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Authors

Goede, Diewwke de
Wester, Femke
Ouden, Dirk-Bart den
et al.

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The Time Course of Verb Processing in Dutch Sentences

Dieuwke de Goede (d.de.goede@let.rug.nl)

Femke Wester (f.wester@let.rug.nl)

Dirk-Bart den Ouden(d.b.den.ouden@let.rug.nl)

Roelien Bastiaanse (y.r.m.bastiaanse@let.rug.nl)

University of Groningen

Graduate School of Behavioral and Cognitive Neurosciences

Department of Linguistics, PO Box 716

9700 AS Groningen, The Netherlands

Lewis P. Shapiro (shapiro@mail.sdsu.edu)

San Diego State University

Department of Communicative Disorders, 5500 Campanile Drive

San Diego, CA 92182-1518

David A. Swinney (dswinney@psy.ucsd.edu)

University of California, San Diego

Department of Psychology, 9500 Gilman Drive

La Jolla, CA 92093-0109

Abstract

In Dutch matrix clauses the verb is not in its base position, but has been moved from the end of the clause to second position. Three Cross-Modal Priming experiments showed that the on-line activation pattern for moved verbs in Dutch differs significantly from the pattern for moved nouns in English. Whereas in *wh*-movement reactivation of moved nouns is found at their base position, the current results suggest that moved verbs are maintained active during the entire clause. The results are discussed in light of a gap-filling account, and three proposals are given to explain the long-lasting activation of the verb.

Introduction

Cross-Modal Priming (CMP) studies (e.g. Love & Swinney, 1996; Swinney, Ford, Bresnan, & Frauenfelder, 1988) have shown that in complex sentences where the object is not in its base position the meaning of this moved constituent is reactivated at its original position, directly after the verb. Swinney et al. (1988) tested reactivation of moved *wh*-phrases in sentences such as:

- (1) The cop saw the boy_i who_i the crowd at the party accused *t*_i of the crime.¹

Since *boy* is the direct object of *accused* in base structure², and English is an SVO language, the base position of *boy* is to the right of the verb *accused*. Therefore, it is assumed that

¹ Following the traditions in processing research, the *t* refers to the gap position (*trace*) and co-indexation indicates the relationship between filler and gap.

² Strictly speaking, 'who' is the direct object of 'accused' and not 'boy', but it is assumed that 'who', because of its coreference with 'boy', has inherited the semantic characteristics of 'boy'.

a trace (or gap) is postulated after *accused*. Using the CMP task³ priming effects were found for probes related to the antecedent *boy* when presented at the gap position (directly after the verb). Importantly, no priming was found at a control position before the verb. In other words, it appears that listeners *reactivate* the meaning of the moved constituent when they encounter the gap. This finding has been replicated many times (for an overview see Featherston, 2001; Love & Swinney, 1996).

Several explanations have been given for this phenomenon. Swinney and colleagues (1988) provide a structural account: the meaning of the moved object is recovered in its base position to regain the canonical sentence structure. This would suggest a close correspondence between linguistic theory (or at least the generative approach) and psychological reality (the functioning of the human parser). Others (e.g. Pickering & Barry, 1991) came up with a verb-centered, semantic, account: the meaning of the moved object is reactivated because after processing the verb a dependency relation is established between the verb and its dependents, that is, its arguments (see also Nicol, 1993).

The current paper is an attempt to broaden this research area by extending the topic of research to the activation

³ The CMP task is a dual task in which participants listen to sentences and make a lexical decision to a visual probe presented at a particular point during each sentence. Faster reaction times to a probe that is associatively related to a particular word in the sentence as compared to reaction times to a probe that is unrelated (but otherwise comparable to the related probe) is attributed to priming effects. If priming is found at a certain point during the sentence, this is taken as evidence that the meaning of the relevant word in the sentence is activated.

pattern of verbs. It is unknown whether *verbs* that are not in their base position are reactivated at this position. If moved verbs show reactivation at their base position, then a strong case can be made for the possibility that listeners attempt to recover base word order whenever they encounter a structure that is non-canonical. However, some characteristics of verbs suggest that moved verbs might behave differently from moved noun constituents.

