Valt het dan nog steeds wel *op*?
Comprehending Dutch particle verbs

Vitória Magalhães Piai
Marcel Bastiaansen[1,3], Rob Schreuder[1,2]
[1]Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands
[2]Donders Institute for Brain, Cognition and Behaviour, Centre for Cognition, Radboud University, Nijmegen, The Netherlands
[3]Donders Institute for Brain, Cognition and Behaviour, Centre for Cognitive Neuroimaging, Radboud University, Nijmegen, The Netherlands

Correspondence to: Vitória Magalhães Piai, Wundtlaan 1, The Netherlands, **email**: vitoria.piai@mpi.nl

Abstract

Dutch particle verbs are formed by a main verb and a particle (e.g., *afstuderen* ‘to graduate’; *af* ‘finished’, *studeren* ‘to study’) and are separable in that the particle may be realized separated from the main verb in certain contexts (e.g., *ik studeer af* ‘I graduate’). When presented separately, the processor must store the main verb and integrate it with the particle further downstream. Little is known about when and how this integration is realized and which factors may influence this process. We report an EEG study on the comprehension of Dutch separable particle verbs. We manipulated a) the "family size" of the main verb and b) the actual realization of the particle, which could be (1) a grammatically and semantically correct particle, (2) a particle forming an existing particle verb yet yielding a semantic violation or (3) a particle forming a non-existing particle verb. For a), we found an anterior negativity which seems to be indicative of increased working memory load. Concerning b), both violations yielded an N400 effect relative to the expected particle. The results suggest that the language system is sensitive to particle completions in order to be able to build an appropriate syntactic structure and to retrieve the meaning of the particle verb. Additionally, the results also suggest that the integration of the particle with the main verb is a semantic process, similar to the integration of words in the sentence.

Keywords: Dutch particle verbs; ERP; N400; anterior negativity, sentence comprehension

Introduction

In the present study, we investigate the processing of particle verbs in Dutch in sentence context using ERPs. Particle verbs, or in Booij's (1990) terminology "separable complex verbs", e.g. *opeten*, "to eat up" (*op* "finished"; *eten* "to eat"), are very frequent in Dutch (Booij, 1990; Schreuder, 1990). They are formed by two elements: the particle (e.g. *op*), which can be a preposition or an adverb, and a main verb (e.g. *eten*). Besides being complex verbs, they are also discontinuous (separable) in the sense that the two elements forming the particle verb can be separated in many syntactic contexts (Booij, 1990). In main clauses, the main verb and the particle may appear separately from each other. An example is given in (1):

(1) De beren eten het vlees op.
the bears eat the meat up
"The bears eat up the meat"

Dutch syntax allows any number of words to intervene between the main verb and the particle. The constraints determining the actual distance between these two elements are not of linguistic but rather of a cognitive nature[1].

According to Hawkins (1999, 2004), two elements form a dependency if the parsing of the second element requires that the first element has been accessed in order for syntactic and semantic properties to be assigned to the former. A verb and its direct object, for example, form such an instance: the access to the verb is required to assign case and Θ-role to the object. Dependencies can also appear in the form of long-distance dependencies, case in which the time interval separating the two terms of the dependency is much longer than in the case of a verb and its direct object in English, for instance. Classical examples of long-distance dependencies are wh-movement constructions, in which filler and gap are mutually dependent and yet present in the input separately, relative clauses and topicalization. Dutch particle verbs, when discontinuous, form instances of long-distance dependencies. Note, however that, as most main verbs which select particles also exist as free-standing forms in Dutch, the long-distance dependencies constituted by particle verbs are uncertain dependencies and in this regard, very different from wh-dependencies, relative clauses and topicalization, in which case the presence of the second element of the dependency is certain.

[1] Observed distances between main verbs and particles in Dutch range from 0 to 15 words (Twente Corpus, 72 million words), with the mean distance of 3.5 words (sd = 1.6) (Kuperman, Piai & Schreuder, 2008).

Regarding their semantics, the meaning of particle verbs may be compositional, partially or completely non-compositional (Booij, 1990; Schreuder, 1990). In other words, these verbs can either have their meanings formed by the combination of the meaning of the two parts, a so called transparent meaning, as in the case of *opeten*, or an opaque meaning in which the meaning of the whole is not given by the combination of the meaning of each one of the parts, as we can see in (2):

(2) *oppassen* "to watch out, to babysit"
op "up" *passen* "to fit"

Moreover, the same particle verb can have both an opaque and a transparent reading (Schreuder, 1990):

(3) *aankomen* "to arrive / to gain weight"
aan "on" *komen* "to come"

As it becomes clear from (3), context plays a very important role as sometimes it is the only factor which will determine what the meaning of the verb is.

In what follows, we present in more detail the complexity involved in processing particle verbs. Next, we discuss the two models proposed in the literature of how particle verbs are processed. In addition, we outline the research questions in which we were interested in the present study. Finally, we provide evidence from ERPs for the way in which the language system deals with such verbs.

From a psycholinguistic perspective, the processing of particle verbs is specially intriguing. The combination of various aspects - the fact that the particle can also be a preposition, the idiomaticity of the meaning and the discontinuity of the two elements - creates an uncertainty on whether an element encountered after the main verb should be categorised as a mere preposition or as a particle, and thus ought to be integrated with the main verb (cf. Schreuder, 1990 for a detailed discussion). Focusing only on comprehension for the moment, let us imagine that the reader or listener encounters the sentence in (4b):

(4) a) Ze <u>viel</u> **op** de dansvloer.
She fell on the dance floor
b) Ze <u>viel</u> **op** de dansvloer **op**.
She VERB on the dance floor on *on+fall*
"She stood out on the dance floor" "to stand out"

Bearing in mind that both visual sentence processing and, especially, auditory sentence processing unfold in time, the main verb is encountered at time point t_1. At this point, all other things being equal, there is no (syntactic) reason to assume that a particle will follow at a later time point t_2 as in most cases the main verb itself can also occur freely in the Dutch language (Booij, 1990) as we see in (4a), in this case meaning “to fall”. At the time the first *op* is encountered, the system can choose to integrate it with the main verb, forming a particle verb, or interpret it as a preposition. If the particle verb is chosen, the meaning “to fall”, which was already retrieved, should be deactivated somehow. Moreover, the parser should signal an error at the continuation of the sentence, the noun phrase (NP) *de dansvloer*, as an NP cannot follow a particle. For the lexicon, however, there is nothing wrong with this continuation. On a next step, this error might tell the parser that the item encountered before should have been assigned to the preposition category. This reassignment would have a strong impact on the verb semantics since the prepositional phrase (PP) *op de dansvloer* would cause the meaning “to stand out” to be recomputed for *vallen*, this time meaning “to fall”. Then, if the system puts forward this last hypothesis, it will again be faced with a problem: now the second *op* is encountered. For the parser, there is no problem in integrating it with the previous main verb. However, the meaning of the main verb will have to be recomputed once more, this time towards “to stand out”. If, on the other hand, at the first *op*, the system chooses to construct a PP *op de dansvloer* right from the beginning, encountering the second *op* still would force the meaning firstly assigned to *vallen*, i.e. “to fall” to be recomputed[2]. From this, it becomes clear that neither the parser nor the lexicon alone can solve the puzzle that particle verbs represent for the language system. A continuous interaction between the two is required in order to account for how Dutch speakers comprehend sentences containing these particle verbs without difficulties.

Schreuder (1990) proposed the first psycholinguistic model of particle verb processing. According to Schreuder, a main verb activates not only its own lexical representation in the mental lexicon, but it also activates part of the so-called Morphological Integration Node (MI node), a node which has direct access to the opaque meaning of a particle verb. Each opaque particle verb - and only opaque particle verbs - has its own MI node and it follows from the model architecture that when the main verb is accessed, part of the MI node of each opaque particle verb is activated. However, MI nodes are abstract entities and hardly carry information. In this regard, their activation is different, i.e. less resource demanding, from what is assumed to be word activation in general (cf. Balota,

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2 Note that the processes here described are just hypothetical. It could also be the case that both analyses run in parallel. So far, there is only little experimental research conducted on particle verbs, which cannot shed light yet on the problem just described.

1994). At the time the particle is encountered, it will activate its lexical representation but it will also fully activate the MI node. Once the integration node is fully activated, the lexical representations of the main verb and the particle as such will be inhibited and the opaque meaning will be activated. Although not stated explicitly in the model, presumably the remaining MI nodes, i.e. the MI nodes of the particle verbs other than the one encountered, are de-activated at this point. Note that the inhibition of the representation of the main verb is especially important for semantically opaque particle verbs. Would the main meaning of *passen* remain active once *oppassen* has been activated, interference effects could emerge. One claim made by this model is that the meaning of the particle verb can only be activated via the MI node, hence only after the particle has been encountered in t_2, since its activation is form-driven. In this sense, no effects such as particle pre-activation should be found before t_2. What is especially important in this model is the fact that both the representations of the main verb as well as of the particle verb are available until the activation of the particle verb has been fully accomplished. The idea behind this double activation is derived from the following. Suppose that at the time a main verb is encountered, e.g. *vallen* "to fall", the system retrieves its lexical representation and then stores only its semantics for further processing. In the case of an opaque particle verb, only the semantic representation of the main verb will not be enough. Why is that the case? To get to the meaning of the opaque particle verb, the system also needs to have the form of the main verb available in order to be able to look through the lexicon. Exemplifying this, let us imagine that *vallen* is encountered and the meaning "to fall" is stored but the form is not. If the particle *af* "off" appears later forming *afvallen* "to lose weight" but the system has only got the meaning "to fall" stored, there is no way to compute the meaning of *afvallen*. Yet opaque particle verbs are fully comprehensible verbs in Dutch. This necessarily means that at some point in the sentence, the opaque meaning of the particle verb can be retrieved. The suggestion in the model is that this retrieval is achieved via the MI node, which has direct access to the opaque meaning of the particle verb. So even if the form of the main verb has not been stored, or the activation of the main verb has decayed, as assumed in many models (e.g. Vosse & Kempen, 2000; Vasishth, 2003) to such an extent that it is no longer available, the MI node will still be fully qualified to act as the element which will activate the meaning of the opaque particle verb and inhibit the transparent meaning of the main verb, which at this point is no longer needed.

Another psycholinguistic model of PV processing was suggested by Hillert and Ackerman (2002). According to the authors, at the time the main verb is encountered, a full listing of lexical entries consistent with the main verb will be kept in a lexical buffer. When a particle is finally encountered, the latter will already be present in the buffer. The language processor then re-accesses the relevant information of the particle and inhibits the remaining particle verb entries. The idea of activation of lexical items from the same morphological family is in line with so called family size effects (Schreuder & Baayen, 1997; de Jong, Schreuder & Baayen, 2000). The family size of a word is the type count of the number of its morphological family members. Roughly, the family size effect refers to the finding that a word with a high family size, i.e. many family members, is responded to more quickly in visual lexical decision than a matched control word with the same surface frequency but low family size. This processing advantage suggests that morphologically related words, although not present in the input, are co-activated with the target word being presented. Even though the activation of family members receives support from other studies, there are still important problems with Hillert and Ackerman's model. To start with, it proposes that when a main verb is encountered, “during online processing the LP [language processor] accesses all of the lexical entries consistent with v[erb] at t_1 and keeps this information in a lexical buffer" (Hillert & Ackerman, 2002, p. 304). At the time the particle is finally encountered, what is needed is "the re-access of the relevant p[article] information and the inhibition of the irrelevant v[erb] entries” (p. 304). This suggestion may sound quite plausible at first sight, but it is certainly not unproblematic. Regarding the first process described in the model, there are at least two issues that deserve attention. To start with, further specifications are lacking. What is the lexical buffer? Can it be assumed to be working memory? What exactly is being buffered? The suggestion is that consistent particle verbs will be buffered. However, as we have shown in the description of the MI model, it is crucial for the comprehension of opaque particle verbs to also store verb forms together with semantic information. An ideal model would buffer not only the semantics of each particle verb but also their forms. Moreover, as mentioned in the Introduction, some particle verbs have both a transparent and an opaque meaning. Ideally, in order for an implementation of Hillert and Ackerman's model to work, what should be buffered at the point the main verb is encountered are all particle verb forms and all possible semantic representations of each one of the particle verbs. In the case of a main verb like *lopen* “to walk”, that would result in at least 15 verb forms and even more semantic representations being buffered! There is general agreement that working memory has limited capacity. Miller (1956) argues in favour of “the magical number seven” whereas Cowan (2001) proposes an even smaller number of only four elements. More recently, a distinction has been made between implicit and explicit working memory (Hassin, Bargh, Engell and McCulloch, in press). Under this view, implicit working memory operates nonconsciously and in this regard, it is a likely candidate to be involved in the kind of operations described by Hillert and Ackerman. Little is known about the capacity of implicit working memory. Hassin and colleagues speculate on the idea that it may be less sensitive to conscious capacity limitations but what exactly “less” would mean is unclear and further research is needed to determine whether this speculation is indeed the case in the first place. With our current knowledge about the limitations of working memory capacity, the amount of buffering required by Hillert and Ackerman’s model in the example given seems implausible. This brings us to the second issue associated with the buffering process. What determines which candidates will enter the buffer? Does context play an important role such that it can constraint the amount of candidates? What is the role of word frequency? Do particle verbs need to pass a certain word frequency threshold before they can be considered by the system as potential candidates? In the next step, it is proposed that the language processor will re-access the relevant information of the particle. Also at this point, a more detailed description is necessary. What exactly is meant by “re-accessing relevant information”? Moreover, in the case of opaque particle verbs, whichever information of the particle is re-accessed, it will not help in composing the meaning of the particle verb formed. Altogether, Hillert and Ackerman's model lacks important specifications. In its current state, it is able to model the processing of particle verbs only in a rudimentary way.

