Semantic and syntactic constraints on the production of subject-verb agreement

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Semantic and syntactic constraints on the production of subject-verb agreement

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General Introduction

In many languages, including English and Dutch, the grammatical subject of a sentence agrees in number—singular or plural—with the main verb. In principle, the system is simple: Singular subjects require singular verbs and plural subjects require plural verbs. In English, number agreement has to be computed more than once every 16 written words; in running speech, this computation is executed on average, at least once every 5 seconds (Bock, 2003). As agreement is implemented so frequently, the process is usually fast and errorless. However, sometimes the number on the verb does not agree with the number of the subject (Bock & Eberhard, 1993; Bock & Miller, 1991; Bock, Nicol, & Cutting, 1999; Haskell & MacDonald, 2005). These errors provide a window into the process of agreement, and enable researchers to study how conceptual information is mapped onto linguistic representations.

The most common agreement error occurs when a verb agrees with a noun that is not the subject (e.g., *the key to the cabinets* ***were*** *rusty from many years of disuse*; Pearlmutter, Garnsey, & Bock, 1999). The plural number of the local noun (*cabinets* in the example)—the noun that is located between the subject head noun and the verb—interferes with the singular number of the head noun *key* and donates a spurious plural number to the verb: *were*. A well-attested property of this attraction effect is that it is asymmetrical with respect to singular and plural agreement: It is much stronger for subjects with singular heads and plural local nouns (*the key to the cabinets*) than for subjects with plural heads and singular local nouns (*the keys to the cabinet*; Bock & Eberhard, 1993; Bock & Miller, 1991; Bock, et al., 1999; Haskell &

MacDonald, 2005; Vigliocco, Butterworth, & Semenza, 1995). One account of this asymmetry is that nouns have a number feature that is specified for plurals, but is empty for singulars. Plurals trigger plural verb agreement, whereas singular verbs are a default when no number feature is specified (e.g., Eberhard, 1997; Eberhard, Cutting, & Bock, 2005).

The strength of this attraction effect is modulated by the properties of the separate nouns as well as the properties of the full subject phrase. Whereas most of these influences are, like the agreement process itself, syntactic in nature, there are semantic influences as well. The duality between syntactic and semantic effects is one of the central issues of this thesis. I will first give a brief overview of the syntactic and semantic influences on subject-verb agreement before introducing the experimental chapters in this thesis (see Häussler, 2012, for a detailed literature review).

Syntactic properties of nouns that influence agreement include grammatical number, morphophonology, and number frequency. Although the attraction effect described above is driven by the grammatical number of the local noun, it can be enhanced by morphophonological features. Singular head nouns with a determiner that is ambiguous for number (such as *de* in Dutch, which can be singular or plural) are more vulnerable to attraction than singular head nouns that have an unambiguous singular determiner (Anton-Mendez & Hartsuiker, 2010; Hartsuiker, Schriefers, Bock, & Kikstra, 2003). Morphophonological features on local nouns, however, have less of an effect on agreement. For instance, singular local nouns ending in *-s* (e.g., *cruise*), which might be mistaken for a plural noun (e.g., *crews*), do not increase attraction (Bock & Eberhard, 1993; Haskell & MacDonald, 2003). In addition, attraction is influenced by the frequency of the singular and plural forms of the local nouns. Barker and Nicol (2000) found that local nouns that are most frequent in their plural

form caused stronger attraction than nouns that are most common in their singular form.

Syntactic properties of the full subject phrase, such as the intervening material between the head and local noun, can influence the strength of attraction as well. When the distance between the head noun and the verb increases, more agreement errors occur (Bock & Cutting, 1992; Gillespie & Pearlmutter, 2013; Haskell & MacDonald, 2005; Kaan, 2002). This effect seems to be limited to the length of the main clause as relative clauses within the subject noun phrase have less of an impact on agreement processes (Bock & Cutting, 1992; Bock & Miller, 1991). Similarly, nouns that are syntactically closer to the head noun have a stronger influence on agreement than nouns that are further away hierarchically (Franck, Vigliocco, & Nicol, 2002, but see Gillespie & Pearlmutter, 2013, for an alternative proposal).

Although subject-verb agreement is mainly a syntactic matter, semantic factors also influence agreement. For instance, when the head noun and the local noun are semantically closely related (e.g., *canoe* and *sailboat*), more agreement errors occur compared to when they are unrelated (Barker, Nicol, & Garrett, 2001). Similarly, Thornton and MacDonald (2003) showed that more agreement errors were produced when both the subject head noun and the local noun were equally plausible as a subject, compared to when only the head noun was a plausible subject. These results suggest that the agreement process does take meaning into account.

The above described effects on agreement all influence the magnitude of the attraction from the grammatical number of the local noun. In addition to being grammatically singular or plural, nouns and noun phrases can also be notionally, or conceptually, singular or plural. The notional number of both isolated nouns and full subject phrases has been shown to influence the agreement process. Most often a

grammatically singular subject is also notionally singular, but deviations exist. For example, some nouns have a plural meaning despite being grammatically singular (e.g., *committee*, *gang*). When such a collective noun is used as a head noun, more attraction errors occur when combined with a plural local noun, compared to a non-collective head noun (Bock, et al., 1999; Haskell & MacDonald, 2003). Effects of collectivity from local nouns have not been reported (e.g., Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001; Deutsch & Dank, 2009).

Whereas collectivity can influence notional number on the word level, distributivity influences notional number at the phrase level. For example, despite being grammatically singular, a phrase such as *the label on the bottles* can be interpreted as referring to the same label on multiple of bottles, thus, as being notionally plural. Indeed, stronger attraction has been found for distributed phrases with plural local nouns compared to non-distributed phrases with plural local nouns (Bock, Carreiras, & Meseguer, 2012; Vigliocco, Butterworth, et al., 1996; Vigliocco, et al., 1995).

Another semantic factor that has an influence on agreement, and one that is of central importance in this thesis, is semantic integration. Solomon and Pearlmutter (2004) describe semantic integration as the relationship between a subject head noun and a local noun at the conceptual level of a sentence. This relationship can be tight (integrated) or weak (unintegrated). For example, in *the ketchup or the mustard*, the two nouns are semantically closely related, because they are both condiments. However, the context does not provide any information about the relation between the two. This makes the *ketchup* and the *mustard* semantically unintegrated. In *the bracelet made of silver*, the two nouns are more closely related; the bracelet is actually made of silver. The effects of semantic integration on agreement have been addressed

in several studies that have yielded inconsistent patterns. Thus, the precise influence of semantic integration on the agreement process remains unclear.

For instance, Solomon and Pearlmutter (2004) argued for a lexical interference account: nouns in an integrated phrase are more likely to be planned in parallel than nouns in an unintegrated phrase. Parallel planning leads to interference when the number features of the nouns mismatch. In five sentence completion experiments, they found a consistently stronger attraction effect for tightly integrated than for weakly integrated subject phrases in which the head and local noun mismatched in number. Solomon and Pearlmutter interpreted this effect to indicate that parallel planning of a head and local noun with mismatching number led to stronger number interference and consequently more attraction errors compared to nouns planned more sequentially. These results fit with other evidence, for instance from speech error analyses and the picture-word interference paradigm, that demonstrates that speakers may processes several phrases in parallel, which can lead to lexical interference (Allum & Wheeldon, 2007; Butterworth, 1981; Oppermann, Jescheniak, Schriefers, & Görges, 2010; Schriefers, 1993).

Brehm and Bock (2013), however, took a different view, proposing that strong integration in the message promotes notional singularity. On this notional number hypothesis, an integrated referent is more likely to be conceived of as a single notional individual, whereas unintegrated referents are more likely to be treated as notional multiples. In their study, Brehm and Bock (2013) found fewer errors after integrated than after the unintegrated preambles. This occurred in both the matching and the mismatching number conditions, and independent of the attraction effect in the mismatching condition. These results do not support Solomon and Pearlmutter's (2004) lexical interference hypothesis, since this predicts that there cannot be any

interference between the number features of the head noun and the local noun in the matching condition, regardless of the degree in integration of the phrases.

Many of the findings described above, such as attraction, the asymmetry of attraction, and notional number effects, are captured in the Marking and Morphing model proposed by Eberhard, Cutting, and Bock (2005). This is a mathematical model of production that uses the number features of all constituents in the subject phrase to predict the probability of a plural verb. The model assumes two stages: marking and morphing. First, the notional number of a message is evaluated; in other words, whether the speaker wants to talk about one or multiple things. In the marking stage, this number value is used for grammatical encoding: The selected nouns receive singular or plural marking. During the morphing stage, the initial notional number value is reconciled with the grammatical number of the selected nouns, and passed on to the verb which then receives the corresponding morphology.

The formula to predict the probability for a plural verb is $S(r) = S(n) + \sum_j w_j \times S(m_j)$, where S(r) stands for the root number of the subject phrase, which consists of the initial notional number S(n) plus the sum of the weighted head noun and local noun number features. The number of the head noun always has a larger weight than the local noun, as the number of the subject phrase usually depends on the number of the head noun. The number values range between -1 and 1, with negative numbers indicating singularity and positive numbers plurality. The model assumes that grammatical singularity is unmarked as a default, with a value of 0, predicting an attraction asymmetry: Attraction can only come from positively marked plurals, not from zero-marked singulars. Note that singulars can be marked and receive a -1 value, for instance when a singular numeral is used (e.g., *one key*). Thus the model predicts moderate notional effects, on both phrase level and word level, independent from

grammatical effects stemming from the local noun number. I used this model as a starting point for my thesis work, as it yields clear predictions that can be experimentally tested.

The debate on the influence of semantic integration motivated the first experimental chapter (Chapter 2). Here, I examined the lexical interference and notional number hypotheses through a series of experiments in Dutch using factorial manipulations of semantic integration and local noun number. Experiment 1 used a constrained sentence completion paradigm. Participants were presented with a written adjective and a subject phrase and had to provide a spoken completion using the adjective. As in the earlier studies, target sentences featured singular head nouns combined with singular or plural local nouns. Error rates for verbs and speech onset times for correct continuations were measured. In the second and third experiment, I used a speeded metalinguistic judgment task introduced by Staub (2009, 2010). Participants silently read the same subject phrases as in Experiment 1 and selected the appropriate Dutch verb phrase (singular or plural) as quickly as possible by pressing one of two buttons. In addition to testing the two competing hypotheses, Chapter 2 aimed to assess whether this forced-choice paradigm, which is simpler and faster to administer and yields results that are faster to analyze, would yield patterns similar to the more laborious spoken sentence completion paradigm.

The results of Chapter 2 suggested that speakers treated integrated sentences as notionally singular, supporting the notional number hypothesis, but also indicated that this semantic effect was independent of the grammatical attraction effect. Therefore, in Chapter 3, I investigated the independence of the semantic effect (integration) and the syntactic effect (attraction), by boosting the integration effect. With a forced-choice judgment task, I showed that the effect of semantic integration

can be increased by presenting pictures along with auditory sentence fragments, while keeping the attraction effect constant. The results suggested that semantic and syntactic influences work independently in the agreement process.

In Chapters 2 and 3, I used sentence completion tasks. Much of the experimental research on agreement has used the sentence completion paradigm first introduced by Bock and Miller (1991). In this paradigm, participants hear or read subject noun phrases, such as *the key to the cabinets*, and complete them by adding matching verb phrases. Many varieties of this task have been used: Subject phrases are presented verbally, either with the whole sentence on the screen, or word-by-word, or auditory with or without accompanying pictures. Completions are given in different manners: Repeating the subject and adding a verb phrase, only producing a verb phrase, using a given adjective or not, or pressing a button for singular or plural. Although the paradigm has successfully revealed many factors that play a role during agreement, it also has its limitations. For instance, participants first have to comprehend the subject phrase, before they can produce their response. In addition, unlike in natural language production, the pre-verbal messages in sentence completion tasks are not generated by the participants themselves. Therefore, in Chapters 4 and 5 I developed novel speeded picture description tasks, which more directly tested the production of subject-verb agreement.

In Chapter 4, I developed a new tool to assess grammatical attraction. Previous agreement studies have typically used the sentence completion paradigm with significant variation in lexical items. This has disadvantages if one wants to assess grammatical attraction independent of lexical factors. Lexical variability may also be disadvantageous for different speaker populations: Speakers with limited vocabularies or speakers with reading difficulties may perform poorly on these tasks irrespective of

their grammatical encoding skills. Using lexically simple items, I aimed to replicate the attraction asymmetry with a sentence completion task and a picture description task. Both tasks showed the asymmetry but to different degrees. The results suggested that the picture description task was more sensitive to attraction and has the advantage of being more broadly applicable.

In Chapters 2 to 4, semantic integration was manipulated, with results consistently supporting the notional number hypothesis, rather than the lexical interference hypothesis. The lexical interference hypothesis proposes that semantic integration encourages parallel planning of noun phrases and that parallel planning increases attraction. I did not find converging evidence for the effect of semantic integration on parallel planning or error rates in the previous chapters. Therefore, Chapter 5 investigated whether parallel planning of mismatching head and local nouns increased the likelihood of agreement errors. In a picture description task, parallel planning was encouraged or discouraged not by varying the degree of semantic integration, but by varying the spatial distance between the head and local noun objects. To assess whether parallel planning was occurring, I manipulated the semantic similarity between the head and local noun objects. The results showed that the manipulations that increased parallel planning did not increase agreement error rates, which again did not support the lexical interference hypothesis.

In Chapter 6, the General Discussion, I discuss the results in more detail and relate them to the Marking and Morphing model. Although the majority of my findings are captured by the model, there are some noteworthy results that are not. Thus, some additions to the model are proposed to account for the results in this thesis.

Chapter 2

Effects of semantic integration on subject-verb agreement: Evidence from Dutch

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Abstract

The generation of subject-verb agreement is a central component of grammatical encoding. It is sensitive to conceptual and grammatical influences, but the interplay between these factors is still not fully understood. We investigate how semantic integration of the subject noun phrase ("the secretary of/with the governor") and local noun number ("the secretary with the governor/governors") affect the ease of selecting the verb form. Two hypotheses are assessed: According to the notional hypothesis, integration encourages the assignment of singular notional number to the noun phrase and facilitates the choice of the singular verb form. According to the lexical interference hypothesis, integration strengthens the competition between nouns within the subject phrase, making it harder to select the verb form when the nouns mismatch in number.

In two experiments, adult speakers of Dutch completed spoken preambles (Experiment 1) or selected appropriate verb forms (Experiment 2). Results showed facilitatory effects of semantic integration (fewer errors and faster responses with increasing integration). These effects did not interact with the effects of local noun number (slower response times and higher error rates for mismatching than for matching noun numbers). The findings thus support the notional hypothesis and a model of agreement where conceptual and lexical factors independently contribute to the determination of the number of the subject noun phrase and, ultimately, the verb.

Introduction

In many languages, including English and Dutch, the grammatical subject of a sentence agrees in number with the main verb. In principle, the system is simple: Singular subjects require singular verbs and plural subjects require plural verbs (e.g., *the dog barks* and *the dogs bark*). The process of agreement is a key component of grammatical encoding, and speakers calculate it in many, if not most of their utterances, and as such, the cognitive processes underlying the generation of agreement have been investigated in numerous studies (Bock & Miller, 1991; Bock, Nicol, & Cutting, 1999; Eberhard, 1997; Franck, Vigliocco, & Nicol, 2002; Haskell & MacDonald, 2003; Humphreys & Bock, 2005; Vigliocco, Butterworth, & Garrett, 1996). Given the frequency with which agreement occurs, it is clear that a comprehensive theory of language production should explain the mechanisms underlying the generation of agreement. In addition, the issue of how agreement is established is tightly linked to other central issues in psycholinguistics, such as how conceptual information is mapped onto linguistic representations, which processing units speakers prefer when they plan utterances, and how conceptual and linguistic information are stored in working memory while utterances are prepared.

Much of the experimental research on the production of agreement has used a sentence completion paradigm first introduced by Bock and Miller (1991). In this paradigm, participants hear or read subject noun phrases, such as *the key to the cabinets*, and complete them by adding matching verb phrases. In order to explore agreement processes, researchers have varied the content and structure of the preambles and observed how these variations affect the participants' choice of verb form. Of particular interest have been the conditions influencing the likelihood of committing agreement errors, such as *the key to the cabinets ARE lost.* Although this

paradigm is not a pure production task as participants must first comprehend the preambles, it has provided critical insight into how both syntactic and semantic constraints influence the generation of agreement. Many agreement studies, including the present investigation, have used preambles where the head noun (*key* in the example), is followed by another noun, called the local noun (*cabinets* in the example). A robust finding across these studies is the attraction effect: When the number of the head noun is singular, speakers are more likely to use an incorrect plural verb form when the number of the local noun is plural relative to when it is singular. The attraction effect points to interference between the number features associated with the head noun and the local noun. Interference could arise during the assignment of number to the subject noun phrase or during the selection of the corresponding verb form (see Bock & Middleton, 2011, for a critical evaluation of different accounts of the attraction effect).

In order to understand the origin of attraction and the cognitive processes involved in the generation of agreement more generally, many studies have varied the conceptual and syntactic properties of the preambles and observed the effects on the rates of agreement errors (e.g., Bock & Cutting, 1992; Bock & Miller, 1991; Franck et al., 2002; Haskell & MacDonald, 2005; Kaan, 2002). The current study focuses on a conceptual variable called semantic integration. The importance of this variable for agreement processes was first highlighted by Solomon and Pearlmutter (2004). They defined integration as "how closely linked two parts of a message are within a discourse representation or mental model" (p.4). In integrated noun phrases, one noun is often physically or characteristically part of the other noun, or role-defined with respect to it. For instance, in *the secretary of the governor* there is a tight relationship between the two concepts referred to in the noun phrases, because being employed by

the governor is a formal role of the secretary. This is not the case in *the secretary with the governor*, which refers to a secretary somewhere close to a governor. Similarly there is a tighter conceptual relationship in *the pizza with the yummy toppings* relative to *the pizza with the tasty beverages*. In five sentence completion experiments, Solomon and Pearlmutter (2004) varied the degree of semantic integration in the preambles and observed the effects on the rates of plural verb agreement and attraction. In all experiments, they found the usual increase in error rates when singular head nouns were combined with plural rather than singular local nouns. More importantly, however, they found a larger attraction effect for integrated relative to unintegrated preambles.

Solomon and Pearlmutter's explanation of the increase in attraction with increased integration put lexical-grammatical number properties at the forefront: Retrieval interference between nouns that differ in grammatical number disrupts the agreement process. More interference arises when referents are integrated, because the components of the referring expression (the subject noun phrase) are more likely to be lexicalized in parallel. As Solomon and Pearlmutter noted, this account fits well with other evidence demonstrating that speakers may process several phrases in parallel, which can lead to lexical interference (Butterworth, 1981; see Allum & Wheeldon, 2007, and Oppermann, Jescheniak, Schriefers, & Görges, 2010, for more recent findings demonstrating parallel processing of several phrases).

However, considering the conceptual representation of number, the interaction with attraction is somewhat paradoxical: More integration typically implies more conceptual unity, and this in turn is typically associated with singular agreement. In line with this view, Brehm and Bock (2013) proposed that stronger integration in the message promotes notional singularity. According to their notional hypothesis, the

variation in conceptual number induced by semantic integration stems from referential properties behind subject noun phrases. Specifically, an integrated referent is more likely to be construed as a single notional entity (i.e., one unit), whereas unintegrated referents are more likely to be treated as notional aggregates (i.e., multiple units). Given the known impact of notional number on agreement processes (Eberhard, 1999; Thornton & MacDonald, 2003; Vigliocco, et al., 1995; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996), this view predicts that strong semantic integration should bias speakers toward the selection of singular verb forms, and weak semantic integration towards the selection of plural verb forms regardless of the plurality of the head and local nouns. To account for Solomon and Pearlmutter's opposite results, Brehm and Bock noted that there was an unusually low response rate for unintegrated subject noun phrases in Solomon and Pearlmutter's experiments. The implication is that less attraction might have occurred after unintegrated subjects because there were fewer opportunities for attraction to occur, not because unintegrated subjects reduced retrieval interference.