Linguistic Background

Whereas in *wh-* and NP-movement whole sentence constituents (XPs) are moved, in verb movement it is only the verb itself (the head, X^0) that moves. Linguists (e.g. Chomsky, 1995) stress that movement of syntactic heads is radically different from movement of syntactic phrases, having for example no effect on interpretation.

In English, the language in which most studies on gap-filling have been performed, verb movement only occurs in negative inversion structures and in questions, where the auxiliary moves. In Dutch, however, verb movement is an omnipresent phenomenon. Dutch is generally agreed to be an SOV language (Koster, 1975, but see Zwart, 1997), but in a matrix clause the finite verb moves from its basic, clause-final, position to the second position in the clause (Verb Second or V2).

Psycholinguistic Background

Verbs play a central and binding role in the sentence: they not only determine the event of the sentence, but they are also linked to all other main constituents of the sentence (the arguments) and assign thematic roles to these constituents. Psycholinguistic studies suggest that these differences between nouns and verbs may matter in sentence processing: influences of argument structure have been found at different levels of sentence processing (for interference effects see Shapiro, Zurif, & Grimshaw, 1987; for syntactic priming effects, see Trueswell & Kim, 1998).

It is unknown what role the characteristics of verbs play in on-line processing of moved verbs, although two unpublished studies suggest that the patterns for verb movement might differ from those found in *wh*-movement. Muckel, Urban and Heartl (p.c.) examined split particle verbs in German SVO sentences in which the matrix verb had been moved to V2 and the particle remained in the base position of the verb (German is an SOV language). Responses to identical probes were faster than responses to control probes at the control probe point (which was placed in front of the word preceding the particle, so two words before the gap) as well as at the experimental probe point. No interaction between probe point and probe type was found, so no evidence was found for *reactivation*.

Basilico, Piñar and Antón-Méndez (1995) ran a CMP-study that focused on moved verbs in Spanish. They used declarative sentences with two different word orders (VSO and VOS) and concluded that in the sentences where the verb was moved (VSO) the verb was activated at the gap. Conclusions about *reactivation* cannot be drawn, however,

because no pre-gap control probe-point was included in the design.

Experiment 1 & 2

In two consecutive CMP experiments, the question was addressed whether or not verb movement has processing consequences similar to *wh*-movement. The experimental sentences in these experiments are Dutch matrix clauses in which the verb has been moved from its base clause-final position to V2 position, leaving behind a gap. If verb movement and *wh*-movement are processed similarly, we expect to find activation of the verb directly after the verb (direct priming), deactivation of the verb in between the overt verb position and the gap, and finally reactivation at the gap (gap-filling).

Method

Participants 44 Participants were tested in experiment 1 and 60 in experiment 2.

Materials Sentences consisting of a matrix clause (SVO) followed by an embedded clause were auditorily presented. In both experiments the matrix clause ended after the direct object. In experiment 1 the direct object occurred directly after the verb (see example sentence 2), in experiment 2 an adjunct preceded the direct object (see example sentence 3).

- (2) De kleine jongens imiteren_i [1] hun fanatieke [2] rood-aangelopen voetbaltrainer t_i , omdat [3] ze later allemaal profvoetballer willen worden.
The little boys imitate_i [1] their fanatical [2] red-faced soccer coach t_i , because [3] they all want to be professional soccer players when they grow up
- (3) De trouwe volgelingen wijzigen_i [1] eens in de zoveel tijd hun altijd [2] controversiële mening t_i [3], want [4] hun leider is een wispelturig man.
The faithful followers change_i [1] once in a while their always [2] controversial opinion t_i [3], because [4] their leader is a rather fickle man.

The probes that were presented during the experimental sentences were verbs that were either associatively related to the finite verb or unrelated but matched to the related probe for baseline lexical decision time, frequency, length and argument structure. Both probe types were pre-tested off-line for any possible inadvertent source of priming. The same prime - unrelated probe - related probe triads were used in both experiments.⁴

Probes were presented at four different positions (see example sentences 2 and 3):

1. *verb* probe point: indicated as [1], placed directly after the verb

⁴ Two triads were excluded in experiment 2 for counterbalancing reasons (we used 4 probe points instead of 3, so the number of experimental sentences had to be dividable by 4).