Studies have shown that language users anticipate, online, not only syntactic structure (Van Berkum, Brown & Hagoort, 1999) but also upcoming meaning (Fedemeier & Kutas, 1999) and even specific upcoming words (Otten & Van Berkum, 2008; cf. Otten & Van Berkum, 2008 for a brief review). In the case of discontinuous particle verbs, it is plausible to presume that an upcoming particle will be predicted by readers of listeners. So far, only one study has addressed this question (Kuperman, Piai & Schreuder, 2008). Using eye-tracking, Kuperman and colleagues presented Dutch readers with discontinuous particle verbs embedded in sentences. The cloze probability of the particle was controlled for with a sentence completion task and known to be higher than 50% in 70% of the sentences. Readers skipped particles twice as often as they fixated on them, suggesting that particles can be pre-activated before being encountered in the input. This finding goes against the prediction made by the MI model that the meaning of the particle verb can only be activated after the particle has been presented in the input. More importantly for us at this point, this finding suggests that, in the case of rich contexts, the pre-activation of a particle may take place already at words preceding the particle itself.

Comprehending particle verbs seems to be a multifaceted task for the language system and so is the investigation of how the system accomplishes this task. Specific models of particle verb processing are not yet able to simulate this process. To our knowledge, so far only a few studies have approached experimentally the comprehension of Dutch particle verbs in sentential context (Kuperman et al, 2008; Zwitserlood, Bolwiender & Drews, 2004; Frazier, Flores d'Arcais & Coolen, 1993) and even less have done so using brain-imaging techniques (Isel, Alter & Friederici, 2005; Urban, 2002). In this sense, our understanding of how particle verbs are processed is still very poor. This study is an attempt to expand our knowledge about the topic. The choice fell on ERPs because it enables us to selectively track the sub-processes involved in language processing as they unfold in time. Making use of these advantages, we explore the comprehension of Dutch particle verbs focusing on two aspects. The first one follows directly from the two processing models proposed in the literature. Both models predict more processing costs at the main verb for particle verbs relative to verbs which do not license particles in Dutch: according to the MI model, the latter lacks MI nodes; according to Hillert and Ackerman's model, the latter will most likely, although not always, have less meanings related to it than will particle verbs (a main verb which licenses particles would always have at least its number of meanings plus one, this one being from at least one particle verb). However, the two models differ regarding their predictions about the costs related to the amount of particle verbs associated with one main verb. Hillert and Ackerman's model predicts increased processing costs as a function of the amount of particle verbs associated with one main verb because the more particle verbs one can form with a main verb, the more candidates will be kept, in their terms, in the lexical buffer. By contrast, according to the MI model, processing main verbs which allow formation of few particle verbs will not differ much from processing main verbs which license many particles as MI nodes are abstract nodes which carry no semantic nor syntactic information and in this sense they differ from the activation of full word representations. It could be the case that more neurons are required for activating full word representations than for activating the MI nodes since the latter have less content. Even if the activation of more MI nodes for the Large condition relative to the Small might be reflected in EEG, it could be a less prominent difference than the difference predicted given Hillert and Ackerman's model. Both models do not directly address the processes playing a role at the object but it is likely that these are similar to the ones involved in processing the main verb. At the particle, both models assume inhibition of irrelevant candidates. If we assume again that the activation of full word representations entails more activated neurons than the activation of MI nodes, then the amount of inhibition needed in Hillert and Ackerman's model will be greater than in the MI model. The way we address this first aspect is by assessing the possibility that the language system will be affected somehow by, firstly, having a particle to deal with and secondly, having more than one particle to choose from, what we call henceforth the Particle Verb Family Size effect. The second aspect we want to explore is the integration of the main verb with the particle and we limit ourselves to two questions, which are inter-related: the first question is concerned with the temporal aspect of the integration and the second with the nature of the integration process. It is generally agreed that word meaning is rapidly integrated into the context, be the latter single word context, sentential context or discourse (Kutas, 1993; Van Berkum, Hagoort & Brown, 1999; Hagoort, Hald, Bastiaansen, & Peterson, 2004; cf. Kutas, van Petten & Kluender, 2006 for a detailed review). This integration process is assumed to be reflected in the N400 (Hillyard & Kutas, 1980), a negative-going potential starting around 250 msec and peaking around 400 msec after the onset of the word with central-parietal scalp distribution; its amplitude decreases the better a word semantically “fits” the context (cf. Kutas et al., 2006 for a detailed review). Using the knowledge we have on the N400 as a tool, we can contrast the integration of the particle with the main verb in a correct sentence context with the integration of the particle with the main verb in contexts which are known to elicit N400 effects. More specifically, by varying the particle forming the particle verb, we created either a semantic violation in the sentence or a non-existing particle verb, which we called a morpholexical violation. Semantic violations in a sentence are well known to elicit N400 effects (cf. Kutas et al., 2006 for a detailed review). Moreover, the particle verbs in the morpholexical violation, for being non-existing verbs, tap even more into the process involved in the integration of the particle with the main verb. If the integration of the particle with the main verb is similar to the integration of words in a sentence, a N400 effect should be found for the semantic violation relative to a correct, semantically well-formed sentence (control) and for the morpholexical violation relative to the control sentence. A further question is whether the effects elicited by the violations relative to the control sentence are similar or not, and if they differ, whether the differences are qualitative or quantitative differences.

The two aspects of interest were translated into two different manipulations of Dutch particle verbs, which were brought together in one experiment whose design is outlined below.

Method

Participants

Thirty students participated in the study (9 males, 23 females; mean age = 22, sd = 3.28). They received a reward of 12 euros for their participation. All participants gave written informed consent and the experiment was conducted according to the declaration of Helsinki (World Medical Association, 1996). All participants were right-handed, native speakers of Dutch with normal or corrected-to-normal vision and had no history of neurological deficits nor were under medication.

Materials

The present study consists of two different manipulations, which are described in what follows.

Particle Verb Family Size

This manipulation was designed to investigate the effect of the Particle Verb Family Size. Therefore, families of particle verbs were created using the Dutch Celex database (Baayen, Piepenbrock & van Rijn, 1995). Verbs which appear in the database in combination with at least five particles were assigned to a family which we call the Large Family; verbs which appear in combination with two or three particles were assigned to the Small Family; verbs which do not appear in combination with any particle were assigned to the Simplex Family. Ninety-three sentences were created with a fixed syntactic structure: subject – main verb – object – (particle) – rest. The main verb and the particle were always presented separately from each other, the main verb being presented at t_1 and the particle at t_2. The main verb was never the first element in the sentence and the particle never appeared in sentence-final position. All main verbs used occur in Dutch as free-standing forms. Thirty-one sentences contained particle verbs taken from the Large Family (Large condition: mean number of particles per main verb = 8.45, sd = 3.17); 31 sentences contained particle verbs from the Small Family (Small condition: mean number of particles per main verb = 2.45, sd = 0.5); 31 sentences contained simplex verbs (Simplex condition). The two particle families differed significantly from each other in the number of particles per main verb ($t_{(60)} = -10.4$; $p = .000$). Table 1 exemplifies the particle verb (PV) family size manipulation.

Table 1

Stimulus examples used in the Particle Verb Family Size manipulation

Condition	Stimulus
Large	De kinderen *blazen* de ballonnen *op* vanwege het feestje.
	The children VERB the balloons PART for the party
	"The children blow up the balloons for the party "
Small	De directeur wijdt de schouwburg in met een lange speech.
	The director VERB the theatre PART with a long speech
	" The director inaugurates the theatre with a long speech"
Simplex	De burgers haten de hinderwet van de gemeente.
	The citizens hate the Nuisance Act of the municipality
	"The citizens hate the Nuisance Act of the municipality"

The lemma frequency and length of the main verb as presented in the materials were matched across the three conditions. An ANOVA revealed no systematic differences among the conditions (lemma frequency of the main verb: $F_{(2)}$ = .025; p = .975; main verb length: $F_{(2)}$ = 1.314, p = .274). It might be the case, as already discussed in the Introduction, that the expectancy of the particle is such that one single particle is already pre-activated after the recognition of the syntactic object of the sentence, i.e. even before the particle itself has been encountered (cf. also Kuperman et al, 2008). Therefore, also the lemma frequency and word length of the object were matched across the three conditions. An ANOVA revealed again no systematic differences across the conditions (Lemma frequency of the object: $F_{(2)}$ = .056; p = .945; object length: $F_{(2)}$ = .019; p = .981).

Pre-tests

The sentences of the Large and Small conditions of the PV family size manipulation were pre-tested. First, we wanted to establish whether the families constructed based on the Celex database were indeed psychologically real in the mental lexicon of Dutch speakers. Second, we wanted to ensure that the locus of particle pre-activation was the same for all sentences across the two conditions. To test the family size of the particle verbs, a particle verb generation task was performed by 16 native speakers of Dutch (3 males, 13 females; mean age = 21.3). They were instructed to generate as many particle verbs as they could given each main verb. Two examples were given in the instructions; however, subjects were not presented with any list containing particles during the task. By doing so, we made sure that the verbs were generated spontaneously rather than being the result of a strategy used by the subjects in which they simply combined the given verbs with the given particles. An average score was computed for each main verb and a t-test revealed a significant difference between the two conditions (Small condition: mean = 1.68, sd = .37; Large condition: mean = 3.08, sd = .71; $t_{(30)} = -10.81$, p = .000). The difference between the two conditions was also significant within each subject. The average scores calculated for the verb generation task correlate with the particle verb family size as in the Celex database (r = .768, p < .01). These results indicate that the main verbs assigned to the Large Family based on the Celex database give rise to more particle verbs generated by our pre-test participants compared to the main verbs assigned to the Small Family.