Brehm and Bock (2013) conducted two experiments to evaluate the contrasting predictions following from their notional hypothesis and Solomon and Pearlmutter's lexical interference hypothesis. One experiment aimed to replicate the findings reported by Solomon and Pearlmutter using the same materials and procedure[1]. As in Solomon and Pearlmutter's study, the attraction effect was found to be stronger for highly integrated than for less integrated preambles. However, this pattern arose primarily because integration led to a lower error rate in the matching (i.e., singular head noun, singular local noun) relative to the mismatching (i.e., singular head noun, plural local noun) condition. Overall, Brehm and Bock found

[1] Solomon and Pearlmutter carried out five experiments and a meta-analysis; Brehm and Bock carried out two experiments using all items from Solomon and Pearlmutter's experiments.

fewer errors after integrated than after the unintegrated preambles. These results are not consistent with Solomon and Pearlmutter's lexical interference hypothesis since there cannot be any interference between the number features of the head and local nouns in the matching condition, regardless of the degree to which the phrases are integrated.

In a second experiment, Brehm and Bock (2013) used the same materials but a different task: Instead of repeating the preambles and completing them in any way they wished, the participants read the preamble silently and then produced a verb phrase combining *is* or *are* with one of four adjectives (*good*, *bad*, *ready*, and *true*; for use of similar paradigms see Gillespie & Pearlmutter, 2011b; Haskell & MacDonald, 2003; Staub, 2009, 2010). This constrained procedure has two advantages over the classic completion paradigm: First, it yields a higher proportion of responses that can be scored with respect to verb number. Second, as the participants do not repeat the preambles, response latencies can be examined as well as error rates. For both dependent measures Brehm and Bock found evidence for attraction, that is, more errors and slower response onsets after plural relative to singular local nouns. In addition they found a facilitatory effect of integration—faster response onsets and fewer errors after integrated than after unintegrated preambles. Importantly, these effects did not interact. These results thus provided critical support for Brehm and Bock's notional hypothesis, and are at odds with the lexical interference hypothesis.

Given the inconsistencies of the findings obtained by Solomon and Pearlmutter and by Brehm and Bock, we sought additional evidence that might help decide between the competing accounts of the effects of semantic integration. The current study was carried out in Dutch, a language which is well suited to this goal because, despite broad similarities in other facets of the languages, English and Dutch

differ in the incidence of number inflection and the relevance of grammatical number specification to verb agreement. In English, regular verbs specify number only for the third-person in the present tense, and not at all in the past tense. Among past-tense verbs, only forms of *to be* (*was* and *were*) carry overt flags for number. By comparison, verbs in Dutch carry inflections that specify number with morphemes that are highly regular and present on most verbs in both the present and past tense. According to the notional hypothesis, integration effects should be present to similar degrees regardless of the lexical-grammatical properties of a language's number morphology. The interference hypothesis makes a different prediction: To the extent that interference among the words carrying lexical-grammatical properties is a source of agreement errors, in a language where lexical-grammatical properties have primacy in the agreement system, it is more likely that mismatching features will lead to error. Thus, if semantic integration creates notional number variations that systematically influence singular and plural number agreement, integration effects in Dutch should be similar to those found in Brehm and Bock: More integration should support singular agreement. But to the extent that integration leads to parallel retrieval and competition between words, as Solomon and Pearlmutter have argued, integration in Dutch is likely to create the opposite effect: Stiff competition between singular and plural noun forms for control of the verb should readily lead to error, due to the nearly exceptionless triggering of plural verb morphology by plural noun morphology.

In the present study we examined these hypotheses using factorial manipulations of integration and local noun number. Experiment 1 used a constrained sentence completion paradigm similar to that used by Brehm and Bock. The main difference was that instead of choosing one of four adjectives on each trial, the participants in our study used an adjective provided at trial onset in conjunction with

the appropriate form of the verb *zijn (to be)*, singular *is* or plural *zijn*. In Experiment 2, we used a speeded metalinguistic judgment task introduced by Staub (2009, 2010). Participants silently read the same preambles as in Experiment 1 and then selected the appropriate Dutch form of *zijn (to be)*, *is* or *zijn*, as quickly as possible. The main goal was to obtain converging evidence for the conclusions drawn on the basis of the results of Experiment 1 using a slightly different method and new samples of participants. In addition, we aimed to assess whether this paradigm, which is simpler and faster to administer and analyze, would be as sensitive to the experimental manipulations as the more laborious spoken preamble completion paradigm.

The predictions for both experiments were the same. First, there should be attraction effects on both error rates and response latencies, indicating that agreement with a singular head noun is more difficult in the presence of a plural rather than a singular local noun. Second, there should be effects of integration on error rates and response times. The notional hypothesis predicts a main effect of integration: faster responses and fewer errors for integrated than unintegrated preambles. By contrast, the lexical interference hypothesis predicts an interaction of integration with attraction: stronger attraction for integrated than unintegrated preambles.

Experiment 1

Method

Participants. The experiments described in this paper were conducted with adult native speakers of Dutch, who were recruited through advertisements in local newspapers. They gave written informed consent before the study and were paid €8 for participating. Experiment 1 was carried out with 27 participants. The data obtained from three participants were excluded from the analyses because they failed to repeat

the preambles correctly on more than a third of the trials. The remaining 24 participants (21 female) ranged in age from 18 to 54 years (M = 26.96 years, SD = 11.1). Seventeen participants were university students.

Materials. The materials consisted of 100 experimental items, 100 fillers, 24 items used on catch trials, and 6 practice items. Each item consisted of a preamble and an adjective. The materials are listed in Appendices A to D.

Sixty-eight of the experimental preambles were Dutch translations or adaptations of items used by Solomon and Pearlmutter (2004) and Brehm and Bock (2013). Adapting the items was necessary to avoid nouns ending in their singular form with *-en* or *-s*. These endings are homophonous to Dutch plural morphemes and might cause number confusion (Haskell & MacDonald, 2003). We also avoided neuter nouns, where the determiner—*het* for singular and *de* for plural—specifies number. Thus all head and local nouns were common gender nouns, which take the number-ambiguous definite article *de*.

Thirty-two of the original preambles included relative clauses (e.g., *the report that described the traffic accident(s*)). These items could not be translated or adapted because in Dutch relative clauses the verb, rather than the local noun, appears in the clause-final position (e.g., *het rapport dat het ongeluk (de ongelukken) beschrijft* - the report that the accident(s) describes). They were replaced by 32 new items, which were structurally similar to the remaining items (see Appendix A).

Each of the 100 experimental items appeared in four versions resulting from crossing the variables Semantic Integration (integrated vs. unintegrated) and Local Noun Number (singular vs. plural, see Table 1 for an example). In 57 items, the integrated and unintegrated version only differed in the preposition (e.g., *the drawing of/with the flower(s)*). In the remaining 43 items, the two versions differed in the local

noun (e.g., *the bowl with the stripe(s)/with the spoon(s)*). As in Solomon and Pearlmutter's (2004) study, the head noun in all experimental preambles was singular.

Table 1
Example of an Experimental Item

Integration	Local Noun Number	Sentence	Adjective
Integrated	Singular	De oppas van de kleuter	geestig
	Plural	De oppas van de kleuters	geestig
Unintegrated	Singular	De oppas met de kleuter	geestig
	Plural	De oppas met de kleuters	geestig
		The baby-sitter of/with the toddler(s)	*funny*

Fifty of the filler items were structurally similar to the experimental items but featured a plural head noun. The remaining 50 filler items were coordinated noun phrases (see Appendix B). Thus, all filler items required plural verb forms. Catch trials (in which participants had to repeat and complete the entire preamble, see Procedure) were constructed to make sure that the participants always read the preambles in such a way that they would be able to repeat them (see Appendix C). The items used on the 24 catch trials were structurally similar to the remaining items, although (due to an oversight) four featured simple noun phrases. Twelve of the catch trials required singular verb forms and the other twelve required plurals. The set of practice items included four items each requiring singular and plural verb forms. Two additional practice trials were catch trials. Each preamble was combined with an adjective, which was selected to be a plausible continuation of the preamble. This was later confirmed in a rating study by 60 participants who did not participate in the main experiments. The participants were asked to rate how plausible they thought the adjective was in combination with the subject of the sentence on a 7-point scale. Every participant saw 50 of the experimental items combined with 25 plausible and

20 implausible filler items, which were expected to yield high and low plausibility ratings, respectively. The average ratings are shown in Table 2.

Table 2
Mean (SD) Plausibility Ratings of the Adjectives for each Condition

	Integration		
	Unintegrated	Integrated	
Singular local noun	4.43 (2.15)	5.67 (1.76)	
Plural local noun	4.53 (2.17)	5.69 (1.74)	
Fillers (high plausibility)			6.48 (1.09)
Fillers (low plausibility)			1.57 (1.22)

Four lists of materials were created and each list was seen by six participants. Each list included all practice, catch, and filler items and one version of each experimental item. In each list, 25 of the experimental items appeared in each condition, and each experimental item was presented in a different condition in each list. Stimuli were shown in black on a grey background, in Arial font (0.4° visual angle).

The lists were divided into a practice block of six trials, and four experimental blocks of 56 trials, each consisting of 25 experimental items, 25 filler items, and six catch trials. The trials in each block were individually randomized and the order of the blocks was fixed.

Procedure. The participants were tested individually in a soundproof booth. The experimental and filler trials had the following structure: First, a small fixation cross (0.5° visual angle) was shown on the left side of the screen (10% from the left margin) for 500 ms. It was followed by the adjective, shown for 1000 ms, another fixation cross, shown for 500 ms, and the preamble. The preamble was presented for 40 ms per character, or 1000 ms, whichever was longest. Then an exclamation mark *(!)* was shown for 500 ms. After 2600 ms the next trial began. The catch trials had the

same structure, except that the word *herhaal (repeat)* was shown instead of the exclamation mark, and the duration of the trials was extended by 2000 ms.

The participants were told that on most of the trials, they would see an exclamation mark and should then complete the preamble using *is* or *zijn* and the adjective shown at trial onset. On some trials, when *herhaal* was shown, they should first reproduce the beginning of the sentence and then add *is* or *zijn* and the adjective.

After the main experiment, integration ratings were collected from the participants. They received a written list of the preambles in the version they had seen before and were asked to rate the degree of semantic integration on a scale from 1 (not very integrated) to 7 (tightly integrated). The instructions and examples were translations of the instructions and examples used by Solomon and Pearlmutter[2]. Participants were asked to rate the integration between the nouns in the preamble, regardless of any semantic similarity between the nouns. The example for a weakly integrated preamble was *de ketchup met de mosterd/the ketchup with the mustard*, and the example for a highly integrated preamble was *de armband van zilver/the bracelet of silver.* Although *ketchup* and *mustard* are semantically closely related, they are not integrated but merely physically close. On the other hand, the *bracelet* is made of *silver*, which makes them highly integrated in this particular phrase.

It could be the case that the participants' evaluation of the items as being more or less integrated changed over the cause of the experiment so that the ratings given after the experiment did not capture their initial impression of the items. To assess whether this was the case, integration ratings were obtained from an additional 60 participants who did not participate in the experiment (see Table 3 below).

[2] We thank N. Pearlmutter for making the text available.

Apparatus. The experiment was programmed in Presentation 15.0 and presented on a CRT monitor with a 1024x768 screen resolution. Response times were registered by the Presentation voice key and later checked and where necessary corrected using PRAAT speech analysis software (Boersma & Weenink, 2010).

Analyses. Although we created an integrated and unintegrated version of each item and the average integration ratings of the stimuli differed according to this manipulation, there was some overlap in the integration ratings (see Appendix A). Therefore, we decided to treat semantic integration as a continuous variable in the main analyses below. Each item was assigned the average integration rating given by the participants of the two main studies and the additional rating study. Appendix E reports supplementary analyses treating integration as a dichotomous variable.

The responses in the main experiment were coded for accuracy and response time. Response times shorter than 200 ms or more than three standard deviations above the participant's mean were excluded from the analyses (246 cases, 6.1% of all responses). Statistical analyses were run using linear mixed effects models with crossed effects of subjects and items using the lme4 package (Bates, 2005; R Development Core Team, 2011). In order to avoid collinearity and to maximize the likelihood of model convergence, the variables list, block, plausibility, semantic integration, and local noun number were mean centered prior to analysis (Baayen, 2008). As histograms showed that the distribution of the response times was rightward skewed, analyses were performed on natural log-transformed response times.

The experimental fixed effects included in the statistical models were Mean Integration Ratings (1 through 7), Local Noun Number (singular vs. plural), and Block (1 through 4). The list participants saw was initially included as a fixed factor, but as it did not contribute to any of the models, we collapsed across this factor.

Similarly, the plausibility of the adjectives did not contribute and was excluded. All models included random intercepts for subjects and items. In order to determine which random factors to include, we used forward selection, starting with a model that included Integration and Local Noun Number, adding Block and the interactions between these variables. Then the random slopes of Integration and Local Noun Number were added to the subjects and items, first one by one, later both of them. Model comparison was used to determine whether the inclusion of various random slopes improved model fit while minimizing model complexity (as measured with AIC/BIC). Whether random slopes were included in a particular analysis is indicated in the results tables. The inclusion of random slopes in the analysis of response times meant that resampling methods for calculating statistical probability were not available. Thus, we adopted the procedure in Baayen (2008) and judged factors significant when the absolute *t*-value exceeded 2. Error rates were analyzed using a logistic linking function (e.g., Jaeger, 2008), a procedure which does provide statistical probabilities, and these are indicated in the results tables below.

Results

Integration ratings. Table 3 summarizes the average integration ratings given by the participants of both experiments and of the supplementary rating study. The table shows that on average, the integrated preambles received higher ratings than unintegrated preambles. The difference between integrated and unintegrated ratings was significant (t (99) = 23, $p < .001$ for the mean ratings). There was no consistent effect of Local Noun Number and no interaction of the two variables.

As the table shows, the average ratings for the three samples were very similar. Moreover, the correlation between the average ratings per item in the two

experiments was high (r = .90). The correlations of the ratings given after the experiments to the ratings of the independent sample, though still substantial, were lower (r = .57 and r = .53 for Experiment 1 and 2, respectively). This suggests that the ratings obtained from the participants after the experiment may not have reflected their initial interpretation of integration during the experiment. Therefore, we stabilized the measure of integration rating by averaging across the three samples of participants. Local noun number did not significantly influence the integration ratings, thus we collapsed ratings across this variable.

Table 3
Mean (SD) Integration Ratings for each Condition

		Integration	
Experiment 1		Unintegrated	Integrated
	Singular local noun	3.18 (1.97)	5.08 (1.93)
	Plural local noun	3.15 (2.02)	4.96 (1.93)
Experiment 2			
	Singular local noun	3.18 (1.90)	4.79 (1.95)
	Plural local noun	3.10 (1.87)	4.78 (1.96)
Independent sample			
	Singular local noun	2.91 (2.05)	4.88 (2.04)
	Plural local noun	2.95 (2.03)	4.93 (2.02)
Mean ratings			
		3.03 (2.00)	4.90 (1.99)

Error rates. Responses from 123 experimental trials (5.1%) were missing because of recording failure or because participants provided no response. Out of the remaining 2277 valid responses, 476 were incorrect (20.9%). Experimental items required a singular response, thus correct adjectives produced with a plural verb were coded as agreement errors. Other errors were responses featuring incorrect adjectives, speech disfluencies or self-repairs, and repetition of the entire preamble.

Figure 1 plots the model's estimates of the logit-transformed error rates depending on local noun number and degree of integration. Results of the analysis (Table 4) revealed main effects of Integration Rating and Local Noun Number, but no interaction between the two variables (see Tables E1 and E2 in Appendix E for analyses treating integration as a dichotomous variable, which confirm our main conclusions). Examination of Figure 1 reveals that participants made more agreement errors after plural than after singular local nouns, and they made more errors after weakly integrated than after tightly integrated preambles. The error rate decreased across the course of the experiment, yielding the significant main effect of Block.

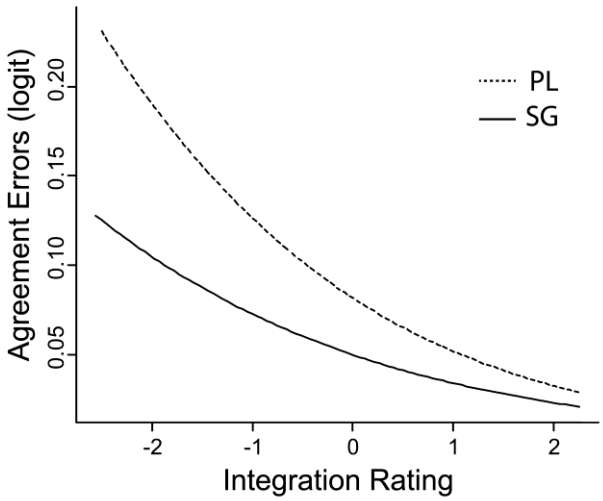


Figure 1. Experiment 1: Error rates for the integration ratings for plural (PL) and singular (SG) local nouns. Lines represent model estimates for each local noun number condition. The value 0 on the x-axis corresponds to the mean integration rating; higher values represent tighter integration.

Table 4
Experiment 1: Agreement Errors predicted by Integration Rating and Local Noun Number

Variable	Coefficient	*SE*	*z*-value	Pr(>|*z*|)	Random Slope
(Intercept)	-2.28	0.24	-9.70	<.001***	
Integration Rating	-0.38	0.06	-6.84	<.001***	items
Local Noun Number	0.21	0.09	2.26	0.024*	subjects, items
Block	-0.11	0.05	-1.99	0.047*	
Number*Block	-0.14	0.04	-3.32	<.001***	
Rating*Number	-0.03	0.05	-0.63	0.528	

Note. * $p<.05$; ** $p<.01$; *** $p<.001$. Interactions with Block indicate a practice effect.

As explained above, the materials included two sets of items differing in whether the degree of integration was varied by using different propositions (as in *the drawing of/with the flower(s)*) or by using different local nouns (*the bowl with the stripe(s)/spoon(s)*). To assess how this variable, Item Type, affected the results, an additional model was run that included Item Type as a predictor. There was no significant main effect of Item Type (β = 0.14, p = .10) and no significant interaction with integration (β = 0.003, p = .95) or with local noun number (β = 0.003, p = .97).

The plausibility ratings showed that integrated items were rated slightly higher than unintegrated items. Indeed, the plausibility and integration ratings were correlated (r = .55). In order to assess whether the effects of integration were affected by the plausibility of the adjective, we ran an additional model that included Plausibility. Because plausibility ratings are partially dependent on integration (but not the reverse for integration ratings), the model included a predictor for plausibility after removing variance associated with integration ratings (i.e., the residuals of Plausibility predicted by Integration). Results of this analysis showed that none of the above-described results were a result of differences in plausibility of the adjective: There was no main effect of Plausibility (β = -0.08, p = 0.41) and no interactions with Plausibility.

Finally, we evaluated the participants' performance on the catch trials. Errors (i.e., any deviations from verbatim recall) occurred on average on 2.8 of 24 preambles (SD = 1.7), and participants made on average 0.9 agreement errors (SD = 0.9).

Response latencies. Only correct responses were included in the analyses of response latencies. Latencies deviating by more than three standard deviations from the participant mean were excluded (0.8% of correct responses). This left 2260 data points for the analyses. Consistent with the error rates, the participants responded

faster after singular than after plural local nouns, and they were faster after tightly integrated than after weakly integrated preambles. Figure 2 plots the model estimates of the natural log-transformed response latencies, and Table 5 reports the results of the statistical analyses (see Tables E3 and E4 in Appendix E for the results of analyses treating integration as a dichotomous variable, confirming the patterns of the main analyses). There were significant main effects of Integration, Local Noun Number, and Block (with response times decreasing across blocks).

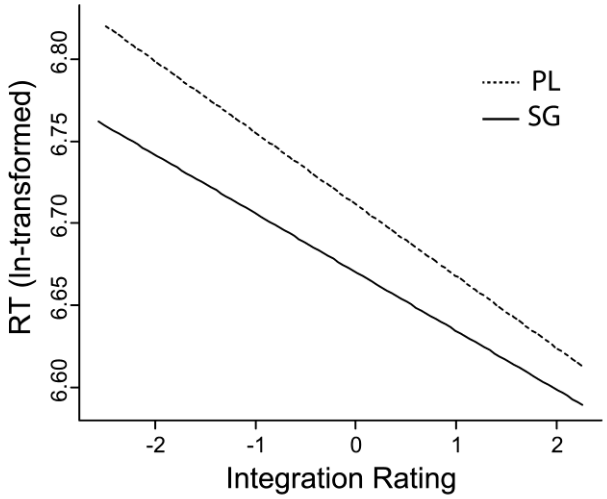


Figure 2. Experiment 1: Natural log-transformed response times (RT) for the integration ratings for plural (PL) and singular (SG) local nouns. Lines represent model estimates of each local noun condition. The value 0 on the x-axis corresponds to the mean integration rating; higher values represent tighter integration.