2. *control* probe point: indicated as [2], presented at 700 ms after [1] in experiment 1 and at 1500 ms after [1] in experiment 2
3. *end-of-clause* probe point: measured in experiment 2 only and indicated as [3], presented at the end of the clause (offset object head noun)
4. *conjunction* probe point: indicated as [3] in experiment 1 and as [4] in experiment 2, presented at the offset of the conjunction.

In experiment 1 42 experimental sentences were used, in experiment 2 there were 40 experimental sentences. In each experiment, an equal number of pseudo-experimental sentences (sentences with the same structure as the experimental sentences) were added and combined with non-words, to prevent any correlation between sentence type and response type. In addition, 20 filler sentences of different structures (10 words, 10 non-words) and 15 yes/no comprehension questions were added (to encourage participants to pay attention to the spoken sentences).

Probe point and probe type were both within-participants factors. All sentences were ordered pseudo-randomly. A completely counterbalanced design was created to assure that all participants saw both related and control probes, and saw probes at all three probe points. Each participant was tested twice, on the same list, but with related and control probes shifted.

Procedures The participants were tested individually in a sound-proof room with no visual distractors. The sentences were presented over headphones with an interval of 1500 ms. The probes were presented on a standard computer screen. The experimental software Tempo (designed at the University of California, San Diego, for running CMP-studies), combined with a response box with two buttons, was used to present the items and register the accuracy and RTs of the responses. Each probe was presented for 300 ms and a response could be given within a 2000 ms interval from stimulus onset. Importantly, the sentences continued without interruption during visual presentation of the probe.

Participants were instructed to listen carefully to the sentences and to expect comprehension questions about some sentences, but only about the sentence immediately prior to the question. Questions were answered and lexical decisions were made by pressing the left button on the button box for *no* and *non-word* and the right button for *yes* and *word*. Participants were instructed to answer as quickly and accurately as possible.

Results

Participants were excluded from further analysis 1) if their error score on the lexical decision task was greater than 10%, 2) if their mean or SD RT deviated from the overall mean or SD by more than 2.5 SD, or 3) if less than 67% of the comprehension questions were answered correctly. Data from three participants were excluded in both experiments.

Error rates were low (1.4% and 1.8%, respectively) and equally distributed across related and control probes and

across probe points. The exclusion of errors and outliers (all values deviating from the participants and item mean for the particular data point with more than 2.5 SD were excluded) resulted in 2.7 and 3.1 percent data loss, respectively.

The mean RTs for all probe points and probe types are presented in Table 1 (the values that are presented here and in the following tables are derived from the subject-analyses; the item-analysis revealed very similar data).

The subject-based ANOVAs revealed a significant main effect of probe type in both experiments; overall, the related probes generated shorter RTs than the control probes (exp 1: $F(1,40) = 7.91, p = .008$; exp 2: $F(1,56) = 4.61, p = .036$). The item-based ANOVA was marginally significant in experiment 1 ($F(2,141) = 3.43, p = .07$), but did not reach significance in experiment 2 ($F(2,139) = .98, p > .3$).

Paired t-tests showed significant⁵ faster responses to related than to control probes (priming) at the *verb* probe point in experiment 1 ($t(40) = 2.53, p = .008$; $t(41) = 1.75, p = .044$), but not in experiment 2 ($t(56) = .15, p > .4$; $t(39) = .29, p > .3$). At the *control* probe point priming was found in both experiments (this effect was significant in the subject analysis (exp 1: $t(40) = 2.64, p = .006$; exp 2: $t(56) = 2.49, p = .008$), but in the item-analysis only a trend was found (exp 1: $t(41) = 1.40, p = .085$; exp 2: $t(39) = 1.37, p = .09$). Furthermore, priming was found at the *end-of-clause* probe point in experiment 2 ($t(56) = 2.08, p = .021$; $t(39) = 1.76, p = .043$). Neither of the experiments, however, showed a priming effect at the *conjunction* probe point (exp 1: $t(40) = .81, p > .2$; $t(41) = .82, p > .2$; exp 2: $t(56) = -.98, p > .15$; $t(39) = -.95, p > .15$).