To address the locus of particle pre-activation, two pre-tests were conducted. The materials were constructed such that the subject of the sentences was always neutral in the sense that it would not bias for any upcoming verb. Furthermore, as already mentioned, the main verbs used are also free-standing forms in Dutch or can combine with other particles as well. We wanted to be certain that in our materials, when encountering the main verb, all its readings would still be possible completions of the sentence, i.e. the free-standing form reading and readings of different particle verbs. This was pre-tested with a sentence completion task. Sixteen native speakers of Dutch who had not participated in the other pre-tests (4 males, 12 females; mean age = 19.8) were presented with the sentences up to and including the main verb. We calculated the percentage of congruent particle completions, i.e. completions with the same particle as the one chosen for the materials, across subjects given only the main verb (mean = 11.29, sd = 11.5, range: 0% - 37.5%). The results showed that 37% of the particles had a cloze probability of zero; only two particles had a cloze probability of 37.5%. The difference in cloze probabilities between the Large and Small conditions was not significant ($t_{(60)} = -1.10$, p = .274). The object of the sentence, however, was not neutral as it helped participants to predict which particle was coming, i.e. pre-activate a particle. The cloze probability of the particle given the object was pre-tested with a sentence completion task in which 22 participants (7 males, 15 females; mean age = 22.2) were presented with the sentences from the materials up to and including the object. We calculated the percentage of congruent particle completions for each main verb across subjects (mean = 82.9, sd = 15.28, range: 50% - 100%). The results showed that only 14% of the particles had a cloze probability between 50% and 63%. The remaining particles had cloze probabilities between 63.5% and 100%, with 47% of the particles having cloze probabilities higher than 90%. The cloze probability of the particle given the main verb did not differ significantly between the two particle conditions (mean Large condition: 12.9, sd = 11.62; mean Small condition: 9.67, sd = 11.39; $t(60) = -1.103$, $p > .05$). The difference in cloze probability of the particle given the object did not differ between the two conditions (mean Large condition: 85.7, sd = 14.9; mean Small condition: 80.06, sd = 15.38; $t(60) = 1.466$, $p > .05$). A t-test revealed a significant difference in cloze probability between the completions given only the main verb and completions given the object ($t(61) = 34.452$, $p < .05$) showing that 1) participants could not predict the upcoming particle given only the subject of the sentence and the main verb in both Large and Small conditions and 2) the context created by the object was constraining enough to pre-activate the same particle for each sentence.

Particle Verb Integration

The Particle Verb Integration manipulation was designed to investigate the processes involved in the integration between the main verb and the particle. The sentences used were all main clauses with particle verbs in which the main verb and the particle were presented separately from each other, the main verb being presented at t_1 and the particle at t_2. The main verb was never the first element in the sentence and the particle never appeared in sentence-final position. Three conditions were created, yielding 120 triplets. The sentences were identical for each triplet except for the particle, which was the manipulated item across the three conditions. In one of the conditions (Control condition), the particle encountered was a particle which yielded a fully grammatical, coherent sentence. In the second condition (Semantic violation), an existing particle verb was chosen whose meaning resulted in a semantic violation in the sentence. For the third condition (Morpholexical violation), non-existing particle verbs were created by combining existing main verbs with existing particles. Table 2 exemplifies the PV Integration manipulation.

It could be the case that the violations would not be interpreted as such given that particles in Dutch can also function as prepositions. For example, the particle verb **nanemen* (*na* "after"; *nemen* "to take") does not exist. However, the sentences in our experiment were presented in written form so prosody could not guide the integration process of the particle to the previous main verb (cf. Isel et al., 2005). Given the fact that *nanemen* does not exist, what could happen is the following: the particle in the sentence *De vrouw neemt de medicijnen na* ("The woman VERB-takes the medicines PART") was supposed to be interpreted as such and, hence, yields a violation. However, the particle *na* also means "after". It could be the case that this particle is interpreted as a preposition and does not yield a violation at all at the point of the particle as this sentence, up to this point, is completely grammatical and interpretable as "The woman takes the medicines after..." for example "having consulted a doctor". To avoid this confound, only adverbs were used in the two violation conditions. The characteristics of adverbial particles in Dutch are such that no correct sentence continuation can be made, contrary to the possible prepositional reading that prepositional particles allow. So, for example, in the sentence presented in Table 2, *De zon brak al vroeg af*, at the point of the adverbial particle "af", the only possible reading of the adverb is the particle reading, to be integrated with the main verb.

Table 2
Stimulus examples used in the PV Integration manipulation[3]

Condition	Stimulus
Control	De zon *brak* al vroeg *door* dus wij vertrokken ook vroeg.
	the sun VERB already early PART thus we left also early
	"The sun broke through early so we also left early"
Semantic violation	De zon *brak* al vroeg ?*af* dus wij vertrokken ook vroeg.
	"The sun broke ?*off early so we also left early"*
Morpholexical violation	De zon *brak* al vroeg **toe* dus wij vertrokken ook vroeg.
	the sun VERB already early PART thus we left also early

Experimental Lists

The materials of the PV Family Size and PV Integration manipulations were put together in the same experimental lists and presented in the same session. Even though Celex counts over 200 particle verbs, all restrictions introduced to the materials made the set of verbs which could be used reduce considerably. In order to obtain a minimum number of items per condition, 19 main verbs from the PV Family Size manipulation were also used in the PV Integration manipulation and their order of appearance was randomized. There was no repetition of main verb within the same manipulation.

In addition to the sentences of the two manipulations, 47 fillers were created in order to distract participants from the purposes of the experiment and to avoid strong particle completion biases. Twenty-three fillers contained a standard semantic violation. The other 24 fillers contained a violation in the selection of the preposition, such as *He is proud *in his daughter*. None of the fillers contained particle verbs. Three experimental lists were created which contained all items of the PV Family Size manipulation, all fillers and 40 sentences of

[3] An asterisk indicates that the particle verb formed is non-existing; the question mark indicates that the particle verb formed yields a semantically malformed sentence.

each condition of the PV Integration manipulation. Participants saw only one sentence of each triplet of the PV Integration manipulation. The whole design of the PV Integration manipulation was completed with three lists. Each list had in total 260 sentences: 93 sentences from the PV Family Size manipulation, 120 sentences from the PV Integration manipulation and 47 fillers. The items in each of the three main lists were randomized for each subject yielding one unique final list per subject.

Procedure

Subjects were seated comfortably in a electrically and acoustically shielded booth. They were instructed to read the sentences silently for comprehension. No extra task was imposed. The experimenter could monitor the subject via a camera and contact with the subject was made via an intercom. Sentences were presented word-by-word in the centre of a computer screen. The experiment started with a practice session so that the subjects could habituate to the pace of trial presentation. A trial began with three asterisks, which were presented for 3000 msec indicating that subjects were allowed to blink and eventually move. A fixation cross, which remained on the screen for 1000 msec, followed the asterisks indicating that the trial was about to start and the subjects should prepare. A blank screen followed the fixation cross for 300 msec until the first word of the sentence appeared. Each word in the sentence was presented for 300 msec followed by a blank screen for 300 msec. The materials were presented in 13 blocks of equal sizes with a break between each block. Subjects decided themselves how long the breaks lasted by pressing a button to proceed to the next block. Each block lasted about 3,5 minutes. The whole session, including subject preparation, lasted around 1 hour and 20 minutes.

EEG recording

The EEG was recorded from 60 scalp electrodes mounted equi-distantly in an elastic cap (as displayed in Figure 1) using the Acticap system, amplified with BrainAmps DC amplifiers (500 Hz sampling, 0.016 - 100 Hz band-pass) and each referred on-line to the left mastoid, re-referenced off-line to averaged mastoids. The horizontal electrooculogram (EOG) was reconstructed from the recorded EEG from the electrodes placed on the left and right temples. The vertical EOG was reconstructed from EEG recorded from the electrodes positioned below and above the left eye. Electrode impedance was kept below 10 kΩ.

ERP analysis

Single waveforms were baseline-corrected using the average EEG activity from the 150 msec prior to the onset of each critical word. Epochs consisted of 150 msec preceding and 1000 msec following the onset of the critical word. Trials which contained eye movements, electrode drifting and muscular artefacts within the epoch were rejected (5.9% of the data for PV Family Size manipulation; 6.7% of the data for PV Integration manipulation).

For the PV Family Size manipulation, there were three critical words: the main verb, the object and the particle. For the PV Integration manipulation, the critical words were the main verb and the particle. For each critical word, average waveforms were computed for each subject across all trials per condition (Large, Small and Simplex for PV Family Size manipulation; Control, Semantic violation and Morpho-lexical violation for PV Integration manipulation). One quadrant for each Hemisphere (left, right) x Region (anterior, posterior) was determined by grouping nine channels in each of the four quadrants. The four quadrants are encircled in red in Figure 1. The average microvoltage within the relevant time windows was computed for each quadrant. The statistical analyses were conducted separately for each manipulation and within each manipulation, the analyses were conducted separately for each of the critical words. All analyses carried out were three-way repeated measures ANOVAs with variables Region (anterior, posterior) x Hemisphere (left, right) x Condition (two or three levels, depending on the analysis). All p-values reported reflect the application of the Greenhouse–Geisser correction with the original degrees of freedom.

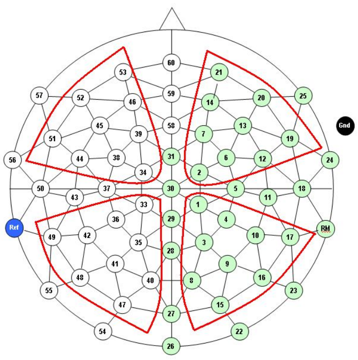

Figure 1. Electrode configuration and the four quadrants used in the analyses

Results

PV Family Size manipulation

For the PV Family Size manipulation, the Condition variable had three levels for both the main verb and the object (Large, Small, Simplex) and two levels for the particle (Large, Small).

Main verb

The waveforms of averaged ERPs to the main verb are displayed in Figure 2 for nine channels. Their position is displayed in the head on the top of the figure: there is one to one correspondence between rows and columns of the head figure and the waveforms, assuming that the bottom middle channel in the head figure belongs to the third row. The waveforms suggest a negativity starting at around 300 msec until roughly 700 msec for the Simplex condition relative to the other the Large and Small conditions in anterior electrodes, more prominent in left anterior electrode sites.

Effects to the main verb for the Particle Verb Family Size

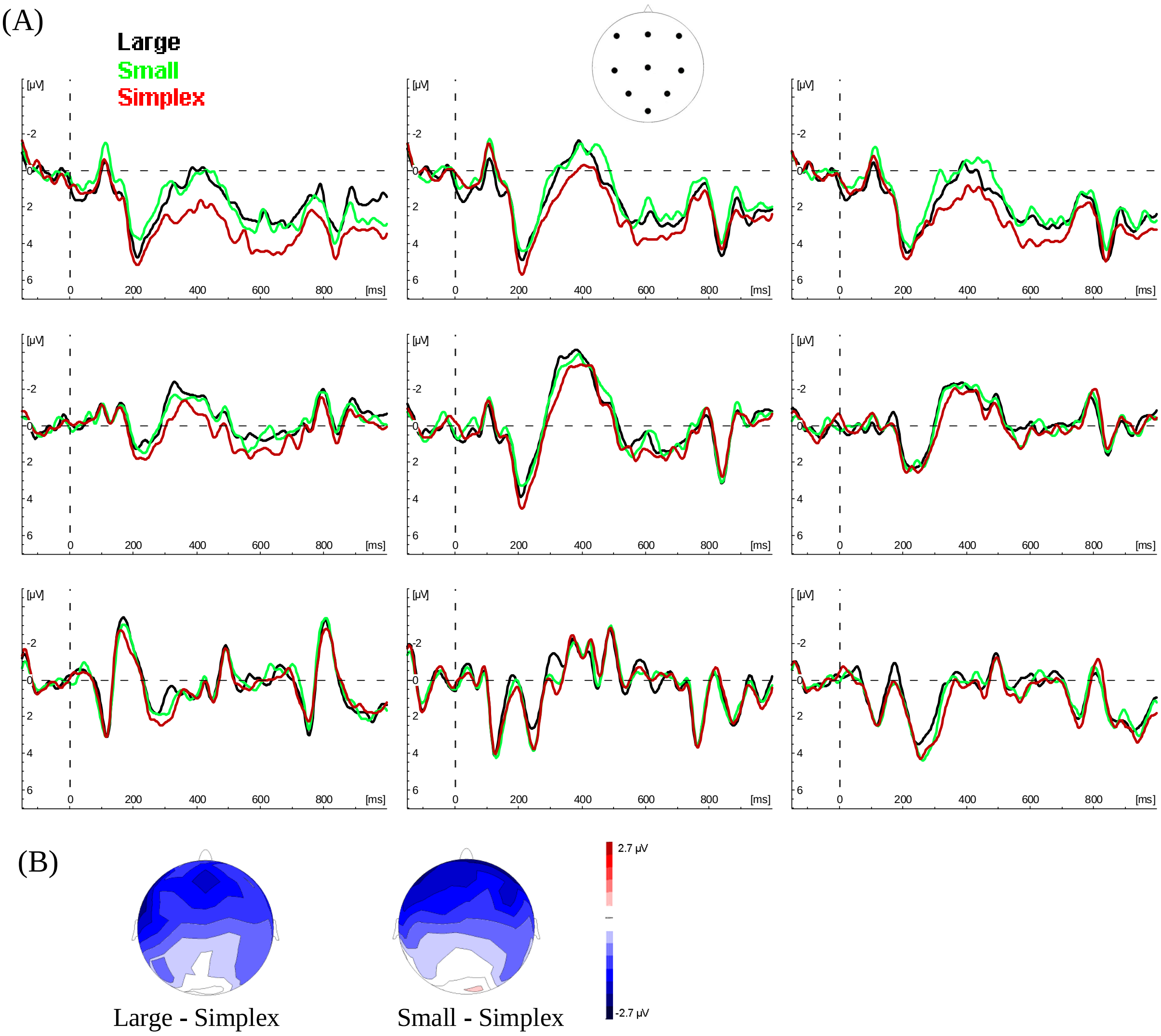

Figure 2. (A) Grand average ERP response to the main verb for the PV Family Size manipulation; Large condition (black line), Small condition (green line), Simplex condition (red line). (B) Topographic scalp voltage maps in the time window 300-500 msec.