Table 5
Experiment 1: Response Times predicted by Integration Rating and Local Noun Number

Variable	Coefficient	*SE*	*t*	Random Slope
(Intercept)	6.73	0.04	184.17*	
Integration Rating	-0.03	0.01	-4.50*	items
Local Noun Number	0.02	0.01	2.36*	subjects
Block	-0.04	0.01	-6.30*	
Rating*Number	-0.01	0.01	-1.31	

Note. *p<.05.

In a model including Item Type, the general patterns were similar, while there was no significant main effect of Item Type (β = 0.02, t = 1.39), or interaction with Integration (β = -0.002, t = -0.27) or with Local Noun Number (β = 0.01, t = 0.68). Similar to the error analysis, Plausibility did not contribute to the model (β = -0.003, t = -0.28) and was excluded from the final model.

Discussion

The present experiment replicated the attraction effect seen in many earlier studies: Participants generated more errors and slower responses when the head noun and local noun mismatched in number relative to when they matched. We also found a main effect of semantic integration: Participants made more errors and responded more slowly when preambles were weakly integrated relative to when they were tightly integrated. Critically, there was no interaction between these variables, suggesting that the effects of semantic integration and local noun number were additive. These results were remarkably stable across numerous analyses. The same patterns arose, for instance, when looking only at the participants who were university students, and also in the newly constructed items as well as in the items that were translated or adapted from Solomon and Pearlmutter's original items.

In addition, the different treatments of semantic integration yielded exactly the same pattern: Whether the ratings of the degree of integration were averaged for each item across the three groups of raters (our main analysis), averaged for each item across the participants in Experiment 1, or whether integration was dichotomized (see the analyses in Appendix E), all analyses showed main effects of Integration and Local Noun Number and no interactions between them.

Another important analysis distinguished between the different types of items used to manipulate semantic integration. The degree of integration in the experimental items was varied by either using a different preposition (*of*/*with*) or changing the local noun (*the bowl with the stripe/spoon*). One might expect that the difference in integration is more clearly instantiated in the latter item type than in the former. This is because in Dutch, as in English, a phrase such as *a picture with a flower*, which was meant to be interpreted in the sense of a *picture next to a flower*, can also be interpreted in the sense of *a picture showing a flower*. Thus, the unintegrated *with*-items might have been given an integrated interpretation. The integration ratings suggested, however, that the participants clearly distinguished between the integrated and unintegrated versions of the *of/with* items. Furthermore, additional analyses of the error rates and response latencies showed that there was neither a main effect of Item Type nor an interaction of Item Type with integration or local noun number.

Finally, it was important to assess whether any of the effects we observed may have come about as a result of differences in plausibility between the sentence materials. The adjectives the participants were asked to use to complete the sentences had been selected to be plausible continuations of the preambles. As noted, a rating study confirmed this but showed slightly higher ratings for integrated sentences compared to unintegrated sentences. Yet, analyses including Plausibility as a predictor ruled out the possibility that differences in integration that were observed were a result of differences in the plausibility of the adjective.

Experiment 2

The main findings of Experiment 1 were that semantic integration facilitated the generation of subject-verb agreement and that this effect was additive to the

attraction effect from the local noun number. The goal of the second experiment was to determine whether these findings could be replicated in a new sample of participants and with a different task. We used a speeded forced-choice task adapted from Staub (2009, 2010) in which participants read the same preambles as in Experiment 1 presented word-by-word. After the end of the preamble, the verb forms *is* and *zijn* were simultaneously presented on the screen, and the participants had to select the correct form as quickly as possible by pressing one of two response buttons. No adjectives were presented. Thus, using this paradigm allowed us to rule out any remaining concerns about the influence of the plausibility of the preamble-adjective combinations. This task is a speeded metalinguistic judgment task directing the participants' attention quite explicitly towards subject-verb agreement. One advantage of this task relative to the preamble completion paradigm is that it is easier to administer and analyze. Replicating the results of Experiment 1 would provide an important validation of this simpler paradigm.

The predictions for this experiment are the same as for Experiment 1. The lexical interference hypothesis predicts an interaction between semantic integration and local noun number, with larger attraction effects for tightly integrated preambles. The notional number hypothesis, on the other hand, predicts main effects of local noun number and of integration: Fewer errors and faster response times for tightly integrated preambles than for weakly integrated preambles.

Method

Participants. The experiment was carried out with 24 participants (16 female), ranging in age from 18 to 59 years (M = 30.29 years, SD = 16.32). Seventeen

participants were university students. None of the participants had taken part in Experiment 1.

Materials. The same preambles were used on experimental and filler trials as in Experiment 1. No adjectives were presented and there were no catch trials. Six additional preambles were created for use in the practice block.

Procedure. Participants were tested individually in a soundproof booth. The experiment was programmed in Presentation 15.0. The trials had the following structure: First, a fixation cross (0.5° visual angle) was presented in the center of the screen for 1000 ms. Then the preamble was presented word-by-word in the center of the screen. Each word was shown for 250 ms and was followed by a blank interval of 150 ms. After presentation of the preamble, the singular and plural forms of the verb to be, *is* and *zijn*, were presented simultaneously, slightly to the left and right of the center of the screen. Participants were instructed to indicate as quickly as possible which of the two forms would be the correct continuation of the preamble by pressing the F-key on their keyboard for the left word and the J-key for the right word. Feedback was provided if the response was incorrect using the word *FOUT* (*wrong*) displayed in red. The next trial began 1500 ms after the response.

The experiment started with a practice block of 12 trials, followed by four blocks of 50 trials each (25 experimental items and 25 filler items). The positions of the two verb forms on the screen alternated across blocks; *is* appeared on the left in blocks 1 and 3, and on the right in blocks 2 and 4. Participants were assigned to one of the four stimulus lists, and each list was seen by six participants. After the main experiment, they rated the degree of integration of the experimental items.

Results

Error rates. Out of the 2400 responses to experimental preambles, 307 were incorrect (12.8%). Weakly integrated preambles yielded on average more errors than tightly integrated preambles, and plural local nouns yielded more errors than singular local nouns. Figure 3 plots the estimated error rates depending on local noun number and degree of integration. The mixed effects model showed main effects of Integration, Local Noun Number, and Block (with error rates decreasing across blocks), but no interactions between these variables (see Table 6). Tables E1 and E2 in Appendix E show the results of analyses treating integration as a dichotomous variable. They confirm the patterns of the main analysis with main effects of Integration and Local Noun Number and no interaction.

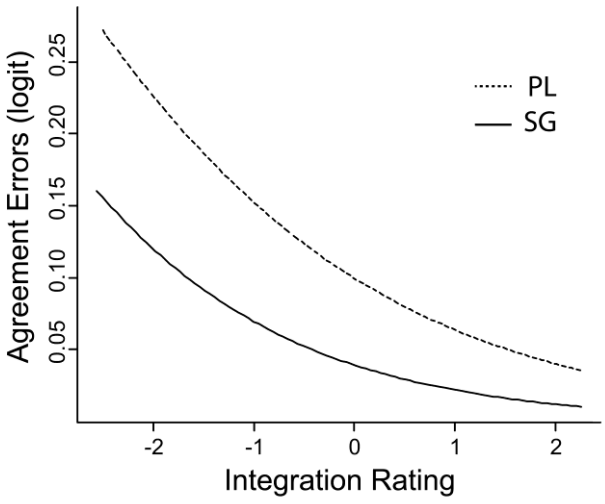


Figure 3. Experiment 2: Error rates for the integration ratings for plural (PL) and singular (SG) local nouns. Lines represent model estimates for each local noun number condition. The value 0 on the x-axis corresponds to the mean integration rating; higher values represent tighter integration.

Table 6
Experiment 2: Agreement Errors predicted by Integration Rating and Local Noun Number

Variable	Coefficient	*SE*	*z*-value	Pr(>|*z*|)	Random Slope
(Intercept)	-2.55	0.22	-11.78	<.001***	
Integration Rating	-0.41	0.08	-5.23	<.001***	items
Local Noun Number	0.41	0.12	3.18	0.001**	subjects, items
Block	-0.19	0.05	-3.64	<.001***	
Rating*Number	0.03	0.06	0.60	0.551	

Note. * p<.05; ** p<.01; *** p<.001.

Item Type (*of*/*with* versus different local nouns) did not influence the error rates, as there was no main effect of Item Type (β = 0.09, p = .35), and no interactions with Integration (β = -0.03, p = .71) or with Local Noun Number (β = 0.05, p = .51).

Response times. Only correct responses were included in the latency analyses. Latencies below 200 ms (3.3% of correct responses) and latencies deviating by more than three standard deviations above the participant mean (1.5%) were excluded from the analyses. The results for the remaining 1992 responses are shown in Figure 4 and Table 7 (see Tables E3 and E4 in Appendix E for analyses with integration as a dichotomous variable).

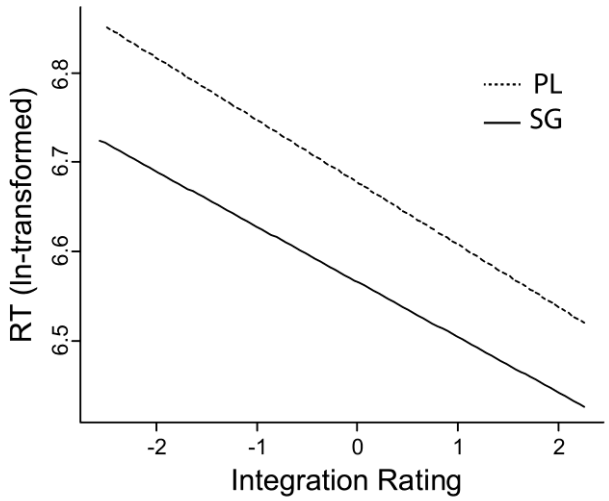


Figure 4. Experiment 2: Natural log-transformed response times (RT) for the integration ratings for plural (PL) and singular (SG) local nouns. Lines represent model estimates of each local noun condition. The value 0 on the x-axis corresponds to the mean integration rating; higher values represent tighter integration.

Table 7
Experiment 2: Response Times predicted by Integration Rating and Local Noun Number

Variable	Coefficient	*SE*	*t*	Random Slope
(Intercept)	6.63	0.11	59.74*	
Rating	-0.05	0.01	-5.80*	items
Local Noun Number	0.06	0.01	5.65*	subjects
Item Type	0.03	0.01	2.69*	subjects, items
Block	-0.01	0.01	-0.85	
Number*Block	-0.01	0.01	-2.21*	
Item Type*Rating	0.02	0.01	2.10*	
Rating*Number	-0.00	0.01	-0.41	

Note. *p<.05. Interactions with Block indicate a practice effect.

The participants were significantly faster to respond to tightly integrated relative to weakly integrated preambles, and they were faster to respond to preambles with singular than with plural local nouns. Results of the mixed effects model showed a main effect of Integration and Local Noun Number, but no interaction between the two variables.

To test for the influence of Item Type, Item Type was included as a factor. Unlike the previous analyses, this analysis indicated that there was a significant main effect of Item Type (β = 0.03, t = 2.59), and an interaction of Item Type and Integration (β = 0.02, t = 2.15), but not of Item Type and Local Noun Number (β = -0.03, t = 1.65). The main effect reflects the fact that items in which integration was manipulated by substituting the local noun (e.g., *the bowl with the spoons/stripes*) yielded longer response times than items in which the preposition was substituted (e.g., *the drawing of/with the flowers).* Also, this type of item (*spoons/stripes*) showed a slightly weaker Integration effect (β = -0.03, t = -2.70) than the (*of/with*) items (β = -0.07, t = -5.44).

Discussion

The results of Experiment 2 are similar to those of Experiment 1. Error rates and response times showed the classic attraction effect, indicating that selecting the appropriate singular verb form was more difficult after plural than after singular local nouns. The facilitatory effect of semantic integration was also replicated: Participants made fewer errors and were faster to select a verb form after tightly integrated than after weakly integrated preambles. As in the first experiment, the effects did not interact. Although the way integration was manipulated (*of/with* versus different local nouns) had an effect on the reaction times, it is important to note that the main effects of integration and local noun number remained significant and did not interact. The results of the two experiments thus suggest that the effects of grammatical number and notional number are independent of each other[3].

One goal of the study was to compare the results of the sentence completion and speeded forced-choice paradigm. The conclusion is clear: The two paradigms yielded similar results, though overall the effects of the experimental variables were somewhat smaller in the speeded forced-choice than in the sentence completion paradigm. The forced-choice task yields an informative response (either a correct response or an agreement error) on virtually all trials. In contrast, in the constrained response task, uninformative responses (e.g., omitted verb forms) can occur. Furthermore, the results of the forced-choice task are faster to analyze than those of the constrained response task where speech onset latencies have to be established. As such, the forced-choice task may be preferable to the constrained or full preamble

[3] In an additional experiment 12 participants completed the same task as in Experiment 2 but, similar to Experiment 1, were required to repeat and complete the preamble verbally on 24 catch trials. The results were very similar to those seen in Experiment 2: There were significantly more errors and longer RTs for preambles with plural local nouns (relative to singular local nouns) and for weakly integrated preambles (relative to tightly integrated preambles). Again, the two variables did not interact.

completion paradigms. Of course one should keep in mind that the forced-choice task is a speeded metalinguistic judgment task, focusing the participants' attention on the verb forms. For some research purposes this may not be optimal (see Staub, 2009, 2010, for further discussion of the task).

General Discussion

The experiments described above assessed the influence of the degree of semantic integration and local noun number on subject-verb agreement in Dutch. On the critical trials of the experiments, the participants read noun phrases that varied in semantic integration (*the secretary of the governor(s)* vs. *the secretary with the governor(s)*), and in which a singular head noun was combined with a singular or a plural local noun. In Experiment 1, the participants produced verb phrases including the singular or plural form of *zijn (to be)* and an adjective provided at trial onset (e.g., *mooi (pretty)* or *oud (old)*), whereas in Experiment 2, they selected the appropriate form of the verb *zijn* with a button press.

The results are easy to summarize: (1) we replicated the attraction effect seen in numerous earlier studies (Bock & Eberhard, 1993; Bock & Miller, 1991; Bock, et al., 1999; Haskell & MacDonald, 2005; Vigliocco, et al., 1995). In both experiments, the participants made fewer errors and were faster to respond when head and local noun matched in number than when they mismatched. (2) Semantic integration facilitated the choice of the correct singular verb forms. Participants made fewer errors and were faster to respond as the degree of integration of the preambles increased. (3) The two effects did not interact with each other.

Lexical Interference versus Notional Accounts of Semantic Integration

The main goal of the present study was to evaluate two hypotheses concerning the origin of the semantic integration effect on agreement processes. According to the lexical interference hypothesis, integration encourages parallel processing of the nouns in the subject noun phrase and therefore strengthens the attraction effect. According to the notional hypothesis, integration encourages the assignment of singular notional number to the subject noun phrase and therefore facilitates the selection of the correct singular verb form. Thus, the lexical interference hypothesis predicts interacting effects of integration and attraction, with stronger attraction arising in integrated relative to unintegrated sentences. In contrast, the notional hypothesis predicts main effects of attraction and integration, with more singular agreement in integrated than unintegrated sentences.

Earlier studies by Solomon and Pearlmutter (2004) and by Brehm and Bock (2013) yielded some evidence for each of these hypotheses. Results obtained by Solomon and Pearlmutter suggested that semantic integration increased attraction, whereas results obtained by Brehm and Bock showed that integration reduced the number of agreement errors. This difference in the results of the two studies was an important reason for assessing the effects of attraction again in the present experiments. Number is marked on a far higher proportion of inflected verb forms in Dutch than in English, and in Dutch, subject-verb agreement might rely more strongly on grammatical and less on notional number (cf. Berg, 1998, for a similar suggestion concerning agreement in German and English). Therefore, one might expect grammatical influences in Dutch to be relatively stronger and notional influences to be weaker relative to English. Thus, if the lexical interference hypothesis is correct, one should be more likely to observe the interaction of semantic integration and local

noun number, as the grammatical features of the words are more highly activated in Dutch.

However, the present results do not support the main prediction from the lexical interference hypothesis: Integration facilitated the selection of the correct singular verb form. Furthermore, it did not systematically affect the size of the attraction effect. This pattern does not support the view that integration leads to more interference among the nouns in the subject noun phrase.

It is important to note that the lexical interference hypothesis encompasses two assumptions, namely that integration leads to increased lexical competition and that increased lexical competition leads to stronger attraction. Our results suggest that in the paradigms we used these assumptions are unlikely to both be correct. However, they do not rule out either of the assumptions individually. Thus, it is possible that nouns are more likely to be processed simultaneously in integrated than in unintegrated preambles (Gillespie & Pearlmutter, 2011b), but if this is the case, it does not measurably increase the competition among the number features of the nouns. Likewise, the present results do not rule out that the time course of processing the nouns in a preamble may affect the strength of the attraction process, and specifically, that simultaneous processing of the head and local noun increases the likelihood of attraction errors (Bock & Cutting, 1992). However, if this is the case, variation of the degree of integration does not substantially alter the time course of noun processing.

Our results fit in well with other findings demonstrating conceptual/notional effects on agreement. Most of these studies manipulated conceptual variables such as collectivity or distributivity. For instance, phrases with collective head nouns (such as *army*, *furniture*), which are grammatically singular but notionally plural, yield larger

attraction effects than those containing notionally and grammatically singular head nouns (Bock, Eberhard, & Cutting, 2004; Bock, et al., 1999; Haskell & MacDonald, 2003). Similarly, phrases such as *the key to the cabinets*, where the head noun specifies a single object, yield weaker attraction effects than distributive phrases such as *the label on the bottles*, where the head noun refers to multiple objects (e.g., one on every bottle; Hartsuiker, Kolk, & Huinck, 1999; Humphreys & Bock, 2005; Vigliocco, Butterworth, et al., 1996; Vigliocco, et al., 1995; Vigliocco, Hartsuiker, et al., 1996).

Most importantly, the pattern of results seen in the present study closely resembles those observed by Brehm and Bock (2013), who also observed fewer agreement errors and, when a speeded task was used, faster responses to integrated than unintegrated preambles. This indicates that the direction of the effect of integration—to facilitate, rather than hinder correct singular agreement—is the same in both English and Dutch. In fact, our results are somewhat more straightforward to interpret than those obtained by Brehm and Bock. When integration was treated as a continuous variable, an interaction emerged in Brehm and Bock's first experiment, with stronger attraction for the low levels of integration. Critically, however, the interaction was not due to the typical change that underlies increased attraction. Rather than an elevation in plural agreement after plural local nouns (i.e., mismatching local nouns), for weakly integrated sentences there was more *singular* agreement after singular local nouns (i.e., matching local nouns, the baseline condition). In Experiment 2, Brehm and Bock again found an interaction between integration and local noun number. Similar to Solomon and Pearlmutter's results, the attraction effect was stronger in integrated than unintegrated sentences. However, this interaction was again explained by a drop in baseline, rather than increased attraction.

This pattern of results was not present in the current investigation. Semantic integration consistently facilitated agreement, and never interacted with the attraction effect.

The pattern of results from our study and (largely) those from Brehm and Bock can be interpreted within the framework of the Marking and Morphing model proposed by Eberhard and colleagues (Eberhard, Cutting, & Bock, 2005). A key assumption of the model is that verb number is governed exclusively by the number assigned to the subject noun phrase (rather than depending directly on the number assigned to the head or local noun). The number assigned to the subject noun phrase (the SAP value) depends on two additive components: the notional specification and the lexical specification. The latter component is a weighted sum of number specifications of the nouns in the noun phrase, with highest weight given to the head noun. In this model, attraction arises because phrases with singular head nouns and singular vs. plural local nouns differ in the contribution to SAP stemming from the lexical specification. By contrast, the semantic integration effect arises because integrated and unintegrated phrases differ in notional specification. SAP values can be transformed into probabilities of choosing singular and plural verb forms and, though this was not done by Eberhard et al., this is possible for latencies as well (for a related approach see Roelofs, 1997). This model predicts that integration should facilitate singular agreement, and that the effects of integration and attraction should typically be additive (see also Anton-Mendez & Hartsuiker, 2010).