Table 1: Mean RTs (and SDs) to probe type as a function of probe position in experiment 1 and 2.

probe type	verb	control	end-of-clause	conjunction
<i>Experiment 1</i>				
control	633 (68)	635 (61)	-	626 (72)
related	617 (65)	621 (66)	-	620 (73)
<i>difference</i>	16 (41)	14 (33)	-	6 (47)
<i>Experiment 2</i>				
control	663 (94)	671 (99)	668 (95)	666 (88)
related	662 (91)	657 (84)	654 (101)	672 (103)
<i>difference</i>	1 (49)	15 (45)	14 (51)	-6 (42)

Conclusion and Discussion

These experiments did not provide evidence for reactivation of the verb at its base position. Both experiments converge on a pattern of activation of the verb at the *control* probe points (700 and 1500 ms after the actual occurrence of the verb in the sentence) and deactivation of the verb immediately following the conjunction linking the matrix to the second clause. The second experiment further shows that the verb is active at the *end of the clause*. The results for the

⁵ As no inhibition effects were expected all t-tests are 1-tailed.

verb probe point, where priming of the verb was expected directly after its occurrence, are less clear. Although significant facilitation of the related probe compared to the control probe was found in experiment 1, experiment 2 surprisingly showed a null-effect at this probe position.⁶

An important question that remains to be answered after these experiments is: Why do verbs remain active for such an extended period of time? One possible reason is that verbs stay active to 'find' their arguments in order to theta-mark them (Argument Structure Hypothesis).⁷ According to this hypothesis continued activation is predicted up to the final argument. As all verbs that were used in the current experiments were two-place verbs, the final argument was always the direct object, which occurred at the end of the matrix clause in both experiments.

Experiment 3

To test the Argument Structure Hypothesis, an experiment was run that employed an adjunct immediately after the second argument. This allowed investigation of whether saturation of the argument structure of the verb is the basis for discontinued activation of the verb, or whether the verb always remains active up till the end of the clause.

Method

Materials The same primes, related probe and control probes were used in experiment 3, but the sentences were slightly altered. The experimental sentences still consisted of a matrix clause followed by an embedded clause, but after the Object Noun Phrase an adjunct was inserted (4). The adjuncts that were used were Adverbial Phrases of Time.

- (4) De domme gedetineerden beroven [1] vijftien rijke bejaarden tijdens hun [2] eerste proefverlof [3], dus vrijlating zit er voorlopig niet in.
The stupid detainees rob [1] fifteen rich seniors during their [2] first parole [3], so release seems to be out of the question for now.

The *verb* probe point (see [1]) was presented slightly later than in experiment 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. The *control* probe point [2] was now at 700 ms after the onset of the adjunct. The final probe point was at the *end of the clause*, directly at the offset of the final word of the adjunct [3].

⁶ Phonological assimilation made it impossible to place all probe points exactly at the onset of the next word. Post hoc analyses showed that probes that were placed too early had a low probability to show faster RTs to related probes than to control probes, whereas the majority of probes that were presented exactly at the onset of the word following the verb showed facilitation for the related probe ($\chi^2(1) = 17.4, p < .001$). Part of the third experiment focuses on this observation.

⁷ More accounts will be discussed in the General Discussion.

Participants and Procedures 48 Participants were tested following the same procedure as in experiment 1 and 2.

Results

The data were handled in the same way as in experiment 1 and 2. Three participants were excluded from further analysis and exclusion of errors and outliers resulted in 3.0 percent data loss.

The RTs for this experiment are presented in table 2 and show faster responses to related probes than control probes at all probe points ($F_1(1,44) = 24.35, p < .001$; $F_2(1,41) = 6.38, p = .016$). So, first of all, directly after the *verb*, a significant priming effect is obtained again, which indicates that a small adaptation in probe placement (consistently at the onset of the first word following the verb or slightly later) resulted in stable priming effects at this probe point ($t_1(44) = 3.08, p = .002$; $t_2(41) = 1.75, p = .044$). But more interestingly, activation of the verb was still evident after all arguments were processed, 700 ms into the adjunct ($t_1(44) = 2.35, p = .012$; $t_2(41) = 2.39, p = .011$), as well as at the end of the clause ($t_1(44) = 2.59, p = .007$; $t_2(41) = 1.77, p = .042$).