The statistical analyses confirm this suggestion in the time window 300-500 msec: there was a main effect of Region [$F_{(1,29)}$ = 6.52, p = .016, MSE = 60.56] and although the main effect of Condition did not reach significance [$F_{(2,58)}$ = 2.28, p = .114, MSE = 18.16], the Condition x Region interaction did [$F_{(2,58)}$ = 4.20, p = .031, MSE = 10.08]. Further analyses confirmed the localisation of the effect in anterior electrode sites: the simple effect of Condition was significant only in the anterior region (posterior regions [$F_{(2,58)}$ = .39, p = .655, MSE = 1.11]; anterior regions [$F_{(2,58)}$ = 5.26, p = .009, MSE = 12.11]). Moreover, contrast analyses confirmed the negativity for the Simplex condition relative to Large and Small conditions in anterior sites (Large - Small [$F_{(1,29)}$ = .51, p = .482, MSE = .22]; Large - Simplex [$F_{(1,29)}$ = 4.73, p = .038, MSE = 25.17]; Small - Simplex [$F_{(1,29)}$ = 11.42, p = .002, MSE = 41.88].

The effects visible in Figure 2 in the time window 500-700 msec were not confirmed. A main effect of Region was found [$F_{(1,29)}$ = 89.71, p = .000, MSE = 430.56] although Condition failed to reach significance as a main effect [$F_{(2,58)}$ = 1.15, p = .322, MSE = 11.42]. The interaction with Region was nevertheless marginally significant [$F_{(2,58)}$ = 3.2, p = .051, MSE = 6.30]. However, the result showing the localisation of the effect in anterior electrodes was not significant (simple effect of Condition in posterior regions [$F_{(2,58)}$ = 1.76, p = .836, MSE = .46] and in anterior regions [$F_{(2,58)}$ = 2.55, p = .09, MSE = 8.54]). The subsequent time windows did not reveal any significant effects nor significant interactions [all Fs < 1].

The analyses confirm the presence of an anterior negativity, slightly left-lateralised as we can see in the scalp topographies in Figure 2B, starting at around 300 msec and lasting certainly until 500 msec, which is the time window reported in the literature for the LAN (Left Anterior Negativity) (cf. Kutas et al, 2006) for the Simplex condition relative to the Large and Small conditions.

Object

The waveforms of averaged ERPs to the object are displayed in Figure 3 for nine electrodes, their positioning being displayed in the head figure above the waveforms as explained previously. The waveforms in Figure 3 suggest an anterior negativity, more prominent in the left hemisphere, between roughly 300-500 msec (in the first channel, seeming to start even earlier) for the Large and Small conditions relative to the Simplex condition. Furthermore, there seems to be a similar negativity between roughly 500-700 msec although it is much less clear than the effect in the previous time interval.

Statistical analyses confirmed the effect for the time window 300-500 msec: the main effect of Condition was marginally significant [$F_{(2,58)}$ = 3.18, p = .051, MSE = 23.17]; the main effects of Region [$F_{(1,29)}$ = 4.43, p = .044, MSE = 26.67] and Hemisphere [$F_{(1,29)}$ = 8.34, p = .007, MSE = 17.9] were significant and so was the three-way interaction Condition x Region x Hemisphere [$F_{(2,58)}$ = 5.97, p = .006, MSE = .63]. In posterior regions, no significant simple effects were found nor significant interactions. In anterior regions, on the other hand, a simple effect of Condition was present [$F_{(2,58)}$ = 3.98, p = .026, MSE = 18.55] although the interaction Condition x Hemisphere was not significant [$F_{(2,58)}$= 1.99, p = .149, MSE = .68]. Contrast analyses revealed a significant difference between the conditions Large and Simplex [$F_{(1,29)}$ = 6.44, p = .017, MSE = 34.34] and a marginally significant difference between conditions Small and Simplex [$F_{(1,29)}$ = 3.99, p = .055, MSE = 14.49]; Conditions Large and Small did not differ significantly [$F_{(1,29)}$ = .97, p = .333, MSE = 4.22].

Effects to the object for the Particle Verb Family Size

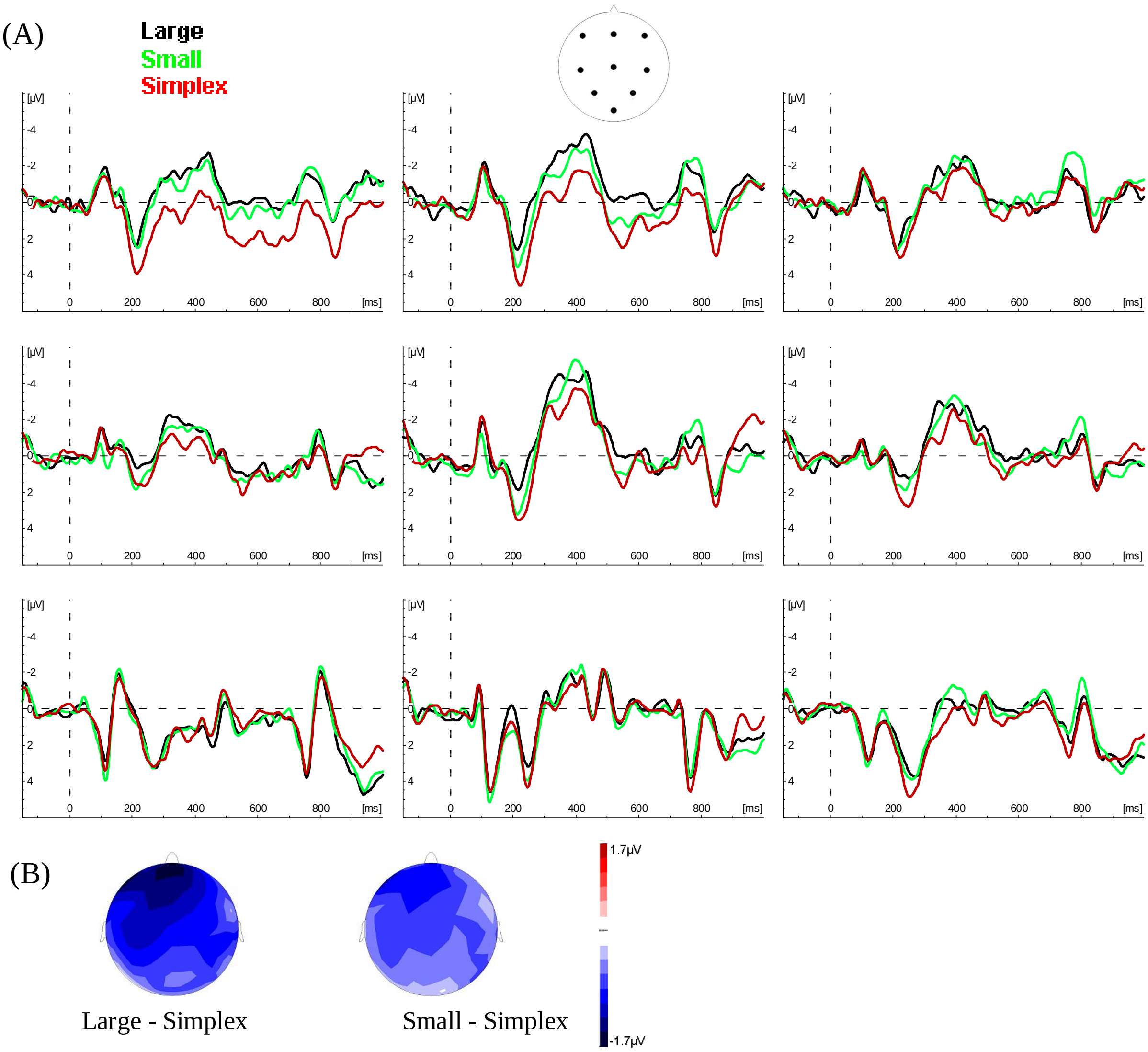

Figure 3. (A) Grand average ERP response to the object in the PV Family Size manipulation; Large condition (black line), Small condition (green line), Simplex condition (red line). (B) Topographic scalp voltage maps in the time window 300-500 msec.

The pattern for the time window 500-700 msec is much less clear also in the analyses, which revealed a main effect of Hemisphere [$F_{(1,29)}$ = 9.07, p = .005, MSE = 12.34] but no main effect of Condition [$F_{(2,58)}$ = 1.06, p = .351, MSE = 11.2] although the three-way interaction Condition x Region x Hemisphere was significant [$F_{(2,58)}$ = 3.75, p = .041, MSE = .72]. In the left hemisphere, the Region x Condition interaction was marginally significant [$F_{(2,58)}$ = 2.91, p = .062, MSE = 3.19] although contrast analyses revealed no significant differences among the conditions (Large – Simplex [$F_{(1,29)}$ = 3.12, p = .088, MSE = 14.48]; Small – Simplex [$F_{(1,29)}$ = 0.41, p = .528, MSE = 1.87]; Large – Small [$F_{(1,29)}$ = 0.93, p = .341, MSE = 5.94]). In the right hemisphere, only the simple effect of Region was significant [$F_{(1,29)}$ = 5.19, p = .03, MSE = 7.3]. In anterior regions, the analyses revealed no simple effect of Condition [$F_{(2,58)}$ = 2.12, p = .129, MSE = 11.91] and the Hemisphere x Condition interaction was not significant either [$F_{(2,58)}$ = 2.41, p = .10, MSE = .787]. In posterior regions, no significant simple effect of Condition nor interactions were found [Fs < 1].

The statistical analyses confirmed the first impression of an anterior negativity, slightly left-lateralised in the time window 300-500 msec after the onset of the object for the two particle conditions relative to the Simplex condition, although the Small – Simplex comparison was only marginally significant.

Particle

The analyses for the particle comprise only two conditions, the Large and Small conditions. The waveforms of grand averaged ERPs to the particle are displayed in Figure 4 for nine channels; their positions are displayed in the head on the top of the figure. Visual inspection of the waveforms suggest a sustained positivity for the Large condition relative to the Small condition starting as early as 100 msec at some anterior electrodes and around 500 msec at central-right electrodes.

The analyses confirm the positivity in the time window 100-300 msec: we found a significant main effect of Condition [$F_{(1,29)}$ = 5.49, p = .026, MSE = 24.2], of Hemisphere [$F_{(1,29)}$ = 4.77, p = .037, MSE = 8.62] and of Region [$F_{(1,29)}$ = 26.64, p = .000, MSE = 110.07] for this time window. A marginally significant Condition x Region interaction was found [$F_{(1,29)}$ = 3.6, p = .068, MSE = 3.47]. As the *p-value* in this case is quite large, no further analyses were conducted.

The deflection we see in Figure 4 in the time window 500-700 msec proved to be statistically unreliable: no main effect of Condition [$F_{(1,29)}$ = 1.73, p = .199, MSE = 16.26] and no significant interactions were found although the main effects of Region [$F_{(1,29)}$ =

20.92, p = .000, MSE = 51.51] and Hemisphere [$F_{(1,29)}$ = 6.01, p = .020, MSE = 13.41] were significant.