Limitations

An important goal of the current study was to obtain additional evidence that might help to arbitrate between the accounts of the integration proposed by Solomon

and Pearlmutter (2004) and by Brehm and Bock (2013). Given this motivation, the choice of paradigm—preamble completion—followed quite naturally. In order to allow for comparisons of the results of the three studies, the general method and the materials had to be as similar as possible. Methodologically this triad of studies fits in well with other psycholinguistic work on agreement, most of which has used the preamble completion paradigm as well.

The preamble completion paradigm used in Experiment 1 is often considered a speech production task because the participants produce the verb phrases. The speeded forced-choice paradigm used in Experiment 2 might also be seen as production task since the participants are asked to indicate which of the two verb forms they would choose if they had to complete the sentence. This would be in line with the view advocated by, for instance, Pickering and Garrod (2007) that predicting upcoming words in spoken or written sentences involves speech production processes. Regardless of the plausibility of this assumption, it is evident that neither of the two versions of the preamble completion task used here is a pure production task, as participants read the preambles rather than generating them on the basis of conceptual information. Thus, the preamble completion task is a hybrid task, involving both comprehension and production components.

The implications of the current findings for the creation of agreement in other tasks, speaking or listening, remain to be determined. The attraction effect appears to be robust to a number of experimental manipulations, and has been shown in comprehension studies as well (Pearlmutter, Garnsey, & Bock, 1999; Wagers, Lau, & Phillips, 2009). More generally, evidence from behavioral and neuropsychological studies suggests that the core mechanisms underlying grammatical processes in comprehension may largely be shared (Menenti, Gierhan, Segaert, & Hagoort, 2011;

Segaert, Menenti, Weber, Petersson, & Hagoort, 2012; Tooley & Bock, 2013). Semantic integration has, to our knowledge, only been studied in the three studies discussed here. It is conceivable that the impact of this variable on agreement is stronger or weaker in other tasks depending, for instance, on how much attention a listener or reader pays to the meaning of the subject noun phrase.

Conclusions

The present study showed that Dutch speakers found it easier to select the correct singular form of the verb when the subject noun phrase was strongly relative to weakly integrated, and when the local noun number was singular relative to when it was plural. Following Brehm and Bock (2013), we interpret our findings within the Marking and Morphing model proposed by Eberhard and colleagues (2005). Accordingly, integration biases the computation of the notional number of the subject noun phrase towards unity, whereas the presence of a plural local noun biases the lexical specification of the noun phrase towards plurality.

Appendix

Appendix A. The experimental items. Items 1 to 57 differ only in preposition, items 58 to 100 differ only in local noun. The average integration ratings are given for the Integrated and Unintegrated items (collapsed over local noun number), respectively.

	Integrated/Unintegrated Singular local noun (plural local noun)	Adjective	Ratings
1	De tekening van/met de bloem(en)* *The drawing of/with the flower(s)*	creatief *creative*	5.30/2.86
2	De afbeelding van/met de edelsteen/edelstenen* *The picture of/with the gem(s)*	duur *expensive*	4.67/4.23
3	De sculptuur van/met de sleutel(s)* *The sculpture of/with the key(s)*	nieuw *new*	3.12/1.88
4	De schets van/met de boekenkast(en)* *The sketch of/with the bookcase(s)*	mooi *beautiful*	5.04/3.33
5	De beeltenis van/met de ballon(nen) *The picture of/with the balloon(s)*	kleurrijk *colorful*	4.07/2.35
6	De verzorger van/met de vogel(s) *The tender of/with the bird(s)*	lelijk *ugly*	5.12/3.52
7	De cassette van/met de lp('s)* *The tape of/with the record(s)*	versleten *worn off*	3.91/1.92
8	De foto van/met de akte(s)** *The photo of/with the certificate(s)*	mislukt *failed*	4.60/3.16
9	De afdruk van/met de memo('s)** *The print out of/with the memo(s)*	vaag *blurred*	4.86/3.14
10	De video van/met de pop(pen)* *The video of/with the puppet(s)*	lang *long*	4.35/2.90
11	De illustratie van/met de landkaart(en)* *The illustration with/of the map(s)*	informatief *informative*	5.09/3.84
12	De fotokopie van/met de publicatie(s)** *The photocopy of/with the publication(s)*	nuttig *useful*	5.54/3.10
13	De reproductie van/met de prent(en)** *The reproduction of/with the engraving(s)*	modern *modern*	5.22/2.75
14	De fax van/met de blauwdruk(ken)* *The fax of/with the blueprint(s)*	achterhaald *outdated*	5.16/4.14
15	De tv-uitzending van/met de film(s)* *The telecast of/with the movie(s)*	saai *boring*	4.78/2.96
16	De uitvergroting van/met de brief/brieven** *The enlargement of/with the letter(s)*	klein *small*	4.02/2.18
17	De beschrijving van/met de cd('s) * *The description of/with the cd(s)*	uitgebreid *extensive*	4.67/2.16
18	De dia van/met de krant(en)* *The slide of/with the newspaper(s)*	helder *bright*	3.43/1.89
19	De verfilming van/met de show(s)** *The screen version of/with the show(s)*	beroemd *famous*	5.68/2.37
20	De uitdraai van/met de scriptie(s) *The print out of/with the thesis/theses*	zwart-wit *black and white*	5.21/3.47
21	De zus van/met de baby('s) *The sister of/with the baby/babies*	blij *happy*	4.09/3.16
22	De polaroidfoto van/met de postzegel(s)* *The polaroid of/with the stamp(s)*	vreemd *strange*	3.78/2.51
23	De ansichtkaart van/met de schoen* *The postcard of/with the shoe(s)*	grappig *funny*	3.86/2.75
24	De poster van/met de kroon/kronen** *The poster of/with the crown(s)*	artistiek *arty*	4.14/2.89
25	De assistent voor/met de inspecteur(s)* *The assistant for/with the inspector(s)*	gestrest *stressed*	3.10/2.90
26	De chauffeur voor/met de acteur(s)* *The chauffeur for/with the actor(s)*	onvriendelijk *unfriendly*	3.47/2.94
27	De leerling voor/met de kleermaker(s)* *The apprentice for/with the tailor(s)*	verlegen *shy*	3.76/2.28

28	De aanhanger van/met de evangelist(en)*	loyaal	4.45/2.96
	The supporter of/with the evangelist(s)	*loyal*	
29	De vertaler van/met de ambassadeur(s)*	slim	4.55/3.06
	The translator of/with the ambassador(s)	*smart*	
30	De secretaresse van/met de bestuurder(s)**	elegant	3.83/3.22
	The secretary of/with the governor(s)	*elegant*	
31	De accountant voor/met de miljonair(s)*	arrogant	4.76/3.19
	The accountant for/with the millionaire(s)	*arrogant*	
32	De verpleegster voor/met de chirurg(en)*	aardig	4.44/3.61
	The nurse for/with the surgeon(s)	*nice*	
33	De adviseur van/met de producent(en)*	ervaren	4.81/3.86
	The consultant of/with the producer(s)	*experienced*	
34	De raadsman van/met de advocaat (advocaten)*	nerveus	5.60/4.33
	The advisor of/with the attorney(s)	*nervous*	
35	De bediende voor/met de diplomaat (diplomaten)*	angstig	3.86/2.50
	The servant for/with the diplomat(s)	*anxious*	
36	De manager van/met de band(s)*	klein	5.53/4.29
	The manager of/with the band(s)	*small*	
37	De agent voor/met de artiest(en)*	drukbezet	4.04/3.47
	The agent for/with the artist(s)	*busy*	
38	De trainer voor/met de atleet (atleten)*	teleurgesteld	5.25/4.47
	The trainer for/with the athlete(s)	*disappointed*	
39	De dokter van/met de patiënt(en)*	zorgzaam	6.23/5.22
	The doctor of/with the patient(s)	*caring*	
40	De leraar voor/met de scholier(en)**	moe	5.00/3.98
	The teacher for/with the pupil(s)	*tired*	
41	De coach van/met de turnster(s)*	energiek	5.07/3.18
	The coach of/with the gymnast(s)	*energetic*	
42	De fotograaf van/met de mannequin(s)*	verward	5.26/2.86
	The photographer of/with the model(s)	*confused*	
43	De promotor voor/met de DJ('s)*	verdrietig	4.70/3.76
	The promoter for/with the DJ(s)	*sad*	
44	De tuinman van/met de landeigenaar (landeigenaren)*	boos	4.46/3.55
	The gardener of/with the landowner(s)	*angry*	
45	De moeder van/met de zuigeling(en)	aardig	5.49/4.76
	The mother of/with the baby/babies)	*nice*	
46	De buurvrouw van/met de jongeman(nen)	vervelend	4.53/2.20
	The neighbor of/with the young man/men	*annoying*	
47	De fan van/met de zanger(s)	opgewonden	5.60/3.36
	The fan of/with the singer(s)	*excited*	
48	De baas van/met de werknemer(s)	oneerlijk	5.70/3.80
	The boss of/with the employee(s)	*unfair*	
49	De bestuurder van/met de trein(en)	bezorgd	5.44/3.64
	The driver of/with the train(s)	*worried*	
50	De collega van/met de vriend(en)	oud	4.31/2.89
	The colleague of/with the friend(s)	*old*	
51	De oppas van/met de kleuter(s)	geestig	5.12/4.46
	The baby-sitter of/with the toddler(s)	*funny*	
52	De fabrikant van/met de creatie(s)	trots	3.93/3.02
	The manufacturer of/with the creation(s)	*proud*	
53	De lakei van/met de prins(en)	lui	5.54/3.98
	The servant of/with the prince(s)	*lazy*	
54	De eigenaar van/met de dure auto(s)	enthousiast	4.94/3.16
	The owner of/with the expensive car(s)	*enthusiastic*	
55	De dochter van/met de zendeling(en)	knap	5.02/2.19
	The daughter of/with the missionary (missionaries)	*handsome*	
56	De vader van/met de jongeman(nen)	verantwoordelijk	4.66/2.88
	The father of/with the young man (men)	*responsible*	
57	De papegaai van/met de kleinzoon(s)	luidruchtig	4.32/3.35
	The parrot of/with the grandson(s)	*noisy*	
58	De dichtbundel met de omgevouwen bladzijde(n)/rode pen(nen)	dun	5.32/3.43
	The volume of poems with the torn page(s)/red pen(s)	*thin*	
59	De panty met de rare opdruk(ken)/vieze handdoek(en)*	schoon	4.98/2.51
	The tights with the crazy print(s)/dirty towel(s)	*clean*	
60	De ring met de nep-diamant(en)/gouden armband(en)*	glinsterend	5.43/1.84
	The ring with the fake diamond(s)/gold bracelet(s)	*shiny*	

61	De appel met de bruine plek(ken)/verse perzik(en)*	lekker	5.22/2.56
	The apple with the brown spot(s)/fresh peach(es)	*tasteful*	
62	De stropdas met de lelijke streep/strepen/katoenen blazer(s)*	rood	5.24/2.44
	The tie with the hideous stripe(s)/cotton blazer(s)	*red*	
63	De klok met de missende wijzer(s)/zwarte portemonnee(s)**	kapot	5.64/2.50
	The clock with the missing hand(s)/black wallet(s)	*broken*	
64	De jas met de kapotte rits(en)/natte paraplu('s)*	vies	5.55/3.39
	The jacket with the faulty zipper(s)/wet umbrella(s)	*dirty*	
65	De kam met de gebroken tand(en)/lege tube(s)**	bruin	5.33/1.40
	The comb with the broken tooth/teeth/empty tube(s)	*brown*	
66	De sleutel met de gekartelde rand(en)/glanzende munt(en)*	roestig	4.78/2.02
	The key with the jagged edge(s)/shiny coin(s)	*rusty*	
67	De fauteuil met de krakende veer (veren)/grote boekenkast(en)**	smal	4.33/2.14
	The chair with the creaky spring(s)/tall bookcase(s)	*narrow*	
68	De telefoon met de missende toets(en)/kapotte broodrooster(s)*	oud	5.04/2.37
	The phone with the missing button(s)/broken toaster(s)	*old*	
69	De bedsprei met de vieze vlek(ken)/wollen deken(s)**	wit	4.96/3.53
	The bedspread with the dirty stain(s)/woolen blanket(s)	*white*	
70	De kroonluchter met de felle lamp(en)/antieke pianokruk(ken)**	grijs	5.61/2.20
	The chandelier with the harsh light(s)/antique music-stool(s)	*grey*	
71	De krant met de kleurige advertentie(s)/koffiemok(ken)**	populair	5.05/2.88
	The newspaper with the colorful ad(s)/coffee mug(s)	*popular*	
72	De trui met de losse zoom (zomen)/zwarte pantalon(s)**	smaakvol	5.53/2.98
	The sweater with the loose hem(s)/black slack(s)	*tasteful*	
73	De rekening met de hoge prijs (prijzen)/afgesloten doos (dozen)*	gescheurd	4.92/1.71
	The receipt with the high price(s)/sealed box(es)	*torn*	
74	De boom met de dode tak(ken)/lage struik(en)*	groot	5.02/3.49
	The tree with the dead branch(es)/small shrub(s)	*tall*	
75	De pizza met de lekkere topping(s)/frisse dorstlesser(s)*	ongezond	4.46/2.31
	The pizza with the tasty topping(s)/fresh beverage(s)	*unhealthy*	
76	De melk met de extra vitamine(s)/bosbessenmuffin(s)*	koud	4.60/1.78
	The milk with the extra vitamin(s)/blueberry muffin(s)	*cold*	
77	De gitaar met de losse snaar/snaren/luide trommel(s)*	vals	5.48/3.06
	The guitar with the loose string(s)/loud drum(s)	*out of tune*	
78	De deken met de losse draad (draden)/schone rok(ken)**	muf	5.02/1.79
	The blanket with the loose thread(s)/clean skirt(s)	*musty*	
79	De beker met de lange scheur(en)/kristallen kom(men)**	tweedehands	3.78/2.59
	The mug with the lengthy crack(s)/crystal bowl(s)	*secondhand*	
80	De fiets met de verbogen spaak (spaken)/surfplank(en)*	paars	5.07/2.59
	The bike with the bent spoke(s)/surfboard(s)	*purple*	
81	De stoel met de losse poot (poten)/oude tafel(s)*	oncomfortabel	5.18/3.74
	The chair with the wobbly leg(s)/old table(s)	*uncomfortable*	
82	De koe met de zwarte vlek(ken)/zwarte geit(en)	ziek	4.98/2.54
	The cow with the black spot(s)/goat(s)	*ill*	
83	De plant met de mooie bloem(en)/ronde steen (stenen)	groen	5.58/2.78
	The plant with the pretty flower(s)/round rock(s)	*green*	
84	De cd met de rustige ballade(s)/spannende roman(s)	stuk	5.54/2.12
	The cd with the slow ballad(s)/exciting novel(s)	*broken*	
85	De piano met de losse toets(en)/scheve kruk(ken)	zwart	5.43/3.39
	The piano with the loose key(s)/lopsided stool(s)	*black*	
86	De schoen met de kapotte veter(s)/schone sok(ken)	bruin	5.88/4.28
	The shoe with the broken lace(s)/clean sock(s)	*brown*	
87	De kom met de rode streep (strepen)/houten lepel(s)	blauw	5.04/3.31
	The bowl with the red stripe(s)/wooden spoon(s)	*blue*	
88	De verzamelmap voor de oude foto(s)/ketting(en)	geërfd	5.14/2.74
	The album for the old photo(s)/necklace(s)	*inherited*	
89	De jongedame met de zere vinger(s)/hond(en)	jong	5.14/2.74
	The young lady with the sore finger(s)/dog(s)	*young*	
90	De bal met de rode stip(pen)/sportschoen(en)	hard	4.71/2.14
	The ball with the red dot(s)/sports shoe(s)	*hard*	
91	De kerstboom met de slinger(s)/kerststal(len)	gigantisch	5.92/4.67
	The Christmas tree with the garland(s)/nativity scene(s)	*gigantic*	
92	De kat met de scherpe nagel(s)/witte muis (muizen)	rood	5.31/3.14
	The cat with the sharp nail(s)/white mouse/mice	*red*	
93	De tegel met de spreuk(en)/fotolijst(en)	opgehangen	5.21/2.90
	The tile with the proverb(s)/photo frame(s)	*hung up*	

94	De laptop met verlichte knop(pen)/broodtrommel(s)	gestolen	5.35/2.72
	The laptop with the illuminated button(s)/bread bin(s)	*stolen*	
95	De woning met de rode deur(en)/vrijstaande garage(s)	bewoond	5.59/4.48
	The residence with the red door(s)/detached garage(s)	*inhabited*	
96	De spijkerbroek met de scheur(en)/trui(en)	tweedehands	5.22/3.09
	The jeans with the tear(s)/sweater(s)	*second-hand*	
97	De blouse met de gouden knoop (knopen)/leren handschoen(en)	oranje	5.70/1.98
	The blouse with the golden button(s)/leather glove(s)	*orange*	
98	De kandelaar met de witte kaars(en)/zilveren schaal (schalen)	waardevol	5.52/3.26
	The chandelier with the white candle(s)/silver platter(s)	*valuable*	
99	De zakdoek met de geborduurde letter(s)/rode kauwgombal(len)	gestreken	4.83/3.18
	The handkerchief with the embroidered character(s)/red bubble gum(s) ironed		
100	De auto met de lekke band(en)/bestelbus(sen)	beschadigd	6.14/3.09
	The car with the flat tire(s)/delivery truck(s)	*damaged*	

Note. Adjectives were not used in Experiment 2. *Direct translation from Solomon & Pearlmutter (2004) **Adaptation from Solomon & Pearlmutter.

