbs are relatively high in word frequency (Gentner, 1981b), which means that the same verb is used often and can fit in many different contexts and can be used with fine distinctions in meaning. On average, verbs have more different word senses than nouns (Fellbaum, 1993; Gentner, 1981b). To demonstrate this, Gentner (1981b) took samples of 100 words from four different frequency levels from the Kucera and Francis (1967) corpus. Each word was assigned to one of four form classes\(^1\): verbs, nouns, modifiers, or function words. While only 27% of the nouns occurred in the two categories with the highest frequency\(^2\), this was the case for 68% of the verbs (Gentner, 1981b, table 1). Furthermore, the number of meaning senses was recorded for each word. The average number of senses per verb was 10.0, the average number for the nouns was 3.2 (Gentner, 1981b, table 1). Since the number of senses per word decreased with decreasing word frequency, and there were more highly frequent verbs than nouns, these numbers are not completely comparable. Nevertheless, also within each frequency category, the average number of senses per word was higher for the verbs than for the nouns. Fellbaum (1993) found the same difference in polysemy between verbs and nouns for all verbs and nouns in the Collins English Dictionary: the average number of senses for nouns (n = 43,636) was 1.74, for verbs (n = 14,190) it was 2.11.

Both Gentner (1981b) and Fellbaum (1993) stress that verbs are more flexible and adjustable than nouns and that their meaning is often dependent on the nouns with which they co-occur. In a paper-and-pencil task, Gentner and France (1988) found that when paraphrasing a sentence in which the meaning of the verb did not fit with the noun that it co-occurred with, participants were more eager to change the meaning of the verb than the

\(^1\) Words which belonged to more than one form class were assigned to the first class listed in the dictionary.
meaning of the noun. In this task, participants were asked to paraphrase simple active S-V sentences. Four noun types were produced by crossing the nouns on two variables: human or animate non-human and concrete or abstract. Each of the verbs preferred one of these four noun types, resulting in sentences where the noun and the verb ‘matched’, and sentences where this was not the case. The authors especially focused on situations where semantic strains forced meaning adjustment because the verb and the nouns did not converge into a natural interpretation, as in (6). If these sentences were paraphrased, the verb was more often the locus of change than the noun. For the example given in (6), participants would, for example, react with (7).

(6) The lizard worshipped.
(7) The chameleon stared at the sun in a daze.

Different rating methods for the resulting paraphrases showed that the participants appeared to treat the nouns as referring to fixed entities and the verbs as conveying flexible, or ‘mutable’ relations, which could, for example, be used metaphorically to agree with the noun. The authors argue that verbs are the central elements in achieving semantic coherence between the different parts of a sentence. Therefore, verbs are dependent on the co-occurring nouns for their meaning.

Verb mutability effects have been replicated in Japanese in two out of three tasks (D. Gentner, personal communication, December 2006). On the third task, a sentence paraphrase task, no differences between verbs and nouns were found in Japanese. This could mean that the mutability difference is less strong in other languages. However, there were some indications that the results were task-related artefacts (Fausey, Yoshida, Asmuth, & Gentner, 2006). In conclusion, the cross-linguistic universality of the differences in noun-verb processing cannot be established convincingly.

Likewise, Kersten (1998, 2003) emphasized the influence of nouns in particular in his findings on motion verbs. He states that the intrinsic motion associated with a verb is general and abstract and that the meaning can change dramatically when it is combined with different nouns, as in the following three examples:

(8) The man ran into the store.
(9) The horse ran a good race.
(10) The car’s engine ran for a few seconds and then sputtered out.

These two categories were the 100 most frequent words and 100 words with a frequency of approximately 100 per million.
Another experiment by Gentner (1981a) revealed even more clearly how the meaning of a verb is tuned or specified by the sentential context. It was found that the combination of a general verb and specific context information could result in recalling a more specific verb instead of the general verb that was used. Participants were asked to read stories containing a general verb for recall. In the experimental condition a sentence or phrase was added, which, when combined with the general verb, might produce the meaning of a more specific verb:

(11) general verb: give
    sentence: He gave Joe the money without complaining
    specific context: He owed Joe the money
    specific verb: pay

Recall was tested with a fill-in-the-blank test. The ‘combination effect’ (recalling the specific verb instead of the general verb) was found to be bigger when the general verb was encountered after the specific information than when it was presented before. This is explained with a semantic integration model: in line with incremental processing models, it is assumed that as soon as the verb comes in, its semantic ‘structure’ is adapted to all previous sentence/discourse information, and this process continues during the rest of the sentence.