Effects to the particle for the Particle Verb Family Size

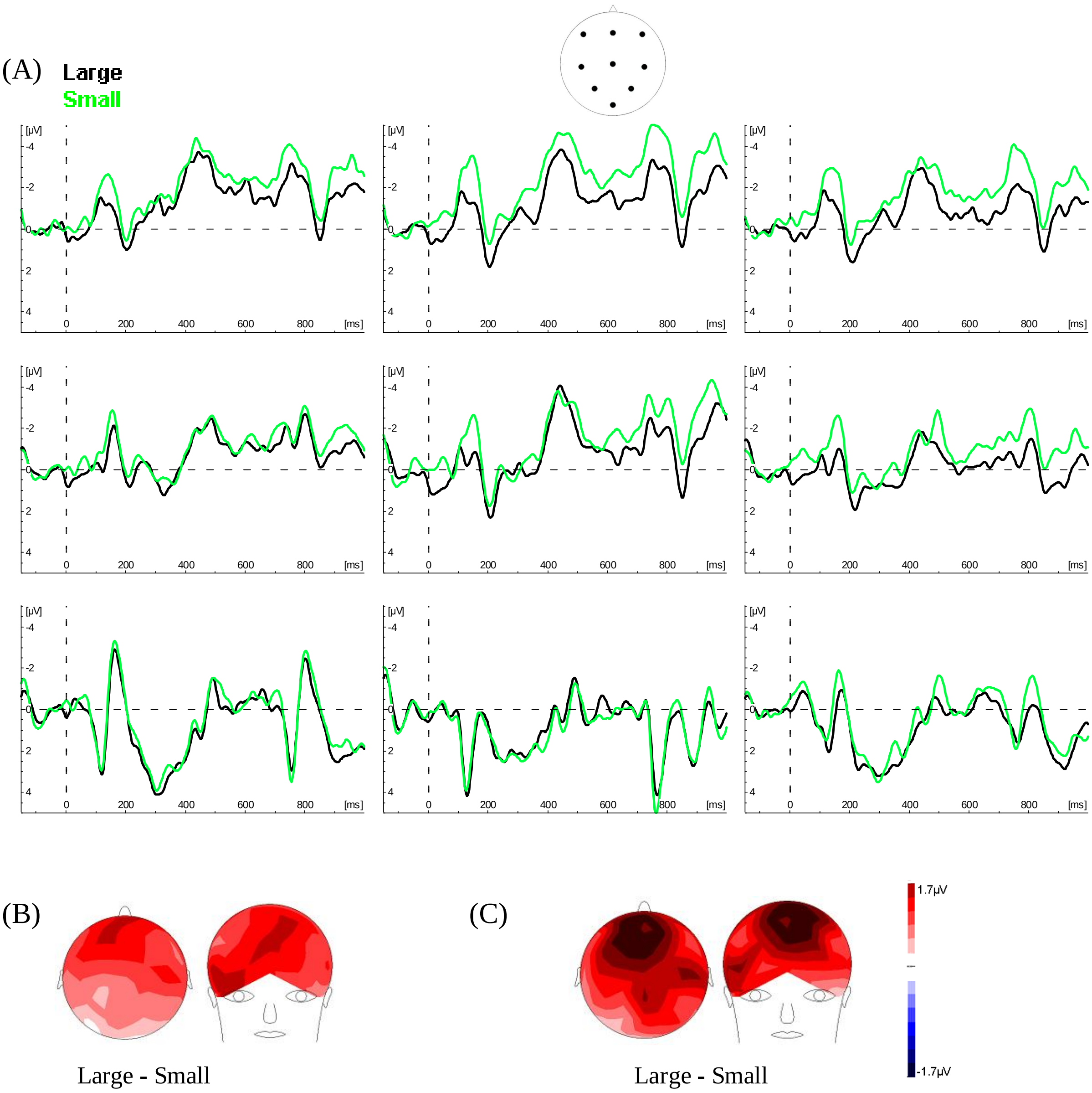

Figure 4. (A) Grand average ERP response to the particle in the PV Family Size manipulation; Large condition (black line), Small condition (green line). (B) Topographic scalp voltage maps in the time window 100-300 msec. (C) Topographic scalp voltage maps in the time window 700-1000 msec.

The analyses in the time window 700-900 msec revealed a significant main effect of Condition [$F_{(1,29)}$ = 4.69, p = .039, MSE = 45.22] but no significant interactions. The time window 900-1000 msec showed a significant main effect of Condition [$F_{(1,29)}$ = 4.31, p = .047, MSE = 49.57] and of Region [$F_{(1,29)}$ = 44.22, p = .000, MSE = 322.24]. Together, these two analyses confirm the presence of a reliable sustained positivity for the Large condition relative to Small starting at 700 msec and continuing for as long as the segment analysed lasts.

Baseline correction

The baseline correction used for the particle consisted of averaging the EEG activity in the 150 msec preceding the onset of the particle, which corresponds to the time window 450-600 msec of the object. Visual inspection of that time window (highlighted in figure 5), however, cast some doubt on the validity of the interval as a baseline. An example is given in figure 5 for three anterior channels, respectively 46, 59 and 14, with their positioning in the head displayed in the right figure.

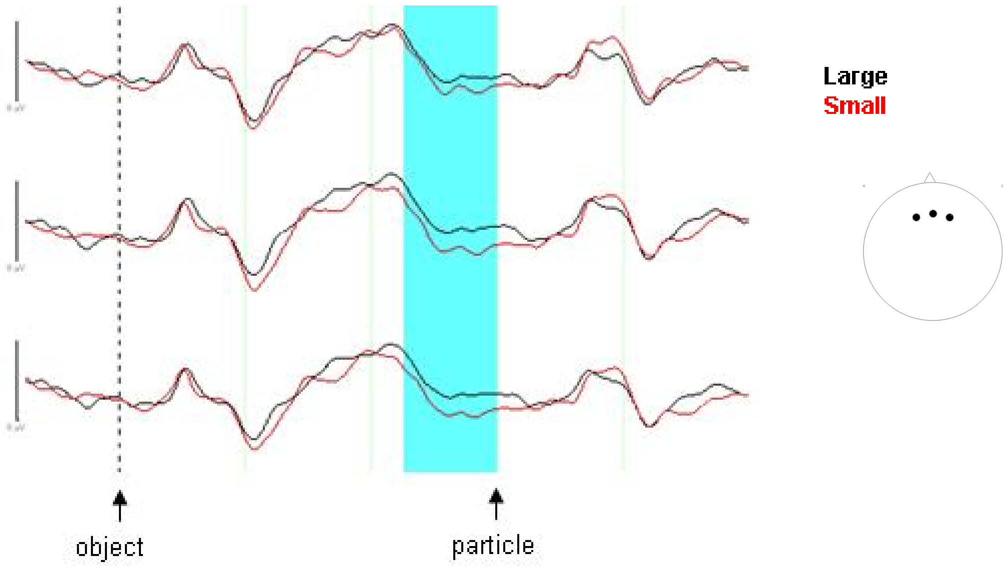

Figure 5. Grand average ERP response to the object in three anterior channels (displayed in the right figure); Large condition (black line), Small condition (red line). The highlighted time window is the interval used for performing baseline correction for the next word, the particle.

In order to validate the use of the described baseline correction, statistical analyses were conducted on the highlighted segment. Using the waveforms of the object, the time window 450 to 600 msec was selected. The same quadrant analyses conducted on the object were conducted on this time window for the conditions Large and Small. The results showed no main effect of condition [$F_{(1,29)} = 1.70$, $p = .202$, MSE = 17.03] nor significant interactions. Moreover, the same time intervals that yielded significant results for the analyses at the particle, i.e. 100-300 and 700-1000 msec were tested with the pre-object baseline correction. This baseline correction consisted of averaging the EEG activity from the 150 msec prior to the onset of the object. The analyses showed the following results. In the time window 100-300 msec of the particle, no main effects were found nor significant interactions [Fs < 1]. However, when the mean average voltage was calculated only for the channels in which the effect was maximum (channels 18, 19, 20, 21, 24 and 25, displayed in figure 6), a main effect of Condition was present [$F_{(1,29)}$ = 5.44, p = .027, MSE = 21.19]. In the time window 700-1000 msec of the particle, no main effect of Condition was found [$F_{(1,29)}$ = 1.12, p = .298, MSE = 20.97] nor significant interactions [Fs < 1]. However, the analyses conducted on the channels where the effect was maximum (the same channels as the previous analysis) revealed a significant main effect of Condition [$F_{(1,29)}$ = 7.94, p = .009, MSE = 32.68]. The results present in the channels with maximum effect parallel the results obtained for the particle when baseline corrected based on the 150 msec prior to the onset of the particle. We firstly showed that no significant differences were found for the time window on which pre-particle baseline correction was performed. Furthermore, the effects found with the first analysis conducted on pre-particle baseline corrected data are still present when a pre-object baseline correction is performed, albeit attenuated. Taken together, these two results seem to suggest that it is safe to perform the pre-particle baseline correction as described in the section ERP analysis for the particles and to acknowledge the results described in the *Particle* section.

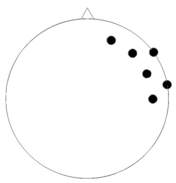

Figure 6. Position of channels 18, 19, 20, 21, 24 and 25

PV Integration manipulation

For the PV Integration manipulation, the Condition variable for both the main verb and the particle had three levels (Control, Semantic Violation, Morpholexical Violation).

Main verb

The waveforms of grand averaged ERPs to the main verb are displayed in Figure 7 for nine channels. Their position is displayed in the head figure on the top of Figure 7. There is one to one correspondence between the channels displayed and the waveforms, assuming that the top-left, top-middle and top-right channels belong to the first row, and bottom-left, bottom-middle and bottom-right channels belong to the third row.

At the main verb, subjects were presented with the same main verbs across conditions. Therefore, we expected no significant main effects of Condition nor interactions. As we can see in Figure 7, the ERPs elicited at the main verb in the three conditions lie on the top of each other. The statistical analyses confirmed this observation: no significant main effects nor interactions were found [Fs < 1] in any time interval.

Particle

The waveforms of grand averaged ERPs to the particle are displayed in Figure 8 for nine channels and their positioning is displayed in the head figure at the top, as explained for the main verbs. The waveforms show a graded negativity starting at around 300 msec and lasting until 500 msec in all channels, more prominent in central-parietal electrode sites, suggesting the presence of a standard N400 effect (cf. Kutas et al. 2006). The semantic violation elicits a larger N400 than the control condition, and the morpholexical violation, on its turn, elicits a larger N400 than the semantic violation. Moreover, a positivity for the violation conditions relative to the control condition seems to be present in central-parietal electrodes in the time window 500-700 msec, which could be indicative of a P600 effect (cf. Kutas et al. 2006).