Appendix B. The filler items

	Sentence	Adjective
1	De reisleider en de toerist	gekidnapt
	The guide and the tourist	*kidnapped*
2	De sokken van de directeur	gebreid
	The socks of the director	*knitted*
3	Het toetsenbord en de muis van de computer	draadloos
	The keyboard and the mouse of the computer	*wireless*
4	De dokter en de verpleegster	behulpzaam
	The doctor and the nurse	*helpful*
5	De leraar en de student	blij
	The teacher and the student	*happy*
6	De pakjes voor de kinderen	bezorgd
	The presents for the children	*delivered*
7	Het resultaat en de verwachting	hoopgevend
	The result and the expectation	*hopeful*
8	De schommel en de wip in de pas aangelegde speeltuin	populair
	The swing and the seesaw in the new playground	*popular*
9	De antwoorden van de politicus	dom
	The answers of the politician	*dumb*
10	De sandwich en de chocolade muffin	verpakt
	The sandwich and the chocolate muffin	*wrapped*
11	De inbrekers met de bivakmutsen	gearresteerd
	The burglars with the balaclavas	*arrested*
12	De klanten van de telefoon-maatschappij	opgelicht
	The costumers of the telephone company	*swindled*
13	De achtbaan en het reuzenrad	favoriet
	The rollercoaster and the big wheel	*favorite*
14	De eenden in het park	brutaal
	The ducks in the park	*impudent*
15	De jongetjes op de kleuterschool	stout
	The boys at the kindergarten	*naughty*
16	De raamkozijnen van het kantoor	geverfd
	The window frames of the office	*painted*
17	De technicus en zijn zoon	sportief
	The technician and his son	*sporty*
18	De pennen uit het etui	leeg
	The pens from the case	*empty*
19	De reizigers op het vliegveld	vermoeid
	The travelers at the airport	*tired*
20	De bus en de trein richting het noorden	vertrokken
	The bus and the train heading north	*departed*
21	De politie-agent en de buurtbewoonster	oplettend
	The police officer and the local	*observant*
22	De kunstenaar en zijn beeldschone muze	gelukkig
	The artist and his gorgeous muse	*happy*
23	De cijfers van de student voor het moeilijke vak	uitmuntend
	The grades of the student for the difficult course	*excellent*
24	De bierglazen op de plank	vies
	The beer glasses on the shelf	*dirty*
25	De kevers op de tak	schattig
	The bugs on the branch	*cute*
26	De skileraar en de cursist	verdwaald
	The skiing instructor and the student	*lost*
27	De voetballers in de lastige wedstrijd	uitgeput
	The soccer players in the tough game	*exhausted*
28	De pantoffels met de rode stippen	warm
	The slippers with the red dots	*warm*
29	De bloemen in de mooie vaas	verdord
	The flowers in the pretty vase	*withered*
30	Het kamermeisje en de receptioniste van het keurige hotel	efficiënt
	The chambermaid and the receptionist of the neat hotel	*efficient*
31	Het album en de cd-single van de nieuwe popgroep	succesvol
	The album and the cd single of the new pop group	*successful*

32	Het bos en het natuurgebied	beschermd
	The forest and the nature reserve	*protected*
33	De potloden van de ijverige scholier	geslepen
	The pencils of the diligent pupil	*sharpened*
34	Het paspoort en de ID-kaart	rechtsgeldig
	The passport and the ID card	*legally valid*
35	De sperziebonen uit de supermarkt	afgeprijsd
	The green beans from the supermarket	*on sale*
36	De stuntman en de cameraman	gewond
	The stuntman and the cameraman	*hurt*
37	De ballonnen voor het feestje	opgeblazen
	The balloons for the party	*blown up*
38	De tanden van de Hollywood acteur	gebleekt
	The teeth of the Hollywood actor	*bleached*
39	Het gerecht en de saus	pikant
	The dish and the sauce	*spicy*
40	De schat en de schatkaart	verborgen
	The treasure and the map	*hidden*
41	De helm en de linker kniebeschermer	beschadigd
	The helmet and the left knee-guard	*damaged*
42	De wortels uit de groentetuin	geoogst
	The carrots from the vegetable garden	*harvested*
43	De resultaten van het slechte onderzoek	onbetrouwbaar
	The results of the bad survey	*unreliable*
44	De gasten voor de trouwerij	opgedoft
	The guests for the wedding	*spruced up*
45	De slagerij en de kapsalon	gesloten
	The butcher's shop and the hairdresser's shop	*closed*
46	De salade en het verse fruit	gezond
	The salad and the fresh fruit	*healthy*
47	De piano's van de muziekschool in de stad	gestemd
	The pianos of the music school in town	*tuned*
48	De worstjes op de barbecue	klaar
	The sausages on the barbecue	*done*
49	De concerten van het populaire orkest	uitverkocht
	The concerts of the popular orchestra	*sold out*
50	De documenten voor de sleuteloverdracht	officieel
	The documents for the handover of the keys	*official*
51	Het hert en het everzwijn	afgeschoten
	The deer and the wild boar	*shot*
52	De spijker en de schroef in de buitenmuur	roestig
	The nail and the screw in the outer wall	*rusty*
53	De wolken in de donkere lucht	onheilspellend
	The clouds in the dark sky	*ominous*
54	De jas en de broek	ouderwets
	The jacket and the pants	*old-fashioned*
55	De supporters van de voetbalclub	agressief
	The supporters of the football club	*aggressive*
56	De sterren aan de hemel	schitterend
	The stars in the sky	*shiny*
57	De tomaat en de appel	rood
	The tomato and the apple	*red*
58	De laborant en de onderzoeker in het ziekenhuis	ambitieus
	The chemist and the researcher in the hospital	*ambitious*
59	De uitspraken van de kroegbaas	dubbelzinnig
	The statements of the public house keeper	*ambiguous*
60	De badkamer en de keuken van het oude huis	vochtig
	The bathroom and the kitchen of the old house	*humid*
61	Het meisje en de automobilist	overstuur
	The girl and the car driver	*upset*
62	De voeten van de marathon-loper	pijnlijk
	The feet of the marathon runner	*painful*
63	De juryleden van het tv-programma	tevreden
	The members of the jury of the television program	*satisfied*
64	De kledingontwerper en het internationale topmodel	arrogant
	The clothing designer and the international top model	*arrogant*

65	De dominee en zijn vrouw	stomverbaasd
	The reverend and his wife	*flabbergasted*
66	De broek en het shirt van de atleet	bezweet
	The pants and the shirt of the athlete	*sweaty*
67	De tractor en de hijskraan	gerepareerd
	The tractor and the hoisting crane	*fixed*
68	De regels van het ingewikkelde spel	uitgeprint
	The rules of the complicated game	*printed*
69	De vragen op het tentamen	ingewikkeld
	The questions on the exam	*complicated*
70	De film en het boek	saai
	The movie and the book	*boring*
71	De gebakjes op het feest	zelfgemaakt
	The cakes at the party	*homemade*
72	De nachtwaker van het museum en de beveiliger	geschrokken
	The night-watcher of the museum and the security guard	*scared*
73	De miljonair en zijn ex-vrouw	rijk
	The millionaire and his ex-wife	*rich*
74	De secretaresse en de conciërge	nijdig
	The secretary and the janitor	*angry*
75	De schuur en de koeienstal	afgebrand
	The barn and the cowshed	*burned down*
76	De bewoners van de grote boerderij	zuinig
	The inhabitants of the big farm	*thrifty*
77	De bergbeklimmers op de top van de berg	hongerig
	The mountaineers on the top of the mountain	*hungry*
78	De vork en het mes	afgewassen
	The fork and the knife	*washed*
79	De prins en de prinses	verliefd
	The prince and the princes	*in love*
80	De sterrenkundige en de tekstschrijver	bevriend
	The astronomer and the scriptwriter	*close*
81	De beek en de rivier	overstroomd
	The brook and the river	*overflown*
82	De huisvrouw en de zuster	opgebeld
	The housekeeper and the sister	*rung*
83	Het aantal deelnemers en het slagingspercentage	teleurstellend
	The number of contesters and the success rate	*disappointing*
84	De eieren in het ontdekte eendennest	kapot
	The eggs in the discovered duck nest	*broken*
85	De brief en de ansichtkaart	gepost
	The letter and the postal card	*mailed*
86	De oma en de opa	opgewekt
	The grandmother and grandfather	*cheerful*
87	De fysiotherapeut en zijn neef	mager
	The physiotherapist and his cousin	*skinny*
88	De straat en het steegje	nauw
	The street and the alley	*narrow*
89	De snoepjes uit de snoepjespot van de meester	op
	The candy out of the candy jar of the teacher	*empty*
90	De danseressen in de voorstelling	knap
	The dancers in the show	*handsome*
91	De nichtjes van de kapper	linkshandig
	The nieces of the hairdresser	*left-handed*
92	De pensionaris en zijn vrouw	vergeetachtig
	The pensioner and his wife	*forgetful*
93	De computers van de middelbare school	gestolen
	The computers of the high school	*stolen*
94	De schets en het schilderij van de beroemde schilder	geveild
	The sketch and the painting of the famous painter	*auctioned*
95	Het sleutelbeen en de bovenarm	gebroken
	The collarbone and the upper arm	*broken*
96	De blaadjes van het jonge boompje	teer
	The leaves of the young tree	*fragile*
97	De zolder en de kelder van het oude huis	stoffig
	The attic and the cellar of the old house	*dusty*

98	De leerlingen van de kunstopleiding	getalenteerd
	The students of the art school	*talented*
99	Het slootwater en het zeewater	getest
	The ditchwater and the seawater	*tested*
100	De vissen in de vijver	groot
	The fish in the pond	*big*

Note. Adjectives were not used in Experiment 2.

Appendix C. The catch items

	Sentence	Adjective
1	De trainingsbroeken	uitverkocht
	The sweatpants	*sold out*
2	De stratenmakers	bekwaam
	The road-makers	*capable*
3	De nagellak en de lippenstift	donkerrood
	The nail polish hand the lipstick	*dark red*
4	De vader en de zoon	zenuwachtig
	The father and the son	*nervous*
5	Het bericht van de kaping	onverwacht
	The news of the hijacking	*unexpected*
6	De opbrengst van de benefietacties	hoog
	The proceeds of the benefit actions	*high*
7	De treinconducteurs in de intercity	streng
	The conductors in the fast train	*strict*
8	De uitslagen van de examens	bekend
	The results of the exams	*announced*
9	De frikadel en de kroket uit de muur	afgekoeld
	The snacks out of the wall	*cooled down*
10	De ruiter en het paard	gevallen
	The rider and the horse	*fallen*
11	Het idee van de uitvinders	geniaal
	The idea of the inventors	*brilliant*
12	De artiest met de bodyguard	beroemd
	The artist with the bodyguard	*famous*
13	De stofzuigers van de speciaalzaak	duur
	The vacuum cleaners from the specialist shop	*expensive*
14	De bewakers	oplettend
	The guards	*observant*
15	De strandjutter en zijn hond	natgeregend
	The beachcomber and his dog	*wet*
16	De kattenbak en de vogelkooi	verschoond
	The litter tray and the bird cage	*cleaned*
17	De moeder met de kinderwagen	ongerust
	The mother with the pram	*worried*
18	De Sinterklaas met de zwarte pieten	aangekomen
	Saint Nicholas and the Black Pete's	*arrived*
19	De wandelaars	vermoeid
	The hikers	*tired*
20	De mannen met de baarden	zeeziek
	The men with the beards	*seasick*
21	De sergeant en de generaal	uitgezonden
	The sergeant and the general	*posted*
22	De kuitspier en de hamstring	verstuikt
	The calf muscle and the hamstring	*sprained*
23	Het kind met de knikkers	blij
	The child with the marbles	*happy*
24	Het plan van de politicus	uitgelekt
	The plan of the politician	*leaked out*

Appendix D. The practice items

	Sentence	Adjective
1	De palmbomen bij het strand	groot
	The palm trees at the beach	*big*
2	De broer van de collega van mijn vader	miljonair
	The brother of the colleague of my father	*millionaire*
3	De kip en het ei	wit
	The chicken and the egg	*white*
4	De overtreding door de wethouder	schandalig
	The offence by the alderman	*scandalous*
5	De sloot achter de kerk	vervuild
	The ditch behind the church	*polluted*
6	De man achter de toonbank	aardig
	The man behind the counter	*friendly*
7	De telefoon en de oplader	gestolen
	The telephone and the charger	*stolen*
8	De vleermuizen in de grot	eng
	The bats in the cave	*scary*
9	De minister van financiën van Italië	hoogopgeleid
	The minister of finance of Italy	*highly educated*
10	De pony's van de kinderboerderij	lief
	The ponies at the children's zoo	*sweet*
11	Het geld op de bank	verdwenen
	The money on the bank	*disappeared*
12	De deuren van de casino's	open
	The doors of the casino's	*open*

Note. Items 7 through 12 were only used in Experiment 2. The adjectives were only used in Experiment 1. Catch trials (items 3 and 5) were only used in Experiment 1 and the follow-up to Experiment 2.

Appendix E. Descriptives and statistics for analyses using dichotomous integration

Table E1

Agreement Error Rates (SD) per Condition

		Integration	
Experiment 1		Unintegrated	Integrated
	Singular local noun	16% (37%)	8% (27%)
	Plural local noun	24% (43%)	12% (33%)
Experiment 2			
	Singular local noun	14% (35%)	2% (16%)
	Plural local noun	24% (43%)	11% (31%)

Table E2

Agreement Errors predicted by Integration treated as a Dichotomous Variable

Experiment 1					
Variable	Coefficient	*SE*	*z*-value	Pr(>|*z*|)	Random Slope
(Intercept)	-2.34	0.24	-9.86	<.001***	
Integration	-0.53	0.10	-5.52	<.001***	subjects
Local Noun Number	0.22	0.10	2.14	0.032*	subjects, items
Block	-0.16	0.06	-2.83	<.01**	
Integration*Number	-0.08	0.07	-1.20	0.232	
Integration*Block	-0.10	0.04	-2.23	0.026*	
Number*Block	-0.15	0.04	-3.35	<.001***	
Experiment 2					
Variable	Coefficient	SE	z-value	Pr(>|z|)	Random Slope
(Intercept)	-2.65	0.22	-12.18	<.001***	
Integration	-0.78	0.12	-6.54	<.001***	subjects
Local Noun Number	0.44	0.13	3.28	0.001**	subjects
Block	-0.21	0.05	-3.91	<.001***	
Integration*Number	0.11	0.09	1.18	0.279	

Note. * p<.05; ** p<.01; *** p<.001. Interactions with Block indicate a practice effect.

Table E3

Response Times (SD) per Condition

		Integration	
Experiment 1		Unintegrated	Integrated
	Singular local noun	906 (348)	844 (323)
	Plural local noun	933 (352)	854 (319)
Experiment 2			
	Singular local noun	992 (814)	835 (560)
	Plural local noun	1035 (798)	960 (676)

Table E4

Response Times predicted by Integration treated as a Dichotomous Variable

Experiment 1				
Variable	Coefficient	*SE*	*t*	Random Slope
(Intercept)	6.73	0.04	183.29*	
Integration	-0.04	0.01	-5.34*	
Local Noun Number	0.02	0.01	2.37*	subjects
Block	-0.04	0.01	-6.75*	
Integration*Number	-0.01	0.01	-0.91	
Integration*Block	-0.01	0.00	-2.58*	
Experiment 2				
Variable	Coefficient	SE	*t*	Random Slope
(Intercept)	6.63	0.11	59.68*	
Integration	-0.07	0.01	-5.50*	subjects, items
Local Noun Number	0.06	0.01	5.67*	subjects
Block	-0.01	0.01	-2.25	
Integration*Number	0.00	0.01	0.36	
Number*Block	-0.01	0.01	-2.25*	

Note. *$|t|>2$. Interactions with Block indicate a practice effect.

Chapter 3

Boosting the notional number effect in the production of subject-verb agreement

Based on: Veenstra, A., & Acheson, D. J. (2014). *Boosting the notional number effect in the production of subject-verb agreement*. Manuscript in preparation.

Abstract

The process of subject-verb agreement in production is influenced by both conceptual (e.g., notional) and grammatical number, yet the extent to which these two factors are independent or interacting remains unclear. Research that has manipulated the notional number of subject noun phrases through semantic integration (e.g., *the driver of/with the mayor*; integrated/unintegrated) has shown that unintegrated phrases are perceived of as notionally plural and yield more errors and longer reaction times than integrated phrases (Brehm & Bock, 2013; Veenstra, Acheson, Bock, & Meyer, 2014). Veenstra et al. argued that the notional integration effect is independent from the grammatical attraction effect (e.g., *the key to the cabinets are lost*). The current study was designed to test the independence of conceptual and grammatical effects on subject-verb agreement by boosting the notional number effect while keeping the attraction effect constant.

A preamble completion task was used in which participants had to complete a subject phrase by selecting a plural or singular verb. Preambles were integrated or unintegrated (the notional number manipulation) and had a singular or plural local noun (the grammatical number manipulation, e.g., *the bowl with the stripe(s)/spoon(s)*). In order to enhance the notional number effect, participants were presented with a picture during auditory presentation of the preamble. Results showed that picture presence enhanced the integration effect: more agreement errors for unintegrated preambles were found in the picture present condition compared to the picture absent condition and this had no effect on the attraction effect. These results thus provide converging evidence for the independence of conceptual and grammatical factors in agreement in production.

Introduction

Subject-verb agreement occurs in nearly every utterance and in most instances this is done correctly and implicitly. In the vast majority of sentences, subjects agree with their verbs in number: a singular subject is followed by a singular verb, and a plural subject is followed by a plural verb. However, noteworthy mistakes have been reported in which a subject and its verb did not end up with the same number specification. These agreement errors have provided important insight into the process of grammatical encoding in production and can be driven by both grammatical and conceptual (or notional) factors.

When the subject phrase is made up of a head noun (*drawing*) and a local noun (*flower*), as in *the drawing of the flower*, the verb conventionally takes the number of the head noun. However, when the grammatical number of the two nouns mismatch, sometimes the verb takes the number of the most recent local noun. Agreement errors occur most often when the head noun is singular and the local noun plural (e.g., *the drawing of the flowers*) which is then incorrectly followed by a plural verb (Bock & Eberhard, 1993; Bock & Miller, 1991). When the grammatical number of two nouns clash, this leads to increased error rates and response times. Since the plural number of the local noun attracts the number that will be passed on to the verb, this is referred to as attraction (Eberhard, 1997; Eberhard, Cutting, & Bock, 2005; Vigliocco, Butterworth, & Semenza, 1995).

In addition to being influenced by grammatical number markings, the process of agreement is also influenced by conceptual factors, such as the notional number of the subject noun phrase. The current study focuses on the notional influence at sentence level which stems from semantic integration. Semantic integration refers to the extent to which nouns within a subject phrase are related to each other (Solomon

& Pearlmutter, 2004). In *the bowl with the wooden spoons*, the *bowl* and the *spoons* are not related (i.e., unintegrated) as they just happen to be in each other's vicinity. On the other hand, in *the bowl with the red stripes*, the *bowl* and the *stripes* are very tightly integrated, since the stripes are part of the bowl. Unintegrated subjects tend to be implicitly regarded as notionally plural, whereas integrated subjects are perceived as notionally singular (Brehm & Bock, 2013). In the unintegrated case, the head noun is grammatically singular, whereas the notional number of the entire subject phrase is plural. As with the attraction effect, the conflict between grammatical number and notional number of the whole noun phrase leads to more agreement errors and longer reaction times for unintegrated compared to integrated subjects (Brehm & Bock, 2013; Veenstra, Acheson, Bock, & Meyer, 2014; but see Solomon & Pearlmutter, 2004, for an alternative account).

In order to investigate the potential interaction between the grammatical and conceptual influences on agreement, predicted by Solomon and Pearlmutter (2004), but not by Brehm and Bock (2013), Veenstra et al. (2014) factorially manipulated semantic integration and local noun number (singular/plural) in a set of preamble completion tasks. Participants read a subject phrase and completed it into a full sentence containing an inflected verb. Results of the study showed that completing unintegrated subjects yielded more errors and longer RTs than integrated subjects, whereas completing subjects with plural local nouns yielded more errors and longer RTs than those with singular local nouns. Critically, these two separate effects showed additive influences as there was no interaction between the two factors and the effect sizes of the two effects did not correlate. These results thus suggest that both conceptual and grammatical influences on agreement are independent from each other (see also Anton-Mendez & Hartsuiker, 2010, for a similar claim). Using

Sternberg's logic of additivity (Sternberg, 1969), if notional and grammatical number have independent influences, it should be possible to boost one factor while keeping the other constant.

The aim of the current study was to determine whether notional influences on subject-verb agreement are independent from grammatical influences, as previous research suggests. As with our previous experiments, semantic integration and local noun number were factorially manipulated within a forced-choice paradigm (Staub, 2009, 2010). In order to manipulate the strength of the semantic integration effect, we used pictures to encourage our participants to form a mental image belonging to the subject preambles. To date, only a few studies of agreement in production have used pictures, with mixed results. Eberhard (1999) found that notional effects could be enhanced by presenting pictures accompanying distributive and non-distributive preambles (Experiment 1), such that distributivity had a reliable effect on agreement errors. Her second experiment, however, showed that the same effect was found without presenting pictures. The notional effect was attributed to the conceptual accessibility of the referent: only depictable items could be used, which are inherently more conceptually accessible than abstract items. However, for a subject phrase to get a distributed interpretation, this need not depend on the mental image of the preamble, but rather on the speaker's interpretation of the preamble's meaning. For instance, *the label on the bottles* might refer to one type of label that is present on multiple bottles—notionally singular—whereas it could also refer to multiple tokens of the same label that is present on multiple bottles—notionally plural. In both instances the picture would look the same, yet the notional number of the interpretation would vary.

Another study that used pictures along the preambles found no effect of the pictures on the strength of the collectivity effect (Bock, Eberhard, Cutting, Meyer, &

Schriefers, 2001). In Experiment 4, the authors presented participants with a picture of the preamble while they listened to a recorded version of the preamble. The participants who saw a picture made an equally small number of agreement errors after collective local nouns, compared to a control group who did not see any pictures. For collective nouns, one would predict an effect of picture since the collected individuals are all present in the picture. However, since collective local nouns have shown to hardly attract agreement (Bock et al., 2006; Deutsch & Dank, 2009), this floor-effect was conceivably not increased by the pictures.

The use of semantic integration as the manipulation of notional number in the present study avoids both of these problems. First, in contrast to the case of distributivity, semantic integration yields no ambiguity about the notional number of the referents as notionally singular and plural versions of the same item (*the bowl with the stripes* versus *the bowl with the spoons*) yield pictures with different numbers of items. Second, unlike the effects of collectivity, semantic integration has been shown to reliably affect agreement errors and response times; hence there is less of a concern for floor effects. If notional effects on agreement are independent from grammatical effects, and if the presence of the picture boosts the notional number of subject noun phrase, the presence of the picture in the current experiment leads to a very clear prediction: Pictures should increase the notional number effect while leaving the grammatical attraction effect from local noun number unaffected.