Also in memory, a stronger effect of sentence context on verbs than on nouns has been found (Kersten & Earles, 2004). Participants were asked to remember either the verbs or the nouns from English intransitive sentences. In a recognition test, sentences were presented that were exactly the same, entirely new, or included either a new verb or a new noun and participants were asked to indicate whether either the verb or the noun (depending on the condition they were in) had appeared in the encoding lists. The verb was recognized significantly better when it was presented in combination with the noun used in the encoding stage. This contextual effect was much smaller in noun recognition. The effects were independent of instruction, indicating that they cannot be attributed to specific strategies adopted by the participants and that the results can be generalized to any conditions requiring the active reading and processing of a sentence.

When reading the previous overview carefully, a small difference in approach might have caught the eye. Whereas Bencini and Goldberg (2000) focused on the relative influence of the verb on overall sentence meaning, others, like Gentner (1981a) and Kersten (1998, 2003), more or less state that the meaning of the verb itself is changed by or dependent on the context it occurs in. Also, there is a split in the specific information in the sentence context that is supposed to be relevant for verb meaning: some authors focus more on structural aspects (argument structure, sentence structure; e.g., Bencini &
Goldberg, 2000; Gleitman, 1994) while others (more or less explicitly) put more stress on the semantic aspects by pointing to the fact that the different nouns (and words from other categories, see Kersten, 1998) that are used in combination with the verb change its sense (e.g., Gentner, 1981a; Gentner & France, 1988; Kersten, 1998; Kersten, 2003; Kersten & Earles, 2004).

1.4. On-line experiments

There is an extensive literature on the processing of ambiguous nouns (e.g., Onifer & Swinney, 1981; Rayner & Duffy, 1986; Swinney, 1979). As verbs in general have more different meanings than nouns (see section 1.3), the lack of studies in the area of lexical ambiguity of verbs is striking. The only studies available concerned noun-verb ambiguities (Frazier & Rayner, 1987; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Tanenhaus, Leiman, & Seidenberg, 1979). In a naming study on cross-categorical verb-noun ambiguities it was found that immediately after a sentence-final category-ambiguous verb both the verb and the noun reading are activated, but that the appropriate reading (based on preceding syntactic context, e.g., (12) versus (13)) is selected within 200 ms (Tanenhaus et al., 1979).

(12) I bought the watch.
(13) I will watch.

In a later study, the same researchers replicated this effect for noun-noun as well as noun-verb ambiguities (Seidenberg et al., 1982). However, different results were found for the two types of ambiguities when a word in the preceding sentence context primed one of the two meanings of the ambiguous words. In the case of noun-noun ambiguities, facilitation was found only for the appropriate reading at both 0 and 200 ms after the word, whereas for noun-verb ambiguities the prime seemed to have no effect and the same pattern was found as in the previous experiments: both meanings were active immediately after the verb, but within 200 ms the relevant one was selected. Eye movement data from a reading experiment by Frazier and Rayner (1987) replicated the finding that syntactic category assignment is delayed in noun-verb ambiguities.

Unfortunately, the possibility that the delay is caused by some inherent properties of verbs is not taken into consideration by these authors. Also, the studies do not reveal much about the possible effects of multiple meanings or senses of a verb during the interpretation of the unfolding sentence. A series of eye-tracking experiments revealed some interesting data on this issue. Pickering and Frisson (2001) showed that lexical ambiguity resolution for verbs is delayed in comparison to nouns. The authors distinguish...
between meaning and sense. When a word has two unrelated interpretations, it is referred
to as a word with two different meanings, or an ambiguous word, whereas related
interpretations of a word are referred to as its senses. The eye-tracking data indicated that
the two meanings of an ambiguous verb both reached a high level of activation before the
processor selected one particular meaning. This selection occurred only at the word after
the target word, in contrast to ambiguous nouns, where effects are reported at the
ambiguous noun itself (although sometimes spilling over to the next word, e.g., Duffy,
Morris, & Rayner, 1988; Rayner & Duffy, 1986). In line with, for example, Bencini and
Goldberg (2000) and Gentner (1981; Gentner & France, 1988), the authors reason that the
interpretation of a verb is highly dependent on the arguments with which it combines in a
particular sentence. To understand the full meaning of, for example, the verb open, one
needs to know whether it concerns opening a door, or a file. In the case of verbs, they argue,
the disambiguating information can be expected to occur very soon after the verb, at least
in SVO sentences, where the verb’s Object(s) immediately follow the verb. Pickering and
Frisson (2001) also state that verbs are more difficult to process than nouns, which would
be a further reason to expect a delay in comparison to the disambiguation of nouns.