Effects to the main verb for the Particle Verb Integration

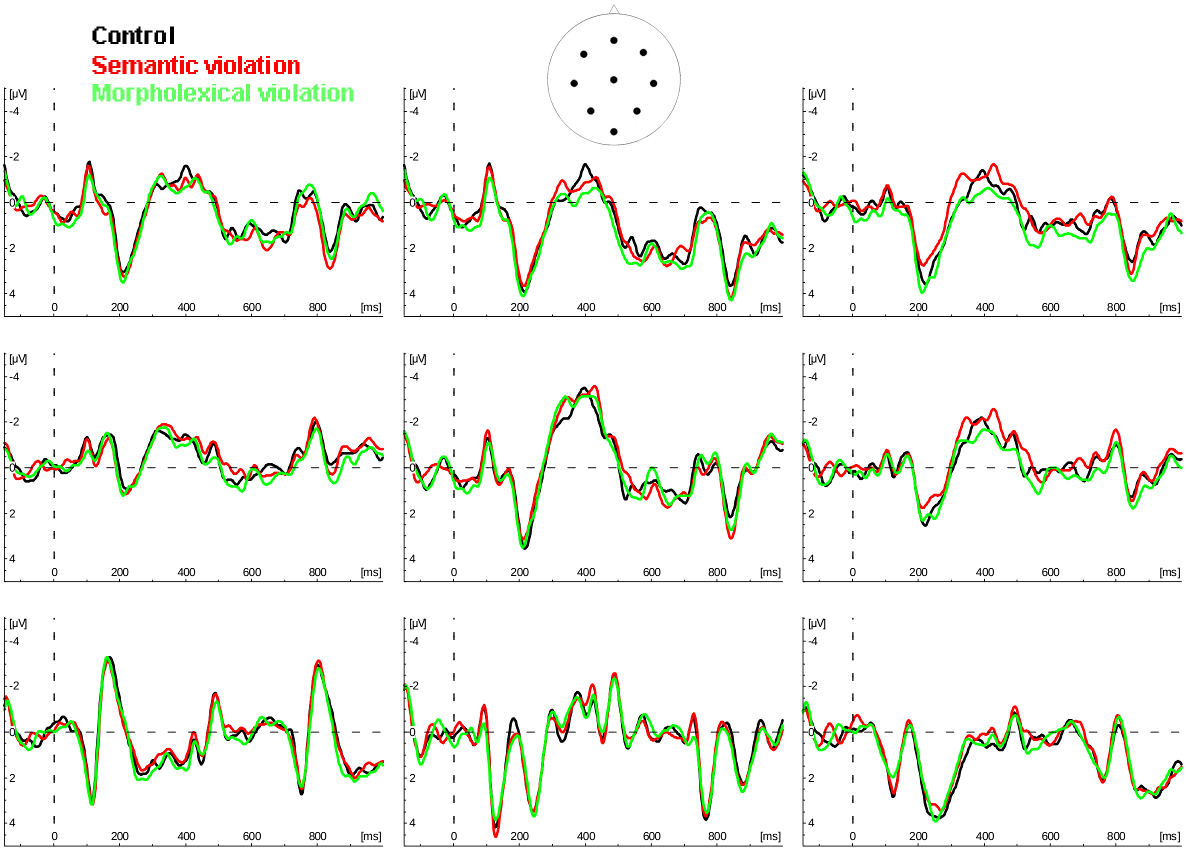

Figure 7. Grand average ERP response to the main verb in the PV Integration manipulation; Control Large condition (black line), Semantic violation (red line), Morpholexical violation (green line)

Effects to the particle for the Particle Verb Integration

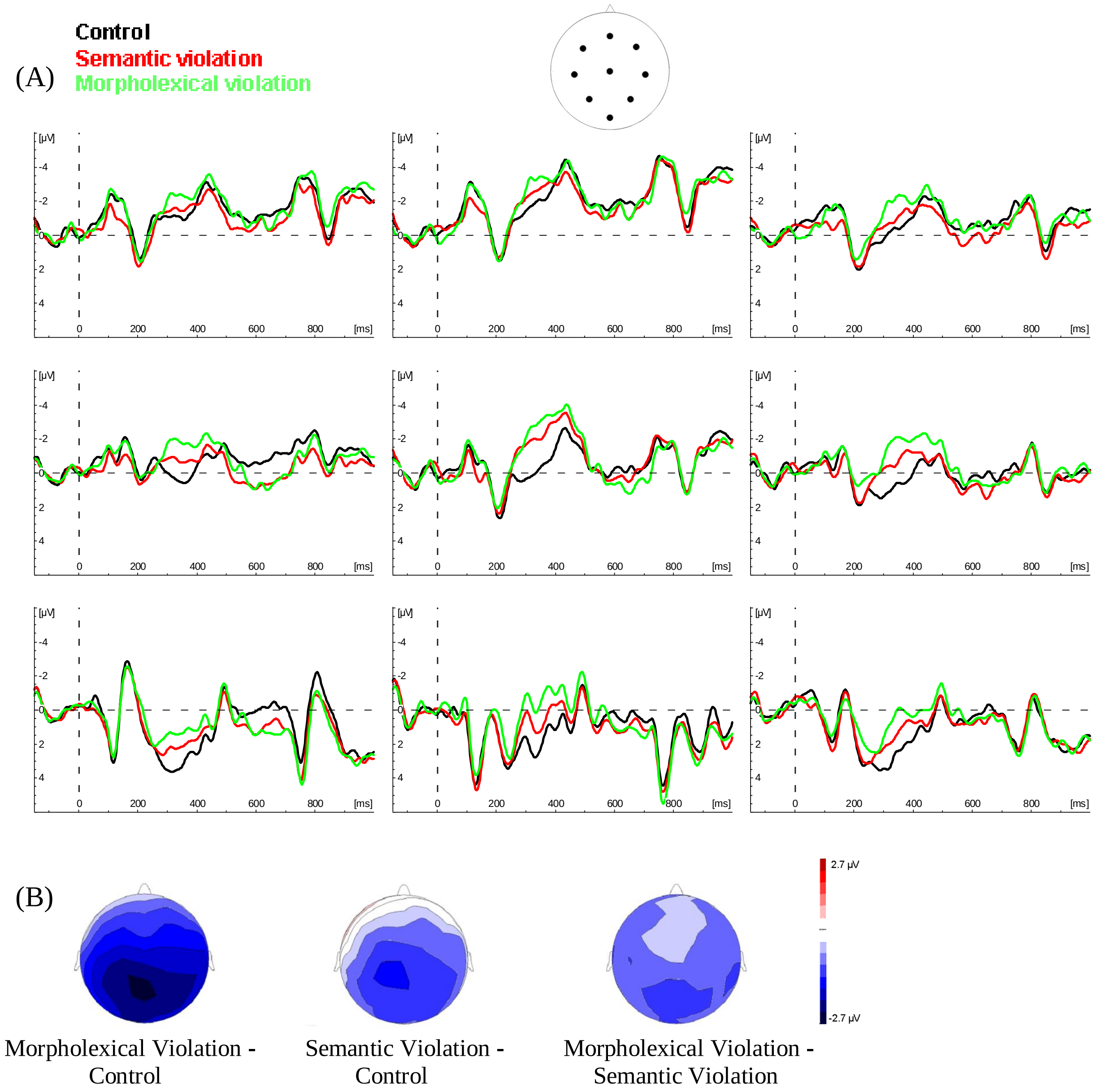

Figure 8. (A) Grand average ERP response to the particle in the PV Integration manipulation; Control condition (black line), Semantic violation (red line), Morpholexical violation (green line). (B) Topographic scalp voltage maps in the time window 300-500 msec.

The ANOVA confirms the presence of an N400 effect. The time window 300-500 msec showed a main effect of Condition [$F_{(2,58)}$ = 8.03, p = .001, MSE = 68.87], of Region [$F_{(1,29)}$ = 59.47, p = .000, MSE = 309.98] and a significant Region x Condition interaction [$F_{(2,58)}$ = 4.8, p = .016, MSE = 10.0]. In the anterior region, a simple effect of Condition was found [$F_{(2,58)}$ = 3.39, p = .043, MSE = 8018] and subsequent analyses revealed a significant difference between the Morpholexical Violation and Control [$F_{(1,29)}$ = 7.2, p = .012, MSE = 27.47] and a marginally significant difference between the Morpholexical and Semantic violations [$F_{(1,29)} = 4.13$, $p = .051$, MSE = 18.69]. In the posterior region, the simple effect of Condition was reliable [$F_{(2,58)} = 11.12$, $p = .000$, MSE = 31.62] with significant differences among all conditions (Semantic Violation - Control [$F_{(1,29)} = 5.26$, $p = .029$, MSE = 31.28]; Morpholexical Violation - Control [$F_{(1,29)} = 18.29$, $p = .000$, MSE = 112.62]; Morpholexical - Semantic Violation [$F_{(1,29)} = 7.65$, $p = .010$, MSE = 25.19]) confirming the central-parietal prominence of the effect.

The time window 500-700 msec showed no significant effect of Condition [$F_{(2,58)} = 1.05$, $p = .356$, MSE = 10.07] nor significant interactions [$Fs < 1$], disconfirming the presence of a P600 effect. To reassure that this effect was really absent, an even more precise time window was selected post-hoc (556 – 770 msec) based on visual inspection of the positivity and subsequently tested. Again, no main effect of Condition was found [$F_{(2,58)} = 1.16$, $p = .320$, MSE = 12.89] nor significant interactions [$Fs < 1$].

Discussion Particle Verb Family Size

In the present study, three classes of particle verb families were constructed based on the amount of particle verb family members that could be formed with the same main verb by changing the particles it could combine with. Three conditions were created from these families: a Large Family condition, a Small Family condition and a condition whose main verbs do not license a particle in Dutch, the Simplex condition. The sentences were constructed with a fixed syntactic structure and the ERP responses to three critical words were analysed: the main verb, the object and the particle (for the Large and Small conditions).

At the main verb, we found an anterior, slightly left lateralised negativity in the time window 300-500 msec for the Large condition relative to the Simplex condition, and for the Small condition relative to the Simplex condition. At the object, an anterior negativity, slightly left lateralised, was found in the time window 300-500 msec for the Large and Small conditions relative to the Simplex condition. This anterior negativity is very similar to the anterior negativity at the main verb: similar deflections with comparable scalp topographies in the same time window for the same contrasts of conditions (although the Small condition differed only marginally from the Simplex condition at the object position). At the particle, an anterior positivity was found in the time windows 100-300 and 700-1000 msec for the Large condition relative to the Small condition.

For both the main verb and the object, the significant contrasts were always the comparison Large and Simplex and Small and Simplex conditions. What makes the Large and the Small conditions similar is the possibility that a particle may appear further in the sentence; what distinguishes them is the size of the subset of what can possibly appear, i.e. the amount of potential particles. What these two conditions have in common and what distinguishes them from the Simplex condition is exactly this possibility: in the case of a Simplex verb, the Dutch speaker's mental lexicon will contain no particle verb entry associated with the main verb. And interestingly having this possibility is exactly what affects the system. We return later to why it might be very important for the system to be sensitive to this possibility.

Anterior negativities (largely left lateralised) around 300 msec have been found mainly following phrase structure violations (Neville, H., Nicol, J.L., Barss, A., Forster, K.I., & Garrett, M.F., 1991; Friederici, Pfeifer & Hahne , 1993). However, in fully grammatical sentences, LANs have been reported for ambiguous words relative to unambiguous words (Hagoort & Brown, 1994) and for long-distance dependencies (wh-dependencies: Fiebach, Schlesewsky & Friederici, 2002; Phillips, Kazanina & Abada, 2005; Kluender & Kutas, 1993; subject and object relative sentences: King & Kutas, 1995) and have often been taken as an index of working memory load (Kluender & Kutas, 1993; see Kutas et al. 2006 for a short review). The anterior negativity found for ambiguous words (Hagoort & Brown, 1994) has been interpreted as evidence for the activation of both meanings of the ambiguous word. The authors suggest that accessing ambiguous words implicates accessing multiple representations, which is taken as more costly than accessing single representations and that would explain the differential processing found for ambiguous words. The effects found for processing long-distance dependencies are interpreted in the light of working memory processes such that increased working memory load is reflected in an anterior negativity, particularly at left hemisphere central electrode sites. The reason why working memory load is increased in long-distance dependencies is due to the fact that the first element of the dependency, for example, the wh-filler in wh-questions, must be retained in working memory until the second element of the dependency, for example the gap, has been encountered.

At this point, our findings for the main verb can be interpreted in two ways. One possible explanation follows Hagoort and Brown (1994): it could be the case that the anterior negativity reflects the activation of multiple meanings of the verb. Suppose that when the main verb is encountered, not only the meaning of the encountered main verb will be activated but also the meaning of the particle verbs that can be formed with that main verb, a hypothesis which is in line with Hillert and Ackerman's model (2002). The other possible explanation follows the left anterior negativity (LAN) found for long-distance dependencies. In the following, we discuss these two accounts and their possible drawbacks.