Experiment

In the experiment, participants selected singular or plural verb forms to continue preambles that were integrated/unintegrated with singular/plural local nouns. As the picture manipulation was between subjects, half of the participants saw a

picture whereas the other half did not. This allowed us to investigate whether notional and grammatical factors work independently in the generation of agreement and whether one of the effects can be boosted while keeping the other constant.

Method

Participants. Fifty-three adult native speakers of Dutch participated in the experiment and received €4 for their participation. All gave written, informed consent prior to their participation. Data from five participants were excluded due to a recording error. Forty-eight participants (41 female) remained, of which 24 participated in the Picture Present condition and 24 in the Picture Absent condition. The average age was 34 years (*SD* = 16.5). Twenty-nine participants were university students.

Materials. There were 60 experimental items, 59 of which were taken from Veenstra, Acheson, Bock, and Meyer (2014) whereas the one new item had the same structure as the previously generated items. Seventeen items differed only in preposition (*van (of)* versus *met (with)*, e.g., *the drawing of/with the flower(s)*), 43 differed only in local noun to mark the distinction between integrated and unintegrated (e.g., *the bowl with the stripe(s)/spoon(s)*). Each item appeared in four versions, crossing integration and local noun number, see Table 1:

Table 1
An Experimental Item in its Four Versions

Local Noun Number	Integration	
	Integrated	Unintegrated
Singular	De kom met de rode streep 	De kom met de houten lepel 
Plural	De kom met de rode strepen 	De kom met de houten lepels 
	The bowl with the red stripe(s)	*The bowl with the wooden spoon(s)*

Note. Pictures appeared only in the Picture Present condition.

The pictures were colored line drawings, drawn for the experiment by an artist[4]. In addition to the experimental items, 60 filler items were generated which were designed to elicit a plural response. Thirty of the filler items consisted of a plural subject head noun (e.g., *the socks of the director*), thirty of them consisted of a coordinated noun phrase (e.g., *the keyboard and the mouse of the computer*), targeting a plural verb response. There were also 24 catch trials with varying subject numbers (see Procedure), and 12 practice items.

Items were presented in four blocks: a practice block of 12 items, followed by three blocks consisting of 15 experimental items, 15 filler items, and 8 catch items. For both the Picture Present and the Picture Absent condition (a between subjects manipulation), four lists were constructed with each version of the experimental items appearing in one list. Participants thus saw a total of 15 items in each of the four conditions, and each list was seen by six participants. Trials in each block were individually randomized but the order of the blocks was fixed.

[4] We would like to thank Tilman Harpe for providing us with the pictures for the preambles.

Procedure. Participants were tested individually in a soundproof booth. The experiment (modeled after Staub, 2009, 2010) was programmed in Presentation 15.0 and presented on an IBM ThinkPad laptop. The trials in the Picture Present condition had the following structure: First, a fixation cross (0.5° visual angle) was presented in the center of the screen for 500 ms, followed by a blank screen for 150 ms. Then the 500 x 500 pixel picture appeared for 2000 ms in the center of the screen, after which the pre-recorded preamble was played. The picture stayed on the screen until the sound recording finished. The recordings were done by a female native speaker of Dutch, and originally included a continuation of the preamble which was cut off to maintain a natural prosody in the preamble. As soon as the sound file finished, the picture disappeared and the singular and plural forms of the verb to be, *is* and *zijn*, were presented simultaneously, slightly to the left and right of the center of the screen (see Fig. 1). Participants were instructed to indicate as quickly as possible which of the two forms would be the correct continuation of the preamble by pressing either the left or the right key on a two button box. To control for the SNARC effect (Dehaene, Bossini, & Giraux, 1993) the singular *is* was always presented on the left side of the screen. Feedback was provided if the response was incorrect using the word *FOUT* (*wrong*) displayed in red. The next trial began 1500 ms after the response.

Figure 1. Picture Present trial structure in Experiment 1.

The Picture Absent condition was presented in a similar fashion except that a fixation cross was presented on the screen for the duration of the sound recording. The Picture Present condition took maximally 5 minutes longer to complete than the Picture Absent condition.

Catch trials were similar to experimental trials, except for the last screen. No verb options were shown, only the word *herhaal! (repeat)* instead. This prompted participants to repeat the entire preamble aloud and complete it into a full sentence. As the catch trials were randomly distributed across the experiment, participants did not know when they would encounter a catch trial, forcing them to pay attention to every single preamble. Responses were recorded with a Sennheiser microphone for 5500 ms from the onset of the prompt.

Scoring and analysis. Adequate performance on the catch trials was used as a prerequisite for participants to be included in the analyses. The upper limit of incorrect preamble repetitions was 25%. None of the participants succeeded this maximum error rate.

Statistical analyses were run in R using linear mixed effects models with crossed effects of subjects and items using the lme4 package (Bates, 2005; R Development Core Team, 2011). In order to avoid collinearity and to maximize the likelihood of model convergence, variables such as List, Block, Integration and Local Noun Number were mean centered prior to analysis (Baayen, 2008). Negative regression coefficients thus indicate earlier blocks, tighter integration and singular local nouns.

The experimental fixed effects included in the statistical models were Picture Presence (present vs. absent), Integration (integrated vs. unintegrated), Local Noun Number (singular vs. plural), and Block (1 through 3). The list participants saw was

initially included as a fixed effect, but it did not contribute significantly to any of the models, thus we collapsed across this factor. Random intercepts were included for subjects and items, as well as random slopes to subjects and items for Picture Presence, Integration and Local Noun Number. We used backward selection, starting with a full model that included all factors, gradually leaving out the non-significant effects. The interaction between Integration and Local Noun Number, as well as the interactions with Picture Presence were kept for theoretical reasons. Model comparison was used to determine whether the inclusion of various random slopes improved model fit while minimizing model complexity (as measured with AIC/BIC). Whether random slopes were included in a particular analysis is indicated in the results tables. Error rates were analyzed using a logistic linking function (e.g., Jaeger, 2008).

Results

Every plural response to an experimental trial was an agreement error. In total, 178 out of 2880 trials were agreement errors, divided over the conditions as follows (see Figure 2):

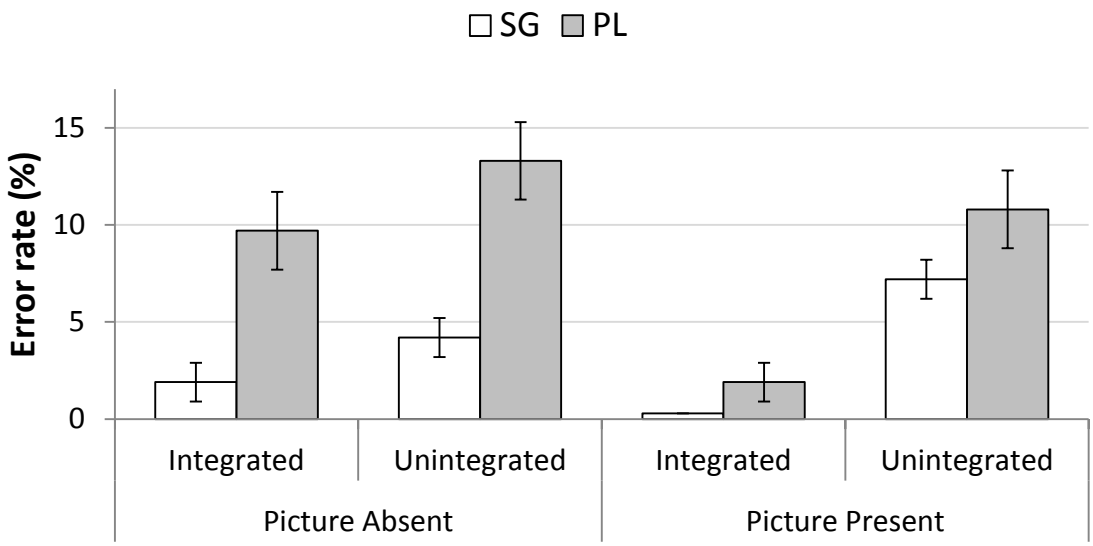


Figure 2. Error rates for Integration by Local Noun Number in the Picture Absent and Picture Present versions. Error bars represent *SE* for illustrative purposes. SG = singular local noun, PL = plural local noun.

Figure 2 shows that when there was a picture present, participants made fewer errors than when there was no picture. In addition, in both picture conditions, unintegrated preambles increased error rates relative to the integrated preambles (the facilitatory effect of integration) and plural local nouns increased error rates relative to singular local nouns (the grammatical attraction effect). The results of the linear mixed effects regression analysis (Table 2) confirmed these patterns:

Table 2
Results of the Logistic Mixed-Effects Model predicting Agreement Errors by Integration, Local Noun Number, Picture Presence, and Block.

Variable	Coefficient	*SE*	*z*-value	Pr(>|*z*|)	Random Slope
(Intercept)	-2.77	0.29	-9.53	<.001***	
Picture Presence	-0.45	0.17	-2.56	.009**	items
Integration	0.94	0.18	5.24	<.001***	subjects, items
Local Noun Number	0.70	0.17	4.19	<.001***	items
Block	-0.40	0.11	-3.69	<.001***	
Picture Presence*Integration	0.56	0.17	3.37	<.001***	
Picture Presence*Noun Number	-0.06	0.17	-0.36	0.720	
Integration*Noun Number	-0.30	0.17	-1.78	0.075	
Picture*Integration*Number	-0.14	0.17	-0.84	0.401	

Note. * p<.05; ** p<.01; *** p<.001. Coefficients correspond to Logits.

The model indicated that there were four significant main effects: Picture Presence, Integration, Local Noun Number, and Block. When there was a picture present, participants made 2% fewer errors than when there was no picture (SD_d = 1.5%). Similar to previous research, the main effect of Integration was driven by a 5% increase in errors (SD_d = 1.4%) for unintegrated relative to integrated preambles. We also found classic attraction effects as participants made 6% more errors when the local noun was plural relative to when it was singular. Finally, the main effect of Block was driven by improved performance over the course of the experiment as participants made 2% fewer errors (SD_d = 2%) with each block. Also similar to previous research, there was no interaction between Integration and Local Noun Number, and no interaction between Picture Presence and Local Noun Number.

Critically, however, we did find that Picture Presence interacted reliably with Integration. As predicted, the magnitude of the Integration effect on error rates was larger when pictures were present relative to when they were absent. Running separate models of the Picture Absent and the Picture Present condition confirmed that the integration effect was strongest when the picture was present, since the coefficient for Integration was larger in the Picture Present condition than in the Picture Absent condition (β = 1.63 versus β = 0.31). In the Picture Present condition, unintegrated preambles yielded 8% more errors than integrated preambles (SD_d = 6.3%), whereas in the Picture Absent condition, unintegrated preambles yielded only 3% more errors than the integrated preambles (SD_d = 7.4%).

General Discussion

This study investigated the notional and grammatical influences on the production of subject-verb agreement when the mental image of the subject phrase

was more activated than in previous completion paradigms. In the traditional preamble completion paradigm, participants are presented with a linguistic form of the preamble (written or spoken), which they have to complete into a full sentence. In proper language production, however, speaking starts with a message—and possibly a mental image of this message—before the linguistic building blocks are assembled (Levelt, 1989). We aimed to enhance the mental image of the preamble by presenting a picture, followed by the linguistic preamble. Presenting the actual words was still necessary to control the experimental manipulations.

It was hypothesized that enhancing the mental image of a preamble would make the notional number of the subject phrase more salient, thereby increasing the notional number effect on agreement, but not the grammatical number effect. We used semantic integration to manipulate notional number and found effects of notional number and of grammatical number: plural notional number and plural local noun number made singular agreement more difficult compared to singular notional number and singular local nouns. The results showed that the integration effect (more errors for unintegrated than integrated preambles) was stronger when there was a picture present, compared to the Picture Absent condition. The grammatical number effect (attraction) was equally strong in both conditions and was evidently not affected by the activation of the mental image.

The current results provide converging evidence for the view that notional and grammatical effects influence agreement processes independently and possibly at different time stamps (Anton-Mendez & Hartsuiker, 2010; Brehm & Bock, 2013; Veenstra, Acheson, Bock, & Meyer, 2014). Sternberg (1969) argues that additivity of effects entails that the independent effects play a role at different stages during language production. It is conceivable that the integration effect comes about during

the message formulation stage as we found that it can be influenced by pictures which make the notional number of the message more salient. The attraction effect comes about during the grammatical encoding stage, when grammatical number markers from sentence parts other than the subject head noun interfere with the verb. Following serial production models (Bock & Levelt, 1994; Garrett, 1988), the conceptual effects can thus occur before and independent of syntactic effects. Similarly, the Marking and Morphing model for agreement production assumes that notional number is marked (independently) before the grammatical number is morphed onto the verb (Eberhard, Cutting, & Bock, 2005).

Our results ultimately show that core grammatical processes such as subject-verb agreement are vulnerable to conceptual influences as well as grammatical interference. Adding to the independence claim is the evidence that the notional effect can be increased while keeping the grammatical effect constant. The ultimate test would of course be the reverse: increasing the grammatical effect while keeping the notional effect constant, which would be the objective of future research.

Appendix

Appendix A. Experimental items

	Integrated/Unintegrated Singular local noun (Plural local noun)
1	De tekening van/met de bloem(en) *The drawing of/with the flower(s)*
2	De afbeelding van/met de edelsteen (edelstenen) *The picture of/with the gem(s)*
3	De sculptuur van/met de sleutel(s) *The sculpture of/with the key(s)*
4	De schets van/met de boekenkast(en) *The sketch of/with the bookcase(s)*
5	De beeltenis van/met de ballon(nen) *The picture of/with the balloon(s)*
6	De foto van/met de akte(s) *The photo of/with the certificate(s)*
7	De afdruk van/met de memo('s) *The print out of/with the memo(s)*
8	De illustratie van/met de landkaart(en) *The illustration with/of the map(s)*
9	De fotokopie van/met de publicatie(s) *The photocopy of/with the publication(s)*
10	De reproductie van/met de prent(en) *The reproduction of/with the engraving(s)*
11	De fax van/met de blauwdruk(ken) *The fax of/with the blueprint(s)*
12	De uitvergroting van/met de brief (brieven) *The enlargement of/with the letter(s)*
13	De dia van/met de krant(en) *The slide of/with the newspaper(s)*
14	De uitdraai van/met de scriptie(s) *The print out of/with the thesis/theses*
15	De polaroidfoto van/met de postzegel(s) *The polaroid of/with the stamp(s)*
16	De ansichtkaart van/met de schoen(en) *The postcard of/with the shoe(s)*
17	De poster van/met de kroon (kronen) *The poster of/with the crown(s)*
18	De dichtbundel met de omgevouwen bladzijde(n)/rode pen(nen) *The volume of poems with the torn page(s)/red pen(s)*
19	De panty met de rare opdruk(ken)/vieze handdoek(en) *The tights with the crazy print(s)/dirty towel(s)*
20	De ring met de nep-diamant(en)/gouden armband(en) *The ring with the fake diamond(s)/gold bracelet(s)*
21	De appel met de bruine plek(ken)/verse perzik(en) *The apple with the brown spot(s)/fresh peach(es)*
22	De stropdas met de lelijke streep (strepen)/katoenen blazer(s) *The tie with the hideous stripe(s)/cotton blazer(s)*
23	De klok met de missende wijzer(s)/zwarte portemonnee(s) *The clock with the missing hand(s)/black wallet(s)*
24	De jas met de kapotte rits(en)/natte paraplu('s) *The jacket with the faulty zipper(s)/wet umbrella(s)*
25	De kam met de gebroken tand(en)/lege tube(s) *The comb with the broken tooth (teeth)/empty tube(s)*
26	De sleutel met de gekartelde rand(en)/glanzende munt(en) *The key with the jagged edge(s)/shiny coin(s)*
27	De fauteuil met de krakende veer (veren)/grote boekenkast(en) *The chair with the creaky spring(s)/tall bookcase(s)*
28	De telefoon met de missende toets(en)/kapotte broodrooster(s) *The phone with the missing button(s)/broken toaster(s)*
29	De bedsprei met de vieze vlek(ken)/wollen deken(s) *The bedspread with the dirty stain(s)/woolen blanket(s)*

30	De kroonluchter met de felle lamp(en)/antieke pianokruk(ken) *The chandelier with the harsh light(s)/antique music-stool(s)*
31	De krant met de kleurige advertentie(s)/koffiemok(ken) *The newspaper with the colorful ad(s)/coffee mug(s)*
32	De trui met de losse zoom (zomen)/zwarte pantalon(s) *The sweater with the loose hem(s)/black slack(s)*
33	De rekening met de hoge prijs (prijzen)/afgesloten doos (dozen) *The receipt with the high price(s)/sealed box(es)*
34	De boom met de dode tak(ken)/lage struik(en) *The tree with the dead branch(es)/small shrub(s)*
35	De pizza met de lekkere topping(s)/frisse dorstlesser(s) *The pizza with the tasty topping(s)/fresh beverage(s)*
36	De melk met de aardbei(en)/bosbessenmuffin(s) *The milk with the strawberry (strawberries)/blueberry muffin(s)*
37	De gitaar met de kapotte snaar (snaren)/luide trommel(s) *The guitar with the loose string(s)/loud drum(s)*
38	De deken met de losse draad (draden)/schone rok(ken) *The blanket with the loose thread(s)/clean skirt(s)*
39	De beker met de lange scheur(en)/kristallen kom(men) *The mug with the lengthy crack(s)/crystal bowl(s)*
40	De fiets met de verbogen spaak (spaken)/surfplank(en) *The bike with the bent spoke(s)/surfboard(s)*
41	De stoel met de losse poot (poten)/oude tafel(s) *The chair with the wobbly leg(s)/old table(s)*
42	De koe met de zwarte vlek(ken)/zwarte geit(en) *The cow with the black spot(s)/goat(s)*
43	De plant met de mooie bloem(en)/ronde steen (stenen) *The plant with the pretty flower(s)/round rock(s)*
44	De cd met de rustige ballade(s)/spannende roman(s) *The cd with the slow ballad(s)/exciting novel(s)*
45	De piano met de losse toets(en)/scheve kruk(ken) *The piano with the loose key(s)/lopsided stool(s)*
46	De schoen met de kapotte veter(s)/schone sok(ken) *The shoe with the broken lace(s)/clean sock(s)*
47	De kom met de rode streep (strepen)/houten lepel(s) *The bowl with the red stripe(s)/wooden spoon(s)*
48	De jongedame met de zere vinger(s)/hond(en) *The young lady with the sore finger(s)/dog(s)*
49	De bal met de rode stip(pen)/sportschoen(en) *The ball with the red dot(s)/sports shoe(s)*
50	De kerstboom met de slinger(s)/kerststal(len) *The Christmas tree with the garland(s)/nativity scene(s)*
51	De kat met de scherpe nagel(s)/witte muis (muizen) *The cat with the sharp nail(s)/white mouse/mice*
52	De tegel met de spreuk(en)/fotolijst(en) *The tile with the proverb(s)/photo frame(s)*
53	De laptop met de verlichte knop(pen)/broodtrommel(s) *The laptop with the illuminated button(s)/bread bin(s)*
54	De woning met de rode deur(en)/vrijstaande garage(s) *The residence with the red door(s)/detached garage(s)*
55	De spijkerbroek met de scheur(en)/trui(en) *The jeans with the tear(s)/sweater(s)*
56	De blouse met de gouden knoop (knopen)/leren handschoen(en) *The blouse with the golden button(s)/leather glove(s)*
57	De kandelaar met de witte kaars(en)/zilveren schaal (schalen) *The chandelier with the white candle(s)/silver platter(s)*
58	De zakdoek met de geborduurde letter(s)/rode kauwgombal(len) *The handkerchief with the embroidered character(s)/red bubble gum(s)*
59	De auto met de lekke band(en)/bestelbus(sen) *The car with the flat tire(s)/delivery truck(s)*
60	De taart met de kers(en)/champagnefles(sen) *The pie with the cherry (cherries)/champagne bottle(s)*

Note. Items were taken from Veenstra, Acheson, Bock, & Meyer (2014), except for item 60.