When verbs with multiple senses (but one meaning) were studied, the data showed a
different pattern: context effects did only emerge at a very late stage. The authors
interpreted these results as indicating that the parser does not select between alternative
senses of a verb, rather “the processor activates a single underspecified meaning for a verb
with multiple senses and uses evidence from context to home in on the appropriate sense”
(Pickering & Frisson, 2001, p. 564). This hypothesis is called the Underspecification Model
and was introduced in an earlier study by the same authors on the processing of literal versus
metonymic interpretation of nouns (Frisson & Pickering, 1999) and developed further in
Frisson and Pickering (2001; for a more general application of underspecification see also
Ferreira, Bailey, & Ferraro, 2002; Sanford & Sturt, 2002).

An example may help to clarify the notion of underspecification. Consider sentence
(14) in which the parser can immediately assign the Agent role to John and make
specifications about the verb hit. However, in the present sentence it remains unclear
whether the act was intentional or not. Thus, the verb remains underspecified in relation to
this value. Information occurring after the verb can help to further specify the meaning of
the verb and to decide whether the hitting was intentional or not. In example (15) the
adverb gives evidence for a value of [- intentional], whereas the value can only be [+ intentional]
because of the rationale clause in (16). In (17) finally, the decision about intentionality may not be made at all.

(14) John hit the wall.
(15) John hit the wall accidentally.
(16) John hit the wall to frighten the assistant.
(17) John hit the wall, bruising or possibly breaking his elbow.

Importantly, Pickering and Frisson (2001) also studied unambiguous verbs, with only one sense, and found context effects during later processing (second-pass time and total-time) as well. They assume that even for these verbs it is possible to (slightly) refine their meaning in a context.

1.5. Conclusion

The verb is the main determinant of the event that a sentence describes, but verbs are more polysemous than nouns and verb meanings are more flexible and adjustable. The meaning of verbs and its influence on overall sentence meaning is dependent on the syntactic structure of the sentence and on which other words (more specifically, nouns) are used. According to the Underspecification Model, verb interpretation is delayed (both in the case of unambiguous and polysemous verbs) and can be seen as a process of zooming in on a better specified interpretation of the verb by using information in the context.

1.6. Implications for the present study

Experiments 1 to 3 (discussed in Chapters 3 and 4) demonstrated that verbs are activated for an extended period of time during on-line sentence processing. The pattern was identical for transitive and intransitive verbs: priming of the matrix verb in second sentence position was found until the end of the matrix clause. The fact that continued priming of the verb was found far beyond the verb itself for intransitive verbs indicated that the duration of this effect was not related to argument structure. Activation of the verb meaning after its final argument cannot be explained in accordance with syntactically oriented models, including models focusing on argument structure, rather it fits easily in a semantic model like the Underspecification Model.

For the present study, the Underspecification Hypothesis implies that when the verb is encountered as part of the unfolding sentence, its meaning might at first remain underspecified, to become well-defined only later, when relevant phrases have been processed. What exactly these relevant phrases are depends on how strict one wants to interpret the model. Although Pickering and Frisson (2001) mainly address the relation between a verb and its arguments, assuming that the argument entails enough information to come to a fully specified sense, they are less strict in a later paper (Frisson & Pickering, 2001). Here, they state that “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 or when the need arises to do so.” (p. 165).

So, the expected pattern is one where activation of the verb slowly builds up during the unfolding sentence until all relevant information (including at least arguments, but possibly also adjuncts or other constituents) has been processed. Since priming is an 'all-or-nothing' phenomenon, a gradual increase in the specification of verb meaning cannot be reflected in a similar gradual increase in the amount of verb priming. Nevertheless, a maintained priming effect (possibly only starting after a certain interval) can be considered to be a reflection of the verb specification process. It is unclear whether the amount of activation available at the verb itself is or is not enough for a priming effect at this point. Data from eye-tracking experiments suggest that the two meanings of ambiguous verbs are only available slightly after the verb, and for polysemous and unambiguous verbs only an underspecified meaning is active at the verb itself. Whether this underspecified meaning is ‘strong’ enough to cause priming effects is unclear.