There are at least two problems with the interpretation that the negativity is caused by the ambiguous meaning of the main verb. First of all, assuming like Hagoort and Brown (1994) that the deflection in the waveform will be more negative in the case of an ambiguous word because activation of more than one meaning takes place, we would expect the condition Large and Small to differ from each other as well: the main verbs in the Large condition can have at least six different meanings (the meaning of the core main verb and the other - at least - five particle verb meanings) whereas the main verbs in the Small condition have around three meanings. The imprecision of this latter is due to the fact that particle verbs can have both a transparent and an opaque meaning (Schreuder, 1990). So it could be the case that the two particle verbs formed with a main verb both have an opaque and a transparent reading, rendering more than three meanings for a main verb from the Small condition. However, this property is also true for the verbs in the Large condition. In this sense, on average, we would expect the main verbs belonging to the Large condition to have more meanings than the main verbs in the Small condition. A significant difference between the Large and Small conditions is, however, not borne out by the results. It is of course conceivable that the graded ambiguity effect, although present, ends up being too subtle for the system either because of ceiling effects, for example, or because of other, stronger effects like the particle verb effect – the difference between having a potential particle verb versus not having a possible particle completion – and, thus, not measurable with the techniques currently used. Secondly, the same kind of negativity found at the main verb is also found at the object. If the ambiguity intrinsic to the verb were the cause of the effect at that point, the same effect should not be present at the object (note that in our materials the object nouns used are not intrinsically ambiguous). More importantly, in our materials, the presence of the object in the Large and Small conditions makes a particle completion mandatory. Moreover, we know from the pre-tests that, after the object has been fully processed, one particle is already pre-activated and this pre-activation is determined by the semantics of the object. Even if there were an ambiguity at the main verb created by the meaning of different particle verbs, at the time the object is processed, this ambiguity is no longer there. And yet a similar effect is found for the main verb and the object. One could argue, of course, that the ambiguity is not yet resolved 300-500 msec after the object. However, lexical ambiguity has been found to be resolved in the N400 time window. Hagoort and Brown (1994), for example, found an N400 effect when the ambiguity was resolved towards the subordinate meaning of the ambiguous word relative to a control word and no differential processing for the dominant meaning of the ambiguous word. Gunter, Wagner and Friederici (2003) found an N400 effect for the resolution of the ambiguity for both the subordinate meaning and the dominant meaning of the ambiguous word. These findings enable us to reject the argument that the ambiguity at the main verb is not yet resolved within 300-500 msec after the onset of the object. The second question emerges, then, whether the negativity we found at the object is itself the reflection of this ambiguity resolution. This hypothesis is, however, less likely than the long-distance dependency account. Ambiguity detection and ambiguity resolution are not reflected by the same ERPs; ambiguous words elicit a LAN whereas disambiguating words seem to elicit an N400 effect (Hagoort & Brown, 1994; Gunter et al., 2003). The effects we find at the main verb and at the object are both anterior negativities, slightly left lateralized. Altogether, it is unlikely that the anterior negativity found at the main verb is a reflection of the activation of multiple meanings or representations of that main verb. It is more conceivable, as we will show now, that the long-distance dependency account is a better account for our findings at this point. Note that the sentences were matched across conditions such that the word frequency of the object and the cloze probability of the particle in the Large and Small conditions at that point were equal. The fact that the anterior negativity is present only for the particle completion sentences relative to the sentences without a particle completion also at the object strongly suggests that the factor causing the negativity is exactly the possibility of a particle completion in the case of the main verb, or even the obligation of a particle completion in the case of the object. This hypothesis is in line with the LAN found for long-distance dependencies. As mentioned in the Introduction, particle verbs are formed by two constituents which are mutually dependent. In our materials, they appeared separately from each other, in this sense forming a long-distance dependency. We come back to the LAN for long-distance dependencies below.

The anterior negativity at the object, as already discussed, is very similar to the anterior negativity at the main verb. So it seems that also at the object, we observe the effects of having a particle completion which is dependent of the main verb compared to not having any completion dependent of it. Interestingly, we know from the pre-tests that at the point our subjects were reading the main verbs, they could not know with certainty that a particle would necessarily follow (and note that the experimental lists also contained sentences without particles). And yet just the mere possibility that a particle may appear is already enough for the system to take that into account, with all its consequences, even though it might turn out to be in vain. But why is it so important for the system to take into consideration that a particle may appear? There are at least two good reasons for this. The first, and more straightforward reason, is to enable the system to build a proper syntactic structure of the sentence. As the sentence unfolds and each new word is encountered, a syntactic structure which accommodates each one of the words is built incrementally (cf. Vosse & Kempen, 2000). In the case of a long-distance dependency, the processing load is increased. As Hawkins (1999, 2004) theorises for wh-dependencies, a constant effort will be made by the language system to associate the first to the second element of the dependency. On the top of this effort, the second element must be identified as belonging to the dependency. At the same time, the system is also engaged in holding the first element in working memory while processing the intervening material and looking for the correct item that will fulfil the dependency. Empirical evidence for the fact that long-distance dependencies are more costly to process has been found with different techniques (reading time: Gibson & Warren, 2004; Stowe, 1986; ERP: Garnsey, Tanenhaus, Chapman, 1989; Phillips et al., 2005; Fiebach et al., 2002). Even though there is uncertainty on whether a particle dependent on the main verb will follow in the case of particle verbs, in theory we can see what the drastic consequences would be of encountering one and not having a position in the structure being built to accommodate it. But the claim we want to make is that having a suitable syntactic structure that can integrate the particle is still not enough. As noted by many scholars (Booij, 1990; Schreuder, 1990; Blom, 2005), many particle verbs have an opaque meaning. As already shown in the description of the MI model, suppose that at the time the main verb is encountered, the system retrieves its meaning and stores it for further processing. Especially in the case of an opaque particle verb, even if there is a slot to fit the particle, the picture is still not complete as having only the meaning of the main verb will not suffice. However, if the form of the main verb is still available, the system can use this form to combine it with the particle and search through the lexicon. In our view, the system is sensitive to particle completions so that, at the time a main verb which licenses a particle is encountered, a) a proper syntactic structure can be built in which a place will be reserved for a potential particle and b) besides the verb semantics being integrated into the representation of the sentence, the verb form will also remain available in working memory for extraordinary processes such as the combination with a particle followed by a search through the lexicon. In this way, if the hypothesis of a particle completion proves true, the particle will have a syntactic spot to be place at and the semantics of the particle verb formed can be recomputed since the necessary elements to access the mental lexicon are available. Under this view, what increases the working memory load is the combination of various factors:

once confronted with a main verb that allows a particle, the system builds a syntactic structure, for example in the manner of Vosse and Kempen (2000), which has the flexibility to take a particle; additionally, the system engages in looking for an element that meets the requirements to fulfil the position while keeping the verb form online, in case this one turns out to be needed for recomputing meaning.

At the particle, an anterior positivity was found in the time windows 100-300 and 700-1000 msec for the Large condition relative to Small. A critical visual inspection of the time window 100-300 msec in Figure 4 casts some doubt, however, on the validity of this effect as the reflection of an underlying cognitive process. The significance of the time interval seems to be caused only by the different amplitudes of the N1 component, which is assumed to reflect discrimination operations within the focus of attention (Luck, 1995; Vogel & Luck, 2000). It is very unlikely that discrimination processes, if they play a role in processing the particle in the first place, will be different for the Large and Small conditions. Therefore, in the remaining, we choose to interpret only the second effect as an indicative of differential processing.

From a descriptive point of view, what happens at the point of the particle is the following: even though the cloze probability of the particle is really high suggesting that one unique particle has already been pre-activated before being encountered, it is only at this point that the system finally gets the **confirmation** from the input that the word encountered is indeed the predicted word. The difference between the two particle verb conditions is the amount of items that could have appeared in that position according to the lexicon.

The results from Kuperman and colleagues (2008) and from our pre-tests argue in favour of the pre-activation of the particle before the particle itself has been processed. Moreover, as we argue in the next section, the integration of the main verb with the particle seems to take place at the semantic level between 300-500 msec. This together suggests that particle pre-activation, activation of particle verb meaning and particle verb integration have already taken place in the time windows preceding our effect. Given this, it becomes more difficult to accept the claim that the positivity found at this point is related to any of the mentioned processes. What remains to be accounted for are the processes following the three just mentioned operations. One possible explanation is, assuming Hillert and Ackerman's (2002) suggestion that all possible particle verb candidates are placed in a lexical buffer, that it is only at the point the predicted particle is finally confirmed that the system can clear out the buffer. We have seen, however, that the view of buffering all possible candidates is very problematic and unlikely to be on the right track. On the other hand, it is still unclear from the

MI model in its current state, whether we should expect differential processing at the particle between the Large and Small conditions; although more MI nodes are de-activated at this point for the Large condition relative to Small, these nodes are assumed to carry no semantic information. Can we expect the inhibition of the MI nodes to be strong enough to increase processing costs and, thus, be reflected in the EEG? A possible, better account for our findings is a way in between. We proposed that the language system builds a structure with a place-holder for a potential particle. When the object is processed, a high expectancy of which particle will follow is created, an assumption which is in accordance with the literature on anticipation and prediction in language (Van Berkum et al., 1999; Fedemeier & Kutas, 1999; Otten & Van Berkum, 2008). Even then, it could be the case that other, less probable candidates also receive some activation, either via spreading from the activation of the expected particle, or because other particles could also be just as suitable candidates as the one expected. This last suggestion receives support from the fact that much of the cloze probability tests run to pre-test experimental materials report correct completion percentages which are not always 100%, showing that, although most subjects agree on one word, other words have also been considered as serious candidates. These less probable candidates might enter the competition with the particle which has the highest degree of expectancy. Even though the expectancy about the upcoming particle leads to its pre-activation, it is only at the time the particle is finally encountered that the previous pre-activation gets the final confirmation. At this point, the remaining competitors can be inhibited. The amount of candidates that could enter the competition is likely to be higher for the Large than for the Small condition. This account is different from Hillert and Ackerman's in that it does not need to assume that all possible particle verbs will enter the competition, but only those which receive activation in the course of the sentence. Yet it does not prevent it from being an ad hoc account which still needs to find empirical support from further studies.

One last point concerning the particle is that one could claim that the null effects in the comparison between the Large and Small conditions are due to the fact that the manipulation is not sensitive enough to capture the underlying existing difference between these two conditions. However, the fact that an effect is present at the particle for the Large condition relative to the Small condition is a suggestion that the manipulation is certainly able to capture the existing differences between these two conditions and, thus, that the absence of an effect earlier in the sentence, i.e. at the main verb and at the object, is simply because, for the system, the difference is either absent or too subtle to elicit measurable patterns. This suggests that at the main verb and at the object, the Particle Verb Family Size is of less importance for the system than it is having a potential particle completion to deal with. The Particle Verb Family Size seems to play a role only at the time the predicted particle is finally confirmed.

Discussion Particle Verb Integration

We now turn to the findings for the PV Integration manipulation.

The PV Integration manipulation was designed to explore the integration of the particle with the main verb. In the control condition, legal particle verbs were used forming intelligible sentences. In the Semantic violation condition, a legal particle verb was used, yielding a semantically ill-formed sentence. In the Morpholexical violation condition, a non-existing particle verb was created by combining an existing main verb with an existing particle. A graded N400 effect was found with the Morpholexical violation eliciting the largest N400, followed by the Semantic violation relative to the control condition. In what follows, we discuss these effects and their interpretation.

The N400 effect found for the Semantic violation condition is in line with the literature on standard semantic violations (cf. Kutas et al. 2006 for a detailed overview). It has been largely accepted that the N400 effect is closely related to semantic processing. More recent work on the N400 effect has made its interpretation slightly shift from seen as an index of semantic integration towards an index of retrieval of stored conceptual knowledge (Kutas & Federmeier, 2000; Kutas et al., 2006; van Berkum, in press). According to the integration hypothesis, the amplitude of the N400 effect is modulated by the difficulty in lexical-semantic integration: words that are harder to integrate in the sentence, for example, elicit a larger negativity than words that are easy to integrate in the sentence. However, the integration hypothesis has been recently undermined by findings of various kinds (see van Berkum, in press for an overview). Kutas and Federmeier (2000) introduced in a review article the relation between long-term semantic memory and the N400 effect, a hypothesis forthcoming from findings on the sensitivity of the N400 amplitude to the organisation of long-term semantic memory (Federmeier and Kutas, 1999). Kutas and colleagues explore further the semantic memory retrieval hypothesis (Kutas et al., 2006). This more recent hypothesis suggests that the amplitude of the N400 is a reflection of the ease with which stored conceptual knowledge associated with meaningful stimulus is retrieved. Van Berkum (in press) reviews the evidence in favour of the retrieval hypothesis and extends it by specifying what could cause the memory retrieval to become more difficult. According to van Berkum, the memory retrieval can be intensified by two factors: contextually disfavoured features and relevance signals. For our discussion, the first factor is of relevance. Van Berkum suggests that at the time a word is encountered, its features can either be supported or not by the context. Contextually unsupported features, for example the features of the word that is creating a semantic violation in a sentence, are retrieved less easily than supported features. In what follows, we opt to interpret our results in the light of the semantic memory retrieval account of the N400 effect as extended by van Berkum.