Appendix B. Filler items

1	De sokken van de directeur *The socks of the director*
2	Het toetsenbord en de muis van de computer *The keyboard and the mouse of the computer*
3	De pakjes voor de kinderen *The presents for the children*
4	De schommel en de wip in de pas aangelegde speeltuin *The swing and the seesaw in the new playground*
5	De sandwich en de chocolade muffin *The sandwich and the chocolate muffin*
6	De inbrekers met de bivakmutsen *The burglars with the balaclavas*
7	De klanten van de telefoon-maatschappij *The customers of the phone company*
8	De achtbaan en het reuzenrad *The rollercoaster and the big wheel*
9	De eenden in het park *The ducks in the park*
10	De jongetjes op de kleuterschool *The boys at the kindergarten*
11	De raamkozijnen van het kantoor *The window frames of the office*
12	De pennen uit het etui *The pens from the case*
13	De reizigers op het vliegveld *The travelers at the airport*
14	De bus en de trein richting het noorden *The bus and the train heading north*
15	De bierglazen op de plank *The beer glasses on the shelf*
16	De kevers op de tak *The bugs on the branch*
17	De voetballers in de lastige wedstrijd *The soccer players in the tough game*
18	De pantoffels met de rode stippen *The slippers with the red dots*
19	De bloemen in de mooie vaas *The flowers in the pretty vase*
20	Het album en de cd-single van de nieuwe popgroep *The album and the cd single of the new pop group*
21	De potloden van de ijverige scholier *The pencils of the diligent pupil*
22	Het paspoort en de id-kaart *The passport and the ID card*
23	De sperziebonen uit de supermarkt *The green beans from the supermarket*
24	De ballonnen voor het feestje *The balloons for the party*
25	De tanden van de Hollywood acteur *The teeth of the Hollywood actor*
26	Het gerecht en de saus *The dish and the sauce*
27	De schat en de schatkaart *The treasure and the map*
28	De helm en de linker kniebeschermer *The helmet and the left knee-guard*
29	De wortels uit de groentetuin *The carrots from the vegetable garden*
30	De gasten voor de trouwerij *The guests for the wedding*
31	De slagerij en de kapsalon *The butcher's shop and the hairdresser's shop*
32	De salade en het verse fruit *The salad and the fresh fruit*

33 De piano's van de muziekschool in de stad
The pianos of the music school in town
34 De worstjes op de barbecue
The sausages on the barbecue
35 De documenten voor de sleuteloverdracht
The documents for the handover of the keys
36 Het hert en het everzwijn
The deer and the wild boar
37 De spijker en de schroef in de buitenmuur
The nail and the screw in the outer wall
38 De wolken in de donkere lucht
The clouds in the dark sky
39 De jas en de broek
The jacket and the pants
40 De supporters van de voetbalclub
The supporters of the football club
41 De sterren aan de hemel
The stars in the sky
42 De tomaat en de appel
The tomato and the apple
43 De badkamer en de keuken van het oude huis
The bathroom and the kitchen of the old house
44 De voeten van de marathon-loper
The feet of the marathon runner
45 De juryleden van het tv-programma
The members of the jury of the television program
46 De broek en het shirt van de atleet
The pants and the shirt of the athlete
47 De tractor en de hijskraan
The tractor and the hoisting crane
48 De film en het boek
The movie and the book
49 De gebakjes op het feest
The cakes at the party
50 De schuur en de koeienstal
The barn and the cowshed
51 De bewoners van de grote boerderij
The inhabitants of the big farm
52 De bergbeklimmers op de top van de berg
The mountaineers on the top of the mountain
53 De vork en het mes
The fork and the knife
54 De beek en de rivier
The brook and the river
55 De eieren in het ontdekte eendennest
The eggs in the discovered duck nest
56 De brief en de ansichtkaart
The letter and the postal card
57 De oma en de opa
The grandmother and grandfather
58 De straat en het steegje
The street and the alley
59 De snoepjes uit de snoepjespot van de meester
The candy out of the candy jar of the teacher
60 De danseressen in de voorstelling
The dancers in the show

Appendix C: Catch items

1	De trainingsbroeken
	The sweatpants
2	De kleuren van de regenboog
	The colors of the rainbow
3	De nagellak en de lippenstift
	The nail polish and the lipstick
4	De heks en de tovenaar
	The witch and the wizard
5	De pop met de armen en benen
	The doll with the arms and legs
6	De hond van de buren
	The dog of the neighbors
7	De frikadel en de kroket uit de muur
	The snacks out of the wall
8	De ruiter en het paard
	The rider and the horse
9	Het signaal van de telefoon
	The signal of the telephone
10	De winkel met de deuren
	The store with the doors
11	De boom bij de vijver en de steen
	The tree near the pond and the rock
12	De stofzuigers van de speciaalzaak
	The vacuum cleaners from the specialist shop
13	De theezakjes uit het kerstpakket
	The tea bags from the Christmas package
14	De strandjutter en zijn hond
	The beachcomber and his dog
15	De kattenbak en de vogelkooi
	The litter tray and the bird cage
16	Het schip en de onderzeeër
	The ship and the submarine
17	De moeder met de kinderwagen
	The mother with the pram
18	De bril van de kunstenaar
	The glasses of the artist
19	De meloen met de mango en de avocado
	The melon with the mango and the avocado
20	De deur van de auto
	The door of the car
21	De mannen met de baarden
	The men with the beards
22	De dakpannen op het fietsenhok
	The roof tiles on the bike shed
23	Het kind met de knikkers
	The child with the marbles
24	De kastanje uit het park
	The chestnut from the park

Appendix D: Practice items

1	De computers van de middelbare school *The computers of the high school*
2	De bovenarm van de sporter *The upper arm of the athlete*
3	De blaadjes van het jonge boompje *The leaves of the young tree*
4	De zolder van het oude huis *The attic of the old house*
5	Het slootwater en het zeewater *The ditch water and the sea water*
6	De vis in de kom *The fish in the bowl*
7	De vlag en de wimpel *The flag and the pennant*
8	De mieren in het keukenkastje *The ants in the kitchen cupboard*
9	De verzameling van speelgoed-autootjes *The collection of toy cars*
10	De muntjes op de toonbank *The coins on the counter*
11	De koffer van de toerist *The suitcase of the tourist*
12	De gympen van de gevangene *The sneakers of the prisoner*

Chapter 4

Subject-verb agreement in a lexically-reduced context:

A tool for assessing grammatical attraction

Based on: Veenstra, A., Acheson, D. J., & Meyer, A. S. (2014). *Subject-verb agreement in a lexically-reduced context: A tool for assessing grammatical attraction*. Manuscript in preparation.

Abstract

The production of subject-verb agreement is often studied using the sentence completion paradigm. However, this paradigm may be limited as participants do not generate their own messages and first have to comprehend the subject phrase before producing agreement. The emphasis on comprehension thus leads to questions about the generalizability of key findings to natural language production.

The aim of the current study was to develop a tool for assessing grammatical agreement. Earlier studies have shown that there is an asymmetry in the tendency to produce agreement errors when noun numbers in a subject phrase are different (i.e., attraction), with more errors for singular heads combined with plural local nouns. We investigated whether this asymmetry would be replicated in Dutch using lexically simple items that repeatedly used the same four shapes throughout the experiment. Experiments 1 and 2 used a sentence completion task and showed a clear attraction asymmetry, with no reliable attraction after plural heads. Experiment 3 used the same items in a speeded picture description task. Although the same asymmetry was present, there was also a reliable attraction effect after plural heads.

Our data suggest that the picture description task may be a more sensitive measure of grammatical agreement than sentence completion, and may be suitable for testing agreement in a broad range of speakers.

Introduction

To study grammatical agreement in language production, many researchers have used the sentence completion paradigm, where speakers repeat a subject phrase and complete it into a full sentence by adding an inflected verb phrase. This paradigm has been successful in uncovering a range of semantic and syntactic constraints on agreement. However, the task is a hybrid task, as it consists of a comprehension part followed by a production part. The comprehension part replaces the message formulation stage in natural language production and may influence performance in the production task. In addition, different lexical items are typically used on each trial, which can be useful if the paradigm is used to study the influence of semantic factors on agreement, but may be less useful if the aim is to isolate the grammatical encoding skills needed for agreement.

The current study investigated whether key findings from the agreement literature can be replicated when the lexical variability of the experimental items is reduced in the sentence completion paradigm and when people have to generate their own message in a new picture description task. The materials consisted of only four different nouns that were used to elicit utterances such as *the star with/next to the circles is blue*. In Experiments 1 and 2, a forced-choice sentence completion task with this small vocabulary was used (Staub 2009, 2010; Veenstra, Acheson, Bock, & Meyer, 2014). In order to assess how agreement patterns with lexically reduced items change across different tasks, Experiment 3 used a speeded picture description task with the same materials.

One of the most often replicated findings in agreement research is attraction, where a verb—incorrectly—agrees with an interfering local noun. Attraction becomes apparent in sentences where the subject phrase contains a head and local noun which

differ in number, as in *the key to the cabinets* ***are*** *missing* (Bock & Miller, 1991). Although the head noun *key* is singular and should determine the number of the verb, the verb receives a plural inflection because of attraction from the plural local noun *cabinets*. Interestingly, an asymmetry in the attraction effect has consistently been observed in which attraction is more prominent in sentences with singular head nouns combined with a plural local noun compared to plural head nouns combined with a singular local noun. In a corpus study reported in Bock and Miller (1991), 82% of all attraction errors involved singular heads, a percentage that was similar to the rates of agreement errors in Bock and Miller's experiments (88% in Experiment 1, 78% and 76% in Experiment 2 and its replication, and 88% in Experiment 3).

This asymmetry has been explained by the morphological marking of number. Plural nouns often possess a plural marker (*-s* in English, *-s* or *–en* in Dutch), which singular nouns do not possess (but see Corbett, 2000, for languages that mark both singular and plural). It has been argued that plurals therefore are marked for number, whereas singulars are an unmarked default. Evidence for this view comes from acquisition studies showing that unmarked forms, such as singulars, are acquired before marked forms, such as plurals (Mervis & Johnson, 1991). To explain the asymmetry in the patterns of agreement errors, it has been proposed that the number of an unmarked singular head noun can mistakenly be overridden by a marked plural local noun, activating the plural feature (Bock & Eberhard, 1993, see also Berent, Pinker, Tzelgov, Bibi, & Goldfarb, 2005). In contrast, a marked plural head noun that already has an activated plural feature does not get affected by an unmarked singular local noun. Further evidence that has been used to argue for unmarked singulars comes from Eberhard (1997), who found that plural attraction was diminished when the singular head noun was explicitly marked for number (e.g., *one key to the*

cabinets), and that singular attraction was increased when the singular local noun was explicitly marked for number (e.g., *the keys to one cabinet*). In the current study, we expected to replicate this asymmetry.

The current study also explored the effect of the preposition used to combine the head and local noun (*with* versus *next to*), as previous research—using lexically rich materials—has shown that prepositions can influence the strength of the conceptual link between nouns. However, the strength of this link is possibly not only driven by the preposition but also by the lexical context of the subject phrase, as well as world knowledge about the objects that are described. We investigated whether integration effects of preposition on agreement are still observed in a lexically-reduced context.

Solomon and Pearlmutter (2004) argued that in *the drawing of the flower*, the flower is tightly linked to the drawing as the flower is part of the drawing. A weaker link is found in *the drawing with the flower*, in which the flower is somewhere in the vicinity of the drawing and is possibly, but not necessarily part of the drawing. Similarly, Gillespie and Pearlmutter (2011a) used the prepositions *for* and *near* to create stronger and weaker conceptual links between head and local nouns (e.g., *the apple for the pie*, in which the apple is more tightly linked to the pie than in *the apple near the pie*). The strength of this conceptual link, semantic integration, can influence the generation of agreement, although its precise effect is debated.

Solomon and Pearlmutter (2004) argued that the nouns in an integrated (i.e., tightly linked) subject phrase are more likely to be planned in parallel than nouns in an unintegrated subject phrase (see also Gillespie & Pearlmutter, 2011b). When nouns are planned in parallel, their number features are active simultaneously and may have more opportunity to interfere with each other. In the case of a head and local noun that

mismatch in number, the interference effect is predicted to be larger when the subject phrase is integrated relative to when the subject phrase is unintegrated. In a series of five sentence completion experiments, Solomon and Pearlmutter consistently found stronger attraction effects for integrated (e.g., *the drawing of the flowers*) than unintegrated sentences (e.g., *the drawing with the flowers*).

Other authors have proposed that semantic integration influences the notional number of a subject phrase, thereby influencing the likelihood of agreement errors. Nouns that are tightly integrated are more likely to be perceived as singular, facilitating singular agreement. By contrast, unintegrated nouns are more likely to be perceived as plurals, making singular agreement harder (Brehm & Bock, 2013; Veenstra et al., 2014). In line with this proposal, Brehm and Bock (2013) used a constrained preamble completion paradigm, and found more errors and longer response times for unintegrated subject phrases than for integrated subject phrases in English. This effect was largely independent of whether the local noun matched or mismatched in number with the head noun. This notional number pattern was replicated in Dutch by Veenstra et al. (2014).

In the current study, we investigated the effects of the prepositions *with* and *next to*. A lexically rich example would be *the sweater with the dogs*, which is tightly integrated as the dogs are part of the sweater as a print, versus *the sweater next to the dogs*, which is unintegrated as the objects just happen to be next to each other. In the earlier studies assessing the same contrast, the items were rich in lexical variability. For example, the Veenstra et al. (2014) study used almost 200 unique nouns for their 100 items (using translation equivalents of the items previously used by Brehm and Bock, 2013, and Solomon and Pearlmutter, 2004). One question we seek to address in

the current study is whether the use of these two prepositions also yields effects with a severe reduction in lexical variability (e.g., *the star with/next to the circles*).

Another issue the current study addresses is the methodology used to assess agreement. The findings described above have been obtained using the sentence completion paradigm. The first study to experimentally investigate the production of subject-verb agreement was by Bock and Miller (1991). The authors designed a sentence completion task in which they presented participants with subject phrases with different characteristics (e.g., *the key to the cabinets*). Participants listened to the subject phrase, repeated it, and added a verb phrase to complete the sentence (e.g., *the key to the cabinets is missing*). This sentence completion task has been refined since, with some variation in modes of subject phrase presentation and sentence completion. In the Bock and Miller study, participants were free to complete the sentence in any way they wished. This led to high rates of trials that could not be scored (close to 40% in Experiment 1 and 2, almost 75% in Experiment 3) because the subject phrase was repeated incorrectly or the verb was uninflected (e.g., a past tense form).

To limit the number of invalid trials, later studies have restricted the ways in which participants could complete the sentences. By presenting participants with an adjective or past participle (e.g., *old* or *broken*) that had to be used in the completion, participants were encouraged to use a form of *to be*, increasing the number of analyzable responses (Barker, Nicol, & Garrett, 2001; Brehm & Bock, 2013; Hartsuiker & Barkhuysen, 2006; Haskell & MacDonald, 2003; Veenstra, et al., 2014; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996). Other studies simply instructed participants to use *to be* (Franck, Vigliocco, & Nicol, 2002), or encouraged the use of forms of *to be* by presenting an infinitive verb that had to be used in a passive

construction, or a verb stem to be used in a perfect tense construction (Hartsuiker, Anton-Mendez, & Van Zee, 2001; Thornton & MacDonald, 2003).

Further refining agreement paradigms, recent studies have included response times as an additional dependent measure. Haskell and MacDonald (2003) presented participants with subject phrases and asked them to form questions using these phrases. As questions often start with an inflected verb, differences in response onset latencies should indicate the time needed to produce agreement. Longer latencies for correct responses were indeed found in conditions that usually yield more agreement errors. Similarly, Brehm and Bock (2013) instructed participants not to repeat the subject phrase, but only read it silently and give the completion aloud as fast as possible. The subject phrase was presented on a computer screen just long enough that participants could read the subject phrase before completing it. The delay between the end of the subject phrase and the start of the response was indicative of difficulties influencing correct agreement, such as mismatching head and local nouns and weak integration. Staub (2009, 2010) also tested whether response times are sensitive to agreement processes in a forced choice task. Here, participants read subject phrases word by word on a computer screen, followed by a screen that showed the singular verb *is* on the left and plural verb *are* on the right. Participants had to press a left or right key as fast as possible for the option they thought would be the best continuation of the subject phrase. Again, longer response times were found when a mismatching noun was present. Veenstra et al. (2014) used both the Staub (2009, 2010) and Brehm and Bock (2013) paradigms with the same set of items, and found comparable patterns of results.

One can wonder, however, how well the results of these completion tasks are generalizable to more natural language production. As noted, the sentence completion

task is a hybrid task: Participants need to comprehend and memorize the subject phrase given to them before they can produce a fitting completion. In addition, the message is not generated by the participants themselves, thereby eliminating the first step in the language production process (Levelt, 1989).

As these disadvantages may have had undesirable influences on the production of agreement, psycholinguists have reduced the comprehension component and developed other types of production tasks. Haskell and MacDonald (2005) designed a card sorting game, in which participants had to ask which of two cards (depicting singular and plural objects and animals) had to go to which destination. The destination depended on the color of the objects, and led to utterances such as *can you tell me whether the horses or the clock is/are red?* (Experiment 2) and *is/are the horses or the clock red?* (Experiment 3). This task allowed the authors to study agreement in disjunctions, while reducing the memory load and the comprehension component. Gillespie and Pearlmutter (2011a) developed a production task to investigate attraction and the effect of semantic integration. Participants saw a display with two pictures to be used as a head noun and a local noun, where the picture to be used as head noun had a colored outline. The color of this outline determined the preposition participants had to use to link the two nouns, blue for *for*, yielding integrated phrases, and green for *near*, yielding unintegrated phrases (e.g., *the apple for/near the pie(s)*). This subject phrase then had to be completed into a full sentence. Results of this study showed the grammatical attraction effect but no effect of semantic integration. The lack of an integration effect in this study may have emerged from the difficulty of the task, which required translating a color into a preposition.

The aim of the current study was twofold: first, we assessed whether the key findings of asymmetrical attraction could be replicated with a sentence completion

task using a small set of items. This would allow us to separate the grammatical aspects in agreement from the lexical aspects. Second, we investigated whether key findings could be replicated with a production task in which the subject phrase was not linguistically offered. One advantage of such a production task is that it can be used to study agreement in broader speaker populations. In order to test for any differences in the magnitude of the agreement effects across experimental paradigms, the same items were used in a set of sentence completion tasks (Experiments 1 and 2) and in the picture-description task (Experiment 3).

Experiment 1

The first experiment was designed to replicate key findings from the literature using a sentence completion task. Here we used the forced-choice task developed by Staub (2009, 2010), which has been shown to be sensitive to local noun number and semantic integration manipulations (Veenstra, Acheson, Bock, & Meyer, 2014). Items were kept relatively simple to isolate grammatical factors in the absence of lexical input. Following earlier research, we predicted an asymmetrical pattern in the attraction effect in error rates: more errors when head and local nouns mismatch in number than when they match; and a stronger attraction effect for items with singular head nouns compared to those with plural head nouns. If the prepositions influence the conceptual link between the head and local noun, either a lexical interference effect (with stronger attraction for *with*-items), or a notional number effect (with more errors overall for *next to*-items) may be expected. Response times were predicted to show similar patterns as the error rates.

Method

Participants. Thirty-one native speakers of Dutch participated after giving written informed consent. Data from three participants were excluded due to poor performance on the catch trials (see below). Of the remaining 28 participants, 22 were female (mean age = 22.4 years). All participants in this study only took part in one of the experiments.

Design and materials. All experiments in this study had a 2 (Head Noun Number: singular/plural) by 2 (Local Noun Number: singular/plural) by 2 (Preposition: *with* (integrated)*/next to* (unintegrated)) factorial design. Each subject phrase consisted of a determiner and a head noun (singular or plural) followed by a preposition (*met/with* or *naast/next to*), which was then followed by a determiner and a local noun (singular or plural). Only common nouns were used, which take the number-ambiguous determiner *de*. Specifically, we used four simple shapes *(cirkel*, *driehoek*, *ster*, *rechthoek*; English: *circle*, *triangle*, *star*, *rectangle*), which were chosen in part because they could easily be named in a picture description task. This led to subject phrases such as *de ster naast de cirkels/the star next to the circles* (see Table 1).