Two experiments are presented: the first one (Experiment 4) is an extension of Experiments 1 and 2, the second one (Experiment 5) does not focus on verbs, rather, it investigates the priming pattern of nouns. In Experiment 4, the matrix clauses that were used in Experiment 1 are extended by adding an adjunct after the Direct Object. This gives the opportunity to investigate in more detail the priming of verbs after a more or less standard syntactic structure (Subject-Verb-Direct Object) has been encountered, but before the end of the clause they 'govern'. In this way, the effects of other, non-obligatory, sentence materials (adjuncts) on verb priming can be observed. If the verb is found to remain active during adjunctive phrases, this cannot be interpreted in line with syntactically oriented models focusing on the relation between the verb and its argument structure (see Chapter 4). Rather, a model like the Underspecification Model would in fact predict such a pattern, as the meaning of the verb is continuously specified, and thus this verb meaning remains in an active state, allowing priming effects to occur.

To be sure that any effect found in the experiments on verb priming is a verb-specific effect and not an effect inherent to the language or the type of sentences used, a CMLP experiment was run which focused on priming of Subject Head Nouns (Experiment 5). In this experiment the possibility is investigated that the same effects are found for another word group tested under the same conditions. Thus, if the effects found in the earlier experiments are in some way related to verb semantics and the fact that verbs are special in relation to nouns, a different priming pattern has to be found for nouns.
2. EXPERIMENT 4: MORE EXTENSIVE MATRIX CLAUSES

2.1. Introduction

The experimental sentences used in Experiment 4 employed an adjunct immediately after the second argument, as in the following example:


*The little boys imitate [1] the fanatical soccer-coach every Saturday [2] morning again [3], because they want later all pro-soccer-player(s) to- become.*

The main goals of this experiment are: first of all, to assess the validity of the Underspecification Model (and other theories on processing of verb meaning) for the present findings, secondly, to further investigate the lack of effect at the position directly after the verb in Experiment 2, and finally to corroborate the findings of Experiment 3: since an adjunct (*every Saturday-morning again*) follows the final argument of the verb (the Direct Object *the fanatical soccer-coach*), the present experiment allowed for a further investigation of whether it is saturation of the argument structure of the verb that is the basis for discontinued activation of the verb, or whether the verb always remains active until the end of the clause (probe position [3] in the example).

2.2. Methods

2.2.1 Participants

Fifty-two students from the University of Groningen took part in the experiment. Seven participants had to be excluded for various reasons (one person did not meet the preset criteria, three participants were excluded for reasons related to the test procedure, and three persons were excluded because their RT means or SD exceeded the overall mean and SD reaction times by more than 2.5 SD). No participants failed the comprehension question criterion of 67% correct.

The remaining 45 participants (6 male, 39 female) were all right-handed native Dutch speakers with a mean age of 20.4 (range 17-27), 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 52 participants

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3 This experiment was run in collaboration with Femke Wester.
were randomly assigned to three groups (counterbalancing probe positions), resulting in 12, 17 and 16 participants per group respectively for the remaining 45 participants.

2.2.2 Materials

This experiment employed the same 42 verbs, related probe and control probes as in Experiment 1. Two verbs were changed to create a more coherent set of verbs with regard to transitivity (see Chapter 3, section 4.2.2; these two verbs were dropped in Experiment 2 where only 40 items were used for counterbalancing reasons); one verb and its probes were changed (zenden = to send, an optionally ditransitive, was replaced by bevriezen = to freeze) and another verb (studeren = to study) was changed into bestuderen, which has approximately the same meaning, but can only be used transitive. The experimental sentences consisted of a matrix clause followed by an embedded or coordinated clause as in Experiments 1 and 2, but after the Object NP an Adjunctive Phrase was inserted. The adjuncts that were used were Adverbial Phrases (AP) of Time. The Object NP was 7 to 9 syllables long, and the AP 8 to 10 syllables.

Probe position [1] was presented slightly later than in Experiments 1 and 2: at the onset of the first word following the verb, and if this point could not be measured adequately, 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 [2] was placed 700 ms after the onset of the adjunct and probe position [3] was placed at the end of the clause, directly at the offset of the final word of the adjunct.

2.2.3 Design and procedure

The design and procedures were the same as in Experiments 1 and 2.

2.3. Results

Descriptive and inferential statistics were performed on the resulting data exactly as in the previous experiments. Three participants were excluded from analysis (see above) and exclusion of errors and outliers resulted in 3.0% data loss. Table 1 presents means (from subject-analyses) for this study. It can be seen from these data that priming (faster responses to related probes than control probes) occurs at each probe position, an observation sustained by a main effect of probe type ($F_1 (1,44) = 24.35, p < .001; F_2 (1,41) = 6.38, p = .016$). A priori planned comparisons demonstrate that this priming is significant at each of the probe positions examined: probe position [1]: $t_1 (44) = 3.08, p = .002; t_2 (41)$
= 1.75, p = .044; probe position [2]: t\(_1\) (44) = 2.35, p = .012; t\(_2\) (41) = 2.39, p = .011; and probe position [3]: t\(_1\) (44) = 2.59, p = .007; t\(_2\) (41) = 1.77, p = .042.