Foremost, it is important to note that the effect found at the particle for the Semantic violation is a semantic effect. This finding strongly suggests that the main verb and the particle have been combined forming the particle verb, the meaning of the latter has been retrieved and an attempt has been made to integrate that meaning into the sentence. If the meaning of the particle verb had not been retrieved and if the language system had not tried to fit it into the sentence, an effect of a different nature should be elicited, for example a syntactic effect like the P600. And, naturally, if the system arrived at the meaning of the particle verb, it must have been the case that the main verb and the particle were combined into a particle verb. Under the semantic memory retrieval hypothesis as extended by van Berkum (in press), the particle verb in the Semantic violation is more difficult to retrieve given the cues provided by the context, which certainly do not favour the particle verb encountered.

A second finding which is crucial is the N400 effect found for the Morpholexical violation relative to the control condition. In the same line of reasoning, the fact that it is also a semantic effect which is elicited by the Morpholexical violation suggests that also in this case the main verb and the particle were combined into one particle verb even though no entry for that particle verb exists in the lexicon of Dutch speakers. The particle verbs used in the Morpholexical violation were non-existing verbs, although composed of existing Dutch verbs and particles, obeying particle verb formation rules and embedded in sentences obeying the Dutch syntactic rules (Booij, 1990; Blom, 2005). In this regard, these particle verbs are very similar to legal pseudowords. Orthographically legal, pronounceable pseudowords have been found to elicit N400 effects, suggesting that also pseudowords may engage semantic memory (Kutas et al., 2006). The N400 effect found for the Morpholexical condition relative to control is in line with the findings on pseudowords and reinforces the suggestion that the main verb and the particle were combined and an attempt was made to find the combination in the lexicon.

Note, however, that the N400 effect for the Morpholexical violation relative to control was larger than for the Semantic violation relative to control. The significant difference found in posterior electrode sites for the Morpholexical violation relative to the Semantic violation confirms this finding. Importantly, what distinguishes the two violations is the fact that in the case of the Semantic violation, the lexicon contains an entry for the particle verb encountered; in the Morpholexical violation case, the search through the mental lexicon will render no results. What seems thus a crucial difference between these two conditions is the role of the mental lexicon, or as we could say, the role of long-term memory in the sense that a search through long-term memory for a given particle verb will not yield any findings in the case of the Morpholexical violation. The difference in magnitude of the effects relative to the control condition can be interpreted under the retrieval hypothesis: given that the N400 indexes the difficulty of retrieving stored conceptual knowledge, not having an entry for an encountered item in semantic memory will make the process even more costly.

Both violation conditions elicited a semantic effect relative to the Control condition, and only a semantic effect. This finding suggests that particle verbs are integrated primarily at the semantic level. Moreover the observed N400 had no shift in latency compared to the standard N400 suggesting that the integration of the particle with the main verb takes place at the same time scale as the integration of any word in the sentence context.

Isel and colleagues (2005) investigated how the parser uses prosodic information when building up phrase structure representations with an ERP experiment. The stimuli were sentences in German presented in the auditory modality. The German language makes use of particle verbs in a very similar way as Dutch. Two conditions in their study are relevant for our discussion. In the Morpholexical condition of Isel et al., a Morpholexical violation was created by combining an existing main verb which cannot take a particle with an existing particle, yielding an illegal, non-existing particle verb. In this condition, the prosody of the main verb suggested an upcoming particle further in the sentence; however, German speakers know that this main verb does not license any particle. In the Prosodic I condition, the same illegal particle verbs were used; however, prosody did not cue an upcoming particle further in the sentence. In the control condition, a legal particle verb was used with the correct prosody. An N400 effect was found at the particle only for the Morpholexical condition relative to control. The authors suggest that the N400 effect, in this case, is reflecting the costs caused by a lexical search for the representation of the non-existing particle verb. Their suggestion is that, as soon as prosody cues upcoming material, the parser will make use of that information to start a search for the representation of the particle verb. In the case of non-existing particle verbs, the lexical search is more costly since there is no entry for that particle verb in the mental lexicon. In the case of the Prosodic I condition, prosody did not cue an upcoming particle and, therefore, no search process was initiated. These results are convergent with our findings that a search through the mental lexicon, or long-term memory if you will, that renders no outcome is more costly for the system and these findings can be accounted for by the semantic memory retrieval hypothesis.

General Discussion

The results from the Particle Verb Family Size manipulation suggest that in the course of the sentence up to the particle, it is not so much the amount of particles that can occur in a later position in the sentence that matters for the system but rather the mere possibility that a particle could follow later in the sentence. The results from the Particle Verb Integration manipulation suggest that an attempt will be made by the language system to combine a previously encountered main verb with an adverb even when there is no entry in the mental lexicon for the particle verb that would be formed from the combination. So once an online cue is present, the search process will start: in the study by Isel and colleagues (2005), prosody is the online cue that triggers the search; in our case, having a main verb which allows a particle will be enough to trigger the system to look for a potential particle candidate. Additionally, we found that particle verb integration is a semantic process in nature which seems to occur in a similar fashion as the integration of words in a sentence.

The responsiveness of the system to the potential appearance of a particle is an important tool, we proposed in the discussion of the Particle Verb Family Size, for the successful processing of particle verbs. When a verb is encountered that not only exists as a free-standing form but also as the main verb of a particle verb in Dutch, we hypothesize that the system will start building a syntactic structure which is able to incorporate a particle, will engage in keeping the form and the semantics of that verb available and will look for a suitable particle candidate, just in case that verb turns out to be part of a particle verb or, even more troublesome for the system, part of an opaque particle verb.

We now come to the point where we can try to accommodate our findings in the two particle verb processing models discussed in the Introduction. Concerning the empirical support for Hillert and Ackerman's model, as for now, our findings cannot be easily reconciled with it. The idea that full buffering will take place when encountering the main verb entails that more material will be buffered for the Large family than for the Small family, and even less for the Simplex family. The prediction that follows from this is a gradual differential processing for the three conditions, or a particle verb family size effect. However, a gradual effect is absent in the data and so is a significant difference between the

Large and Small conditions at both the main verb and the object. It could be the case, however, that the Particle Verb Family Size effect at these two points is much more subtle for the system than the particle verb effect and thus not measurable with the techniques currently used. Furthermore, we found a semantic effect in the Morpholexical violation relative to the control condition instead of syntactic effects. We interpret the absence of a (E)LAN or a P600 effect as evidence against the idea of buffering all particle verbs associated to the main verb as the latter is processed. If it were the case that a full list of particle verbs is buffered at the time the main verb is encountered, coming across a particle which is not listed would necessarily mean that the particle – main verb combination does not exist, and thus, that the item encountered should not be assigned to the particle category. In this case, either a revision process would take place, yielding a P600 effect (Isel et al. 2005; Kaan & Swaab, 2003) or maybe even a word class violation reflected by an ELAN (Friederici, 2002; Kutas et al., 2006). Of course, one could claim that the Morphological violations used are an extraordinary case of particle verbs. Note, however, that particle verb formation is a productive process (Booij, 2002; Blom, 2005): a simple google search, for example, results in more than 1,000 tokens of the novel particle verbs *insnuiven* (in+snort cocaine) and *inblowen* (in+smoke marijuana) in analogy to *indrinken* (in+drink), which is the practice among the youth to start drinking at home before going out at night. It is unclear from the model how the system would treat novel particle verbs like these. The meaning of these two novel particle verbs is, due to the analogy to *indrinken*, highly predictable and compositional (although their frequencies are not high enough to be included in a dictionary of the Dutch language, for example). Yet it is not likely that these two entries will enter the buffer at the time their main verb is encountered. How does the system treat the particle in order to arrive at the meaning of the particle verb if the only tool it can use to retrieve meaning is the re-access of an item that necessarily had to have been buffered before? As we can see, some adjustments in the model are needed in order for it to work in theory and to account for the empirical findings. On the theoretical level, better specifications of the components, such as “lexical buffer”, processes, such as “re-access of relevant particle information” and restrictions imposed to the activation of candidates should be given. Although the idea of co-activation of family members sounds appealing and finds some empirical support in the literature, it may at the same time, as we argued in the Introduction, become problematic in terms of working memory if one assumes that, for example, all fifteen family members of a main verb will be activated with the same strength. Another crucial point that needs revision is the fact that, as stated now in the model, the only way the system can arrive at the meaning of the particle verb is via previous activation. If, for some reason, the particle verb formed has not been activated before, comprehension will fail completely. On the empirical level, the model predicts a graded increase in processing costs as a function of larger particle verb family sizes but we did not find such an effect. We cannot completely exclude, however, the possibility that we failed to measure this graded effect. Moreover, the role a syntactic object might play throughout the processing is unclear; yet we found in both our pre-tests as well as with ERPs that the object of the sentence plays an important role and may be responsible for particle pre-activation/selection. These are a few suggestions about the adjustments the model lacks.

The other model suggested in the literature and reviewed in the Introduction is the MI model (Schreuder, 1990). One important characteristic of the MI model is that the particle verb is activated via the MI node, which in turn is activated by both the main verb and the particle being present in the input. Our findings at the main verb and at the object cannot be fully accounted for by the MI model. Simplex verbs do not have an MI node whereas particle verbs do and these are exactly the cases in which we find differential processing in the EEG. However, the model in its current state proposes that MI nodes are basically empty entities. It is unclear then whether the activation and maintenance of the MI nodes would be sufficient to increase working memory load relative to a verb which lacks MI nodes, and yet not enough to cause a difference in working memory load between activating and maintaining few or many nodes. Moreover, the high cloze probability of the particles in the pre-tests suggests that particle verbs can be accessed before the activation of the particle. However, the valuable aspect of the model is that it draws the attention to the fact that it is not enough to only have the semantics of the main verb and a spot for the particle to comprehend particle verbs. All in all, also in the case of the MI model, some adjustments are needed if one wants to use it to account for the empirical findings. One point that needs revision is the rigidness of the predictive aspect of the model: the presence of the particle does not seem to be a necessary condition for the access of the particle verb, a finding which the model cannot account for in its current state. Furthermore, the exact role of the MI nodes needs to be better specified. The current picture is that differences found in the EEG for the main verb and the object are exactly the differences for which a MI node is postulated. We do not know yet, however, whether this is the exact prediction we should derive from the model.

Conclusion

The present study was centered on exploring the comprehension of particle verbs in Dutch. Using ERPs, we investigated both the processes underlying the integration of the main verb with the particle and what we called the Particle Verb Family Size effect. Participants read sentences containing inflected existing and non-existing particle verbs, and grammatical sentences with (particle) verbs of various particle verb family sizes. The results together suggest that the language system will actively engage in preparing itself for a possible particle appearance: it will both prepare the syntactic structure in order for it to allow the adjunction of a particle as well as keep the form of the main verb available in case a new search through the lexicon proves necessary. Performing these tasks increases working memory load, which is reflected in a slightly left-lateralized anterior negativity. The responsiveness of the system to the possibility of an upcoming particle is assumed to be an important mechanism the system relies on in order to cope with the complex task disjoint particles pose to the language system. Additionally, the integration of the main verb with the particle seems to be a semantic process, which takes place in similar fashion as words are integrated into the sentence context. Finally, the two models of particle verb processing in their current states cannot account for the empirical findings. An ideal model would have to have both a structure building component to account for the fact that the language system is sensitive to potential particle completions as well as a memory component to account for the increased working memory load as long as the presence of a particle has not been confirmed.

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