Table 1
An Example Item in Eight Conditions

		Preposition	
		with	next to
Singular Head	Singular Local	*the star with the circle*	*the star next to the circle*
	Plural Local	*the star with the circles*	*the star next to the circles*
Plural Head	Singular Local	*the stars with the circle*	*the stars next to the circle*
	Plural Local	*the stars with the circles*	*the stars next to the circles*

Whereas Staub (2009; 2010) presented his participants with *is/are*, participants were presented with full verb phrases, such as *is blue/are blue*. This was done in order

to facilitate the comparison of the results to those of the picture description task in Experiment 3, where speakers produced full sentences. As the trial ended with the decision between the options presented, a full verb phrase completed the sentence, whereas choosing *is/are* would leave the sentence unfinished. Using full verb phrases also allowed for different colors to be used with the same subject phrases, increasing the number of items. Four colors were used (blue, red, yellow, and green), resulting in a total of 64 items in eight conditions. The resulting 512 trials were divided over two lists and the first and last halves of these lists were recombined to form two additional lists. In every list, each noun appeared 64 times as a head noun and 64 times a local noun. All four colors appeared 64 times, and the prepositions each appeared 128 times. Sixty-four filler items were constructed with different structures, such as *the star or the circle*, or *the star and the circle*, to prevent participants from basing their answer on the first noun.

In addition to trials requiring a button press, there were also 32 catch trials that matched the structure of the experimental and filler items. Catch trials were added to encourage participants to fully process the subject phrases, and to form a mental model of the subject phrase. This mental model may then be used to reconstruct the subject phrase and complete it into a full sentence (Potter & Lombardi, 1990). On catch trials, participants had to repeat the subject phrase and provide their own continuation verbally (see Procedure). Finally, a practice block of 10 trials was added to each list as well. Items were presented in a fixed random order.

Procedure. Participants were tested individually in a sound-proof booth in front of a computer. First, a fixation cross appeared in the center of the screen for 1000 ms at 0.4° visual angle. Then the subject phrase was presented in the center of the screen in a word-by-word fashion. Each word appeared for 250 ms, followed by a

blank screen for 150 ms. After presentation of the subject phrase, a screen with two verb phrases appeared; the singular option on the left and the plural option on the right. Participants were instructed to press the corresponding button on a two-button button box as quickly as possible. Feedback was provided in case of an incorrect answer (the word *fout* (*wrong*) would appear for 1500 ms); when the answer was correct, the next trial followed after a blank screen for 1500 ms. Catch trials had a structure similar to the experimental items, except that instead of the screen with two verb phrase options, the word *herhaal* (*repeat*) appeared, prompting participants to repeat the subject phrase and complete the sentence aloud. Answers were recorded for 3000 ms. The experiment consisted of a practice block of 10 trials and 4 experimental blocks each containing 64 experimental, 8 catch and 16 filler trials.

Scoring and analysis. The responses were coded for accuracy and response time. Response times shorter than 200 ms or more than three standard deviations above the participant's mean were excluded from the analyses. Three participants made over 15% errors on catch trials. Their data were excluded, because the high number of repetition errors raised doubts about their processing of the subject phrases on experimental trials.

Statistical analyses were run in R version 2.14 using linear mixed effects models with crossed effects of subjects and items using the lme4 package (Bates, 2005; R Development Core Team, 2011). In order to avoid collinearity and to maximize the likelihood of model convergence, variables such as Mismatch, Block, Preposition and Head Noun Number were mean centered prior to analysis (Baayen, 2008). Given the coding used, negative regression coefficients correspond to more errors or longer response times for number match, earlier blocks, *with*, and singular head nouns. As histograms showed that the distribution of the response times was

rightward skewed, analyses were performed on natural log-transformed response times.

The fixed effects were Head Noun Number (singular vs. plural), Mismatch (between the head and local noun number: yes vs. no), Preposition (*with* vs. *next to*), and Block (1 through 4). The list participants saw was initially included as a fixed effect, but did not contribute significantly to any of the models, thus we collapsed across this factor. Random intercepts were included for subjects and items, as well as random slopes to subjects and items for Head Noun Number, Mismatch, Preposition, and Block. Model selection started with a full model, leaving out non-significant interactions with each step, after which the model was tested for complexity (as measured with AIC/BIC). Maximal random slopes were included where possible (Barr, Levy, Scheepers, & Tily, 2013). Main effects were kept for theoretical reasons. Error rates were analyzed using a logistic linking function (e.g., Jaeger, 2008). The inclusion of random slopes in the analysis of response times meant that resampling methods for calculating statistical probability were not available. Thus, factors were judged significant when the absolute *t*-value exceeded 2 (Baayen, 2008).

Results

Agreement errors. Agreement errors consisted of plural answers given to trials with a singular head noun and singular answers given to trials with a plural head noun. Trials in which an answer was given faster than 200 ms were excluded from the analysis (3.9% of the data). On these trials, participants may have decided on their answer before the sentence was completed, possibly limiting the influence of the local noun. The proportions of agreement errors are shown in Figure 1.

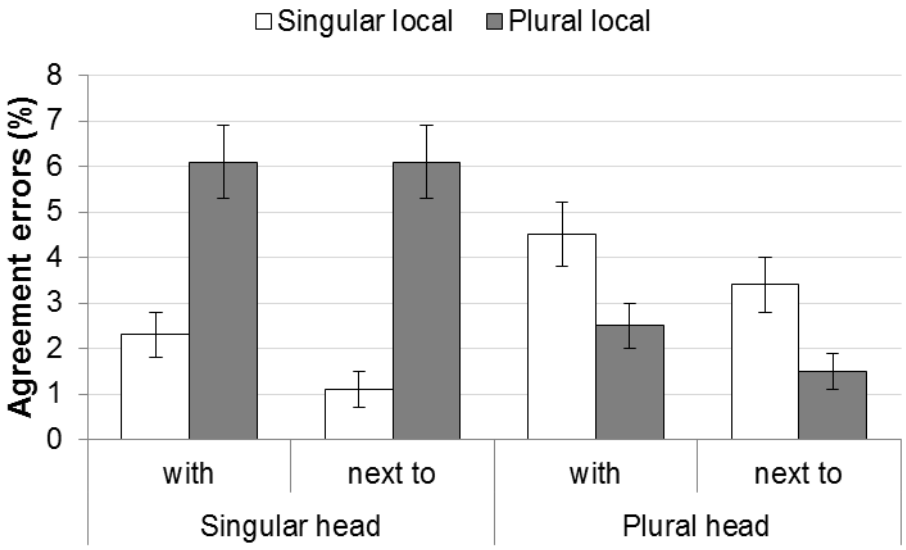


Figure 1. Agreement errors in Experiment 1. Error bars show the *SE* of the mean across participants, for illustrative purposes.

The figure shows that there was attraction for both singular and plural head nouns, which was stronger for singular head nouns. The preposition *with* appeared to increase error rates. These patterns were confirmed by the statistical analysis, see Table 2.

Table 2
Logistic Mixed-Effects Model predicting Agreement Errors in Experiment 1

Variable	Coefficient	*SE*	*z*-value	Pr(>|*z*|)	Random Slope
(Intercept)	-4.15	0.19	-22.17	<.001	subjects, items
Head Noun Number	0.00	0.10	0.02	.984	subjects, items
Mismatch	0.38	0.11	3.50	<.001	subjects, items
Preposition	-0.20	0.09	-2.37	.017	subjects, items
Block	-0.39	0.07	-5.42	<.001	subjects, items
Head Number * Mismatch	-0.24	0.09	-2.65	.007	

Note. Coefficients correspond to Logits.

The statistical analysis showed main effects of Mismatch, Preposition, and Block. The main effect of Mismatch shows that items with mismatching head and local nouns yielded more errors than items with matching head and local nouns. The main effect of Preposition came from the fact that there were more errors for *with*-

items than *next to*-items. The effect of Block came from the fact that participants made fewer errors over the course of the experiment. The analysis also showed that the Mismatch effect interacted with Head Noun Number, which was followed up with separate analyses for singular and plural heads. The Mismatch effect was significant for singular heads (β = 0.64, *SE* = 0.16, p <.001), but not for plural heads (β = 0.14, *SE* = 0.14, p = .327). This fits with the classic attraction asymmetry.

Response times. Incorrect responses, responses faster than 200 ms, and responses more than three standard deviations above the participant's mean were excluded (8.7% of the data). The response times showed roughly the same pattern as the agreement errors, see Figure 2:

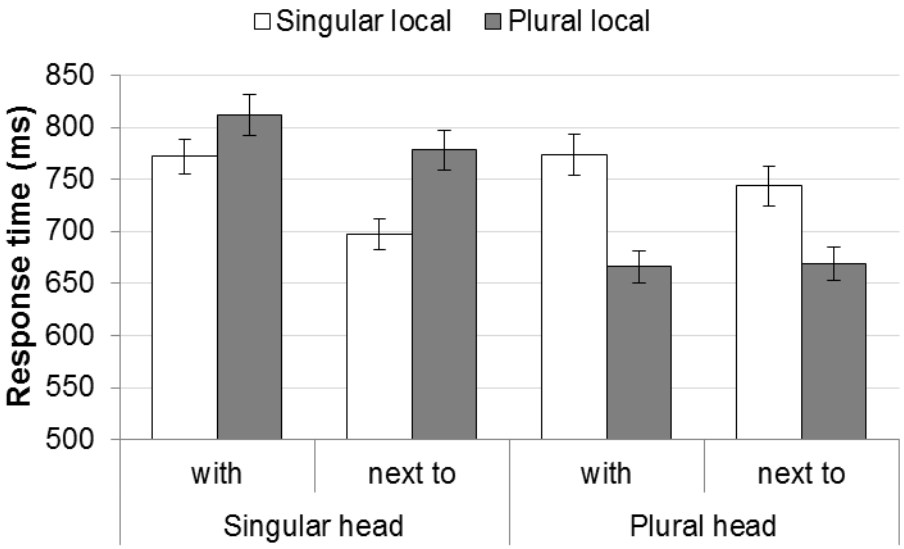


Figure 2. Response times in Experiment 1. Error bars show the *SE* of the mean across participants, for illustrative purposes.

The statistical analysis (see Table 3) revealed only main effects of Head Noun Number, Mismatch, Preposition, and Block. The main effect of Head Noun Number came from slower responses in choosing the verb phrase when the head noun was singular than when it was plural. The main effect of Mismatch shows that participants

were slower when the numbers of the head and local noun mismatched rather than matched. The effect of Preposition showed that participants were slower when the item contained *with* relative to when it contained *next to*. Finally, participants became faster over the course of the experiment, as indicated by the effect of Block.

Table 3
Logistic Mixed-Effects Model predicting Response Times in Experiment 1

Variable	Coefficient	*SE*	*t*	Random Slope
(intercept)	6.41	0.08	81.65	subjects, items
Head Noun Number	-0.03	0.01	-3.43	subjects, items
Mismatch	0.04	0.01	4.08	subjects, items
Preposition	-0.02	0.01	-2.14	subjects, items
Block	-0.09	0.01	-7.97	subjects, items

Discussion

In Experiment 1, participants completed subject phrases that were presented on the screen with button presses for singular and plural verb phrases. The items were lexically simple and repetitive. The main question that we addressed was whether the standard finding of asymmetrical attraction could be replicated in a lexically impoverished context, and whether there was any effect of semantic integration caused by the preposition in the subject phrase.

The results showed attraction for both singular and plural heads. Error rates showed a classic attraction asymmetry as the attraction effect was significant for singular heads combined with plural local nouns, but not for plural heads combined with singular local nouns. In contrast, response times showed no such asymmetry: both singular and plural head nouns yielded reliable attraction. The response time measure may be more sensitive to agreement difficulties as it is a continuous measure which is informative even in correct responses.

Although there was a main effect of the preposition in the current experiment, the pattern of results does not fit with either the lexical interference account or the notional number account. Specifically, the lexical interference account would predict a stronger attraction effect for the *with*-items than for *next to*-items. The notional number hypothesis would predict an overall increase in errors for the *next to*-items. The results, however, showed an overall increase in errors for the *with*-items. Higher error rates for the *with*-items than for the *next to*-items suggested that the phrases containing *with* were more difficult. This might be due to the ambiguity of the preposition *with*, which could be interpreted as a tightly integrated phrase (e.g., the star that contains the circle) or as a weakly integrated phrase (e.g., the star that is in the vicinity of a circle). Given this ambiguity, participants might not have created detailed mental models of the scenarios. They may have used a 'good enough' approach (Ferreira, Bailey, & Ferraro, 2002), focusing more on grammatical cues that were sufficient to choose the response, relative to semantic cues. To encourage participants to activate a mental model of the subject phrase, we added picture verification trials using pictures that clearly distinguished between integrated and unintegrated settings in Experiment 2.

Experiment 2

Method

Participants. Twenty-eight native speakers of Dutch participated after giving written informed consent (18 were female, mean age = 21 years).

Materials. The materials were identical to Experiment 1, except that the catch trials were replaced with 128 picture verification trials. On these trials, full sentences (e.g., *the star next to the circles is blue*) were paired with pictures (see Table 4). Half

of the pictures matched the sentence; the other half did not match the sentence in one respect. In these cases, the head noun, local noun, preposition, or color did not match.

Table 4
An Example of Matching Pictures in eight Conditions in Experiment 2

	Singular Head		Plural Head	
	with	*next to*	*with*	*next to*
Singular Local				
	The star with/next to the circle is blue		*The rectangles with/next to the triangle are red*	
Plural Local				
	The star with/next to the circles is blue		*The rectangles with/next to the triangles are red*	

Procedure. The procedure was identical to Experiment 1, except for the additional picture verification trials. On these trials, participants were presented word-by-word with a full sentence, followed by a picture. Above this picture was the question whether the picture fitted the sentence (e.g., *klopt dit?/does this match?*), on the bottom left and right the words *ja*/*yes* and *nee*/*no*. Participants were instructed to indicate their answer on the two-button button box as fast as possible. Feedback *fout* (*wrong*) was provided for 1500 ms in case of an incorrect answer.

Scoring and analysis. Scoring and analysis were identical to Experiment 1. An upper limit for errors on picture verification trials was set at 20%; however, none of the participants exceeded this limit.

Results

Agreement errors. The rates of agreement errors are shown in Figure 3:

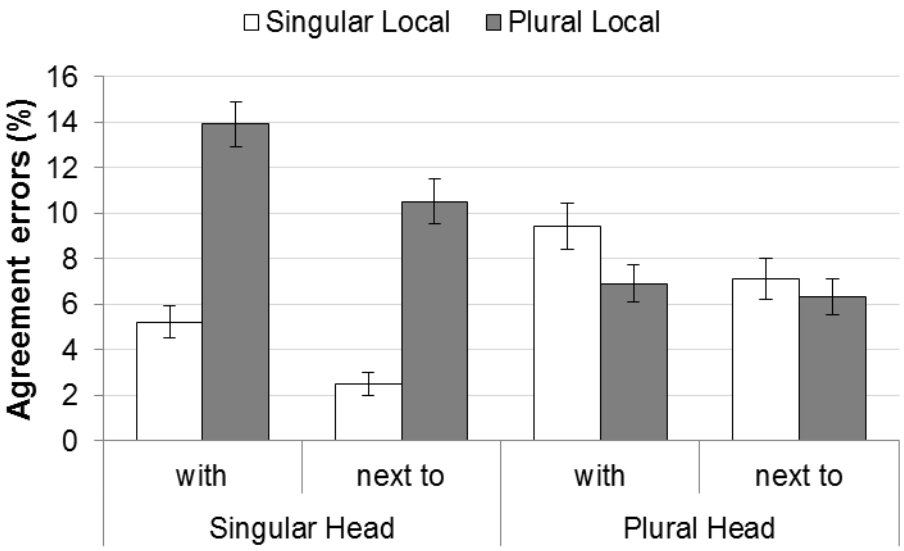


Figure 3. Agreement errors in Experiment 2. Error bars show the *SE* of the mean across participants, for illustrative purposes.

The statistical analysis (see Table 5) indicated main effects of Mismatch and Preposition. The main effect of Mismatch showed that more errors were made when the head and local noun mismatched compared to when they matched, and the main effect of Preposition showed that more errors were made for items containing *with* compared to items containing *next to*. There was an interaction between Head Noun Number and Mismatch. Follow up analyses revealed that there was a mismatch effect for singular heads ($\beta = 0.63$, $SE = 0.11$, $p < .001$), whereas there was no such effect for the plural heads ($\beta = 0.12$, $SE = 0.09$, $p = .191$). Again, this fits with an attraction asymmetry. There was also an interaction between Preposition and Block. This interaction indicated that the Preposition effect decreased over the course of the experiment.

Table 5
Logistic Mixed-Effects Model predicting Agreement Errors in Experiment 2

Variable	Coefficient	*SE*	*z*-value	Pr(>|*z*|)	Random Slope
(Intercept)	-2.92	0.14	-20.53	<.001	subjects, items
Head Noun Number	0.03	0.09	0.32	.749	subjects, items
Mismatch	0.37	0.07	5.00	<.001	subjects, items
Preposition	-0.20	0.07	-2.69	.007	subjects, items
Block	-0.05	0.04	-1.20	.232	subjects, items
Head Number * Mismatch	-0.23	0.06	-23.83	<.001	
Preposition * Block	-0.10	0.04	-2.78	.005	

Note. Coefficients correspond to Logits.

Response times. Incorrect responses, responses faster than 200 ms, and responses more than three standard deviations above the participants' mean were excluded from the analyses (9.4% of the data). The pattern of response times is presented in Figure 4:

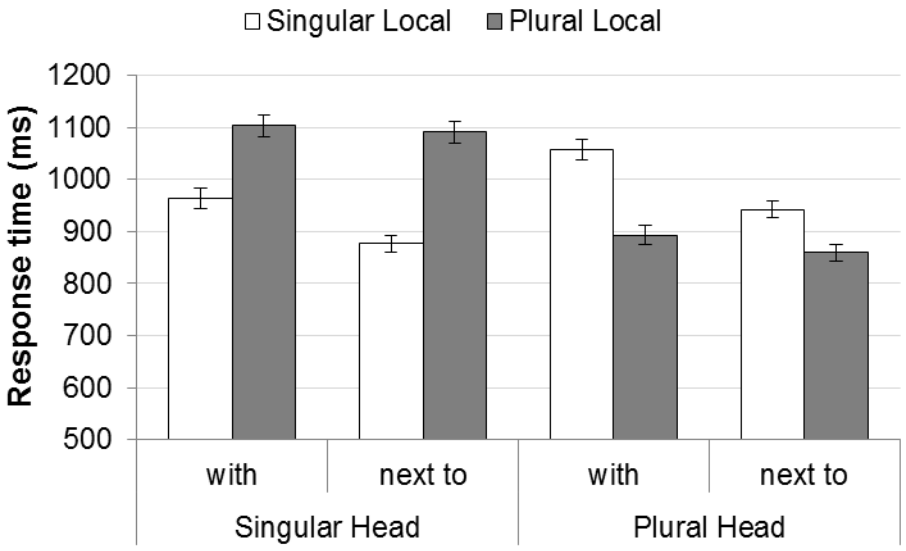


Figure 4. Response times in Experiment 2. Error bars show the *SE* of the mean across participants, for illustrative purposes.

There was a Mismatch effect for both singular and plural heads. Also, an overall effect of Preposition was present. The statistical analysis (see Table 6) found main effects of Head Noun Number, Mismatch, Preposition, and Block. The main effect of Head Noun Number indicated that responses to singular heads took longer

relative to plural heads. The main effect of Mismatch indicated that participants took longer to reply to phrases with mismatching head and local nouns than to phrases with matching head and local nouns. The main effect of Preposition came from slower responses to *with*-items relative to *next to*-items. There was also a main effect of Block, indicating that responses were given faster as the experiment progressed. There was a three-way interaction between Head Noun Number, Mismatch, and Preposition. Separate analyses for singular and plural heads revealed that, apart from main effects of Mismatch (β = 0.08, *SE* = 0.02, *t* = 5.69) and Preposition (β = -0.02, *SE* = 0.01, *t* = -2.07), there was no Mismatch by Preposition interaction for singular heads (β = 0.01, *SE* = 0.01, *t* = 1.35). For plural heads, however, in addition to main effects of Mismatch (β = 0.07, *SE* = 0.01, *t* = 5.48) and Preposition (β = -0.03, *SE* = 0.01, *t* = -2.70), there was a Mismatch by Preposition interaction (β = -0.02, *SE* = 0.01, *t* = -2.58). This interaction showed that the mismatch effect was larger for the items containing *with* (β = 0.08, *SE* = 0.02, *t* = 5.27), than for the items containing *next to* (β = 0.04, *SE* = 0.01, *t* = 2.87).

Table 6
Logistic Mixed-Effects Model predicting Response Times in Experiment 2

Variable	Coefficient	*SE*	*t*	Random Slope
(intercept)	6.75	0.06	119.87	subjects, items
Head Noun Number	-0.03	0.01	-3.33	subjects, items
Mismatch