Table 1. Mean (and SD) reaction times (in ms) to related and control probes for each probe position in Experiment 4.

<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>721 (86)</td>
<td>723 (95)</td>
<td>712 (89)</td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>697 (89)</td>
<td>706 (96)</td>
<td>693 (88)</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>24 **</td>
<td>17 *</td>
<td>19 **</td>
<td></td>
</tr>
</tbody>
</table>

* p<.05 (paired samples t-test, subject-analyses, 1-tailed)
** p<.01 (paired samples t-test, subject-analyses, 1-tailed)

The little boys imitate [1] the fanatical soccer-coach every Saturday [2] morning again [3], because they want all pro-soccer-player(s) to become.

2.4. Discussion

The present experiment shows that the meaning of a verb in Dutch declarative matrix clauses remains active throughout the entire clause, even after the final argument and a subsequent adjunctive phrase have been encountered. This finding confirms the conclusion of Experiment 3, which demonstrated that argument structure cannot explain the extended period of priming found for matrix verbs. Furthermore, it is in line with an interpretation of the Underspecification Model in which not only arguments, but all upcoming sentential information is relevant for specifying or zooming in on the exact meaning of a verb.

The priming effect at probe position [1], which was placed directly after the verb (though slightly later than in Experiments 1 and 2), is clearly present and significant in this experiment. This confirms the hypothesis offered in the discussion of Experiment 2 concerning the lack of an effect at probe position [1] in that study being caused by placement of the probes in too early a position.

It seems worthwhile to try and explain the instability of the direct priming effect over four experiments with the Underspecification Model. According to this model, directly upon encountering a verb, its exact meaning is not clear yet. Rather, a core meaning, or underspecified meaning is composed at first. Whether this meaning should be defined enough to cause a direct priming effect at the offset of the verb cannot be gathered from the model. This could depend on the relevance of the Subject NP, the only sentence part that has been encountered before the parser comes across the verb.
To test this possibility, a post-hoc paper-and-pencil test was run which measured whether the combinations of Subject NPs and verbs used felt “logical”, or how much effort it took to come up with a plausible event representation or a sensible continuation of the sentence. This was a rather intuitive measure which was scored by five linguists on a scale from 1-7. The higher the score, the more sensible the combination of Subject NP and verb. The underlying assumption is that for items with a high score, the meaning of the verb is more specified (the event being described made more sense to the participants) than for items with a low score. The mean score for all items in this experiment was 5.07 (range of mean scores per item: 2.8 to 7.0). To find out whether the items which scored highest were also the items with the largest priming effects, the mean scores per item were correlated with the ‘priming’ effect (difference in RTs between the control and related probe in the CMLP task). This correlation was small, but marginally significant (Pearson r = .24, p = .07; 1-tailed). Taking into account the roughness of the test, this suggests that the hypothesis offered should not be discarded immediately.

The two explanations for the lack of priming in Experiment 2 may be very well two sides of the same coin. Indeed, when looking for priming effects too soon after the presentation of a verb in a sentence context, no effects are to be expected. However, a tiny delay can be enough to find stable priming, especially if the preceding constituent (the Subject NP) adds information to the meaning of the verb.

3. EXPERIMENT 5: DUTCH NOUNS

3.1. Introduction

Although the results of the previous four experiments demonstrated that the pattern of verb priming does not mimic the pattern found repeatedly for nouns in non-canonical positions, another check is necessary to be sure that the results are unique for verbs. To be sure that any effect found in the experiments on verb priming is a verb-specific effect and not an effect inherent to the language or the type of sentences used, a CMLP experiment was run that focused on priming of Subject head Nouns. In this study, the sentence structures used were similar to those in the verb experiments.

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4 This experiment was designed and run by Marlous Westra as part of her Bachelor’s thesis.
3.2. Methods

3.2.1 Participants

Thirty-three right-handed undergraduate students (5 men, 38 women; mean age 22.15 years) were paid for taking part in the experiment. All participants were native speakers of Dutch. Two participants were later excluded for making too many errors in the Lexical Decision Task.

3.2.2 Materials

Thirty experimental sentences with the following sentence structure were created: Subject NP – verb – two prepositional phrases (PPs) – secondary clause. The Subject NP always consisted of 7 to 8 syllables and comprised a definite article, an adjective and a singular Agent. To exclude the possibility of inadvertent priming effects caused by other arguments, the verbs were all verbs that do not take a Direct Object. Although the existence of such effects has not been demonstrated to our knowledge, the studies on identifying errors in argument structure (e.g., Friederici & Frisch, 2000, see Chapter 4) suggest that at each new argument, a check against the argument structure defined by the verb might occur. The two PPs together were 12-14 syllables in length, thus allowing ample time between the verb and the second probe position and between the second probe position and the end of the matrix clause to avoid end-of-sentence effects which might obscure gap-filling effects (Balogh et al., 1998). For the same reason, an embedded clause was added to the matrix clause. This secondary clause was not subject to any restrictions.


The happy baker [1] cycles with his head [2] up through the streets, because his rolls well sell.

BROOD (BREAD) – DROOM (DREAM)

Primbing of the noun was checked at two positions in the matrix clause: directly after the noun itself, at the onset of the word following the Subject Head Noun (probe position [1]), and at 1000 ms after the verb (probe position [2]). This second position was placed relatively late, because the main question to be answered was whether the Subject is deactivated somewhere during the matrix clause, and not so much how soon this was the case.

For each sentence, a target probe word related to the Subject was selected, partly based on intuition and partly based on an off-line Association Test (Pretest 1), where 40 participants had to come up with one or two responses (words) for each word in a list of 135 nouns. All nouns that were plausible Agents and had an association quotient of .40 or higher were selected (n = 25) and combined with 38 new prime-related probe pairs (based
on intuition of the researchers) and 35 filler pairs. These words were presented in an off-
line word-word Relatedness Test (Pretest 2). Eleven participants rated all pairs of potential
primes and related probes (and the filler pairs) for relatedness on a scale of 1-10. Of the
intuitively formed pairs, only those were selected that had a relatedness score of 8 or higher
(n = 12). For the 28 pairs that were finally used in the experiment the mean relatedness
scores was 8.43 (SD = .41) for the 16 pairs that were selected from the association test, and
8.50 (SD = .24) for the 12 ‘new’ pairs. The difference was not significant (t (26) = .55, p > .5,
2-tailed).

The related probes were then matched to unrelated control probes based on baseline
lexical decision time (as measured in Pretest 3, an Unprimed List LDT, performed by 24
right-handed participants), length and frequency (CELEX; Burnage, 1990). For numerical
details see Table 2.

Table 2. Characteristics of related and unrelated control probes in Experiment 5

<table>
<thead>
<tr>
<th></th>
<th>Related probes (n=30)</th>
<th>Control probes (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>SD</td>
<td>range</td>
</tr>
<tr>
<td>Baseline RT (in ms)</td>
<td>526.3</td>
<td>26.4</td>
</tr>
<tr>
<td>Frequency (logarithmic)</td>
<td>1.87</td>
<td>0.53</td>
</tr>
<tr>
<td>Number of letters</td>
<td>5.3</td>
<td>1.9</td>
</tr>
<tr>
<td>Number of syllables</td>
<td>1.6</td>
<td>0.8</td>
</tr>
</tbody>
</table>

The logic of the CMLP task hinges on the assumption that the related probes are
related only to the prime word in the sentence, the Subject Head Noun in this case, and that
the control probes are not related to any word in the sentence (Tabossi, 1996). This
assumption was tested in an off-line Relatedness Test (Pretest 4). In this test the sentences
were split up into three fragments: the Subject NP, the verb plus first PP, and the second
PP. In three lists, these fragments were presented in combination with the related and
control probe and eight filler items. The lists were counterbalanced in such a way that each
fragment type occurred equally often in each list and no fragments from the same sentence
were used in the same list. For each list ten undergraduate students rated the relatedness
between the fragment and each probe word on a scale from 1 to 7. Based on the results,
relevant sentence fragments were adapted if the mean score for the related probe was
higher than 4, except for the cases where it concerned the Subject NP (17 adaptations). If
the score for the control probe was higher than 4 on one of the fragments, the control
probe was replaced (three times). Two sentences were excluded because no adequate
control probe could be selected from the words tested in the baseline LDT (Pretest 3).
Paired t-tests for the remaining items showed a significant difference between related
probes and control probes for the Subject NP fragment (t (25) = 37.9, p < .001), which is as expected, since this fragment includes the prime noun. For the other two fragments there was no significant difference between related and control probes (verb + adjunct fragment: t (19) = -.23, p > .8; PP fragment: t (16) = 1.4, p > .15).