Table 2: Mean RTs (and SDs) to probe type as a function of probe position in experiment 3.

probe type	verb	control	end-of- clause	conjunction
control	721 (86)	723 (95)	712 (89)	-
related	697 (89)	706 (96)	693 (88)	-
<i>difference</i>	24 (53)	17 (48)	19 (48)	-

Conclusion

The current experiment shows that verbs in Dutch declarative matrix clauses are maintained active throughout their entire clause, even after all arguments have been encountered.

General Discussion

The aim of the first two experiments was to evaluate whether moved verbs (in Dutch) behave similarly to moved nouns, which show reactivation of the moved constituent at the location of the gap. The results show that, at least in Dutch, processing of moved verbs is different from that of moved noun constituents in English. No evidence was provided for reactivation of the verb at its base (clause-final) position. Instead, the experiments demonstrated that the verb remains active from the point where it is first encountered up to the offset of the object head noun, clause-finally. So even though activation of the verb at the site of the gap was found in the second experiment, the verb was also active at the control probe points, unlike in the gap-filling studies in English (Love & Swinney, 1996).

The question whether verb movement is reflected in psychological reality cannot be answered on the basis of these data. Although we did not find evidence for reactivation, a syntactically based *Gap-Filling Account* can

still hold for the data; the verb was indeed active at the gap. It is possible that, instead of being reactivated, verbs are maintained active until the gap (and because of the gap).

The studies by Basilico et al. (1995) and Muckel et al. (p.c.) show that the present results do not stand alone. The results from both studies can be interpreted in different ways, but their findings might well be in line with ours. Muckel et al. found activation of a split particle verb at a control probe point and at the particle. Since they did not test for priming directly after the verb and do not present baseline reaction times for the two probe types the results are suggestive of either continued activation of the verb or no activation at all⁸. Basilico et al. found activation of the verb at the site of the assumed gap (VS*O) in Spanish sentences with non-basic word order. However, they did not test directly after the verb, neither did they use a control probe point to check whether the activation of the verb had faded in between. It is possible, therefore, that a moved verb in Spanish also remains active.

As far as the third experiment is concerned, current linguistics theories disagree about the position of adjuncts and therefore it remains unclear whether the base position of the verb should be postulated at the end of the clause (after the adjunct) or after the direct object (in front of the adjunct). If the verb gap is posited in front of the adjunct in sentences like the ones used in experiment 3, the results of this particular experiment show activation of the verb even after the gap and thus provide evidence against the Gap-Filling Account as an explanation for our data.

It is not inconceivable that movement of verbs is not reflected in psychological reality. In *wh*-extraction, all linguistic theories accept some kind of relation between the *wh*-constituent and the verb later in the sentence. In movement of noun constituents, gap-filling is necessary to assign thematic roles to constituents that are detached from their subcategorizer. In contrast, the assumption of verb movement is very theory-internal to generative linguistics (Chomsky, 1995). Also, where verb movement is concerned, gap-filling is not necessary for sentence interpretation but only for structural, syntactic reasons: to fulfill requirements formulated by formal syntactic theory.

The Gap-Filling Account can definitely be rejected if non-moved verbs are also found to remain active in English. A study in English will be performed by Lewis Shapiro and David Swinney. In this study sentences similar to the ones used in the present experiments will be used. In English, the finite verb is in base position, and there is no gap at the end of the clause. If the verb does not remain active in English, the present results are most likely to be due to restoration of the base word order (gap-filling). If, however, the results for the study on English are similar to the results of the experiments discussed in this paper, other accounts will gain in credibility.

⁸ In this case, the priming effects can be explained by the materials: identical probes are generally more 'sensitive to priming' than associatively related primes.

Three possible alternative accounts will be discussed in the final section of this paper.⁹ The first account is the *Argument Structure Account* which was tested in experiment 3. According to this explanation, verbs remain active to be able to assign theta roles to their arguments. This hypothesis was falsified in experiment 3 where activation of the verb was found during an adjunct phrase placed after the final argument.