In a Goodness-of-fit Test (Pretest 5) 14 undergraduate students rated the fit of both the related and the control probes in combination with the sentence parts up to and including each probe position. Only the 28 sentences that remained after the Relatedness Test were taken into the analysis. For both sentence fragments the scores were low (see Table 3) and differences between related and control probe were not significant in a paired samples t-test (up to probe position [1]: t (27) = -1.6, p > .1; up to probe position [2]: t (27) = 1.06, p > .2).

Table 3. Off-line Goodness-of-fit Test scores for related and unrelated control probes in Experiment 5 (scale 0-7).

<table>
<thead>
<tr>
<th>Probe Position</th>
<th>Related probes</th>
<th>Control probes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>[1]</td>
<td>1.57</td>
<td>0.51</td>
</tr>
<tr>
<td>[2]</td>
<td>1.38</td>
<td>0.99</td>
</tr>
</tbody>
</table>

In addition to the 28 experimental sentences, 28 filler sentences with a similar structure were created and combined with 28 non-word probes. In this way, an equal number of ‘word’ versus ‘non-word’ lexical decisions appeared for sentences with this particular structure. Finally, 28 filler sentences with different structures were created, half of which were combined with words and half with non-words.

Fourteen spoken comprehension questions were randomly interspersed throughout the whole experiment to make sure that participants paid attention to the sentences. The yes/no questions focused on factual aspects of different parts of the sentences.

3.2.3 Design and procedure

The design and procedures were the same as in previous Experiments, with the only difference that different probes were used for the filler sentences in the two sessions of the experiment.

3.3 Results

Descriptive and inferential statistics were performed on the resulting data precisely as in the earlier Experiments. Error rates were low (1.5%) and the exclusion of 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 4.0% data loss.

The repeated measurements ANOVA showed an overall effect of probe type in the subject-analysis ($F_1(1,30) = 7.01, p = .013$), but not in the item-analysis ($F_2(1,27) = 2.11, p = .16$). The interaction effect was not significant ($F_1(1,30) = .92, p > .3; F_2(1,27) = .70, p > .4$). Nevertheless, the numerical difference in RTs between control and related probes is much more pronounced at the first probe position (see Table 4) and paired-samples t-tests confirmed this: a significant priming effect was found at the first probe position, but not at test position [2] (probe position [1]: $t_1(30) = 2.23, p = .017; t_2(27) = 1.62, p = .058$; probe position [2]: $t_1(30) = 1.52, p = .07; t_2(27) = .69, p > .2$).

Table 4. Mean (and SD) reaction times (in ms) to related and control probes for each probe position in Experiment 5 (subject-analysis).

<table>
<thead>
<tr>
<th>Probe Type</th>
<th>Probe Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[1]</td>
</tr>
<tr>
<td>Control</td>
<td>640 (130)</td>
</tr>
<tr>
<td>Related</td>
<td>620 (105)</td>
</tr>
<tr>
<td>Difference</td>
<td>20 *</td>
</tr>
</tbody>
</table>

* p<.05 (paired samples t-test, subject-analyses, 1-tailed)


The happy baker [1] cycles with his head [2] up through the streets, because his rolls well sell.

3.4. **Discussion**

The data show immediate priming of Subject Head Nouns after their occurrence, but no priming one second after the verb. Although the discontinuation of priming is not corroborated by a significant interaction in the ANOVA, the pattern is different from the continued priming pattern found in the same time frame for matrix verbs in the previous Experiments. The pattern of deactivation of nouns after their occurrence is in line with English and German studies on nouns (see Chapter 3). These results provide enough information to build on during the interpretation of our core data: the pattern of verb priming.
4. **GENERAL DISCUSSION**

4.1. **Summary of the results**

The results of Experiments 1 and 2 (Chapter 3) revealed inconsistent priming of the matrix verb immediately after its occurrence, with a stable priming effect continuing throughout the matrix clause. Such activation disappeared immediately when a conjunction was encountered. Experiments 3 (Chapter 4) and 4 (this chapter) revealed that this pattern was not related to argument structure, rather, the verb remained activated during a clause-final adjunct as well. The results of Experiment 5 indicated that the pattern discussed here is unique for verbs.

4.2. **Direct priming**

In the literature, the Underspecification Hypothesis (Frisson & Pickering, 1999, 2001; Pickering & Frisson, 2001) has been put forward in relation to the semantic features of verbs. The suggestion is that the meaning of a verb, when first encountered, is not immediately fully specified, because its precise meaning is context dependent. In line with this, our data showed unstable priming effects directly at the offset of the verb, which seemed to be related to timing issues: the later the probe is presented, the bigger the chance that priming is found. If this is reformulated in underspecification terms, it can be stated that because the meaning of the verb is underspecified at first, the immediate priming effect is not very solid. It is an open question how far the meaning of the verb needs to be specified to produce priming effects. The present data suggest that the threshold is reached relatively fast: only a very minimal change in presentation timing of the probe resulted in significant priming effects in Experiment 3 and 4.

4.3. **Continued activation: Arguments versus adjuncts**

More important for the present data is the trajectory to full specification of verb meaning. According to the underspecification hypothesis, evidence from the remainder of the sentence is used to zoom in to a more specific interpretation of the verb. The current assumption is that the maintained priming of the verb in the experiments is a reflection of this specification process. This means that specification continues throughout the entire clause of which the verb forms the core and that, in this respect, there is no difference in the way arguments and adjuncts are processed.

This viewpoint is incompatible with some models of sentence processing, particularly because many accounts claim a privileged role for verbs and their arguments (e.g., Frazier & Clifton, 1996; MacDonald, Pearlmutter, & Seidenberg, 1994). Even a recent semantic
theory which *does* take into account the adjustability of verb meanings, assigns a main role
to arguments and ignores adjuncts (Kintsch, 2001): Latent Semantic Analysis (LSA) is a
computational model which does not distinguish different meanings or senses of a word.
Rather, the core meaning of a word is defined and context is used to modify it to deduce
the correct sense. For verbs, an algorithm strengthens the features that are appropriate for
the argument with which it is combined in a particular sentence. Thus, the meaning of a
predicate is adjusted as it is applied to different arguments. So, according to this model, the
exact meaning of a verb depends on the argument it operates on.

**Figure 1.** Fragment of a network according to LSA. Solid lines indicate positive
connections, dashed lines indicate inhibitory connections.

![Diagram of a network](image)

In LSA the meaning of a word is represented by a vector in a high-dimensional
semantic space. Word vectors can be combined to represent the meaning of simple
sentences using a context-sensitive algorithm. This algorithm is called Predication and is
derived from the construction-integration model of text comprehension (Kintsch, 1988). In
a self-inhibiting integration network, the predicate and the argument(s) are presented in
combination with words from their semantic neighborhood. The items most strongly
related to the predicate and the argument acquire positive action values, whereas irrelevant
relations will be inhibited. Subsequently, the most strongly activated items in the network
will be used to construct a vector for the predicate-argument sentence. Figure 1 (after
Kintsch, 2001, p. 180) shows an example for the predicate *run* in combination with the
noun *horse*.

Nevertheless, it is clear that information about *where*, *when*, and *why* something
happened, information often carried by adjuncts, is essential to interpret the event

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5 Or arguments; the model is not only concerned with simple verb-argument sentences, but can also apply to
subject-verb-object. Kintsch (2001) analyzes these sentences or propositions as NP (N1) + VP (V + N2) and
assumes that two separate predicate operations are involved: V is predicated about N2 first, as was the case in
simple verb-argument structures, and after that, the resulting VP is predicated about N1.
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. Frisson and Pickering (2001) indeed choose an interpretation of the Underspecification Hypothesis in which they do not refer to any sentential elements in particular, but state that further specification can take place as long as it is necessary.

4.4. The end point of verb activation

In Experiments 1 and 2, no priming was found immediately after the conjunction. The conjunction is a clear signal for the start of a new clause. Therefore, the end of the priming effect is probably related to the clause boundary. All information presented in a clause can be linked to the main verb of that clause, but when a new clause starts, a new verb appears and takes over this role. Therefore, it can be assumed 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), and that this process stops when a clause boundary signals that a new event is being described.

In a verb-final language like Dutch, the relation between the matrix verb and its clause is even more clear: particles (compare (20) and (21)) and negations often appear at the end of the clause, yet they can change the meaning of the verb considerably, supporting the claim that it is worthwhile for the parser to delay a final interpretation until the end of the clause.

(20) De man geeft zijn dochter aan.
   The man gives his daughter on.
   (The man reports his daughter.)

(21) De man geeft zijn dochter weg.
   The man gives his daughter away.

The influence of the matrix verb during the embedded clause, and the influence of the clause boundary on the activation pattern of the matrix verb will be discussed in the next chapter.