An alternative syntactic explanation for the present data is the *VP-shell Theory* (Larson, 1988). According to the variant of Van Zonneveld & Bastiaanse (2000), both arguments and adjuncts are in SpecVP positions. This is only possible when the VP is recursive: it takes a VP as a complement. The VP-shell theory thus predicts a sentence structure with as many VPs as there are specifiers (arguments and adjuncts). The VP-shell in itself is a complement of IP. An example of sentences as used in experiment 2 can illustrate this (figure 1).

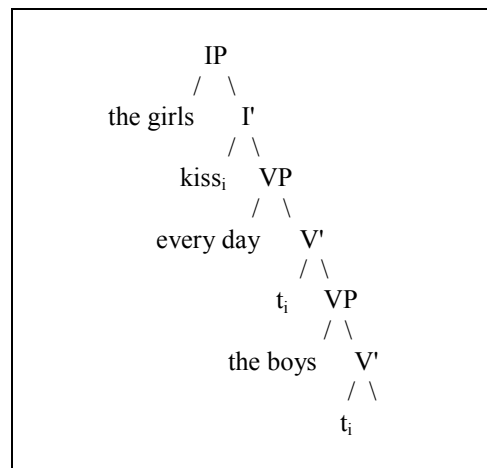


Figure 1: Syntactic representation for Dutch, according to VP-shell theory (simplified version of an experimental sentence from experiment 2).

As this figure shows, there is an empty V⁰ position in the first and second VP. According to Van Zonneveld & Bastiaanse (2000) the verb is not 'moved' to the head of I', but it is 'lexicalized' or 'activated' again in each head position of V'. This means that the verb is active during the entire clause and, unlike nouns, does not need to be reactivated at the gap position.

⁹ These accounts are all based on the assumption that only verbs show long-lasting activation. Although no continued activation for *wh*-constituents was found in CMP experiments within the standard *wh*-movement paradigms, Nicol (1993) could not exclude a pattern of maintained activation of PPs in sentences with ditransitive verbs, where the PP was fronted, and of subjects in S - relative clause - V - O sentences, where priming of the subject was found after the verb. Nevertheless, other explanations could apply to these data as well (or even better), suggesting that detailed studies on the activation pattern of nouns need to be done as well. We are currently preparing a study on the activation pattern of nouns.

The verb thus remains active within its own clause boundary. Only when a new CP or IP is encountered, with a new VP-shell structure as its complement, the activation of the verb is no longer necessary and will therefore disappear. This is exactly what was found in the present experiments. Interestingly, unlike the Gap-filling Account, VP-shell theory predicts similar verb-activation patterns for both English and Dutch matrix clauses, because in both cases the verb c-commands the entire VP-shell.

A third theory (*Semantic Account*) is deduced from studies that show that verbs are more polysemous than nouns (Fellbaum, 1993; Gentner & France, 1988) and are more adjustable and mutable. In a paper-and-pencil task, Gentner & France (1988) found that if the meaning of a verb does not fit with the noun that it co-occurs with, participants are more eager to change the meaning of the verb than the meaning of the noun. Interestingly, these mutability effects are seen in on-line processing as well: an eye-tracking study by Pickering and Frisson (Pickering & Frisson, 2001) showed that lexical ambiguity resolution for verbs is delayed compared to nouns. The suggestion of these authors is that the interpretation of a verb is highly dependent on the arguments with which it combines in a particular sentence. Interestingly, this is also the case for non-ambiguous verbs that have multiple senses. To understand the full meaning of, for example, the verb *open*, one needs to know whether it concerns *opening a door*, or *a file*. According to the “underspecification model” (Frisson & Pickering, 1999) “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). Therefore, also in the case of unambiguous verbs, delaying the interpretation process until the arguments are processed seems to make sense.

Although Pickering and Frisson focus on the role of arguments, it is possible that adjuncts play a role in the interpretation of the verb, too. Actually, one should notice that verb-interpretation and sentence-interpretation are intermingled and can be seen as ongoing processes, which possibly only stop at clause boundaries. This also suggests that the VP-shell Account and the Semantic Account might be difficult to tease apart and should perhaps be interpreted as accounts that explain the same phenomena, but do so at a different linguistic level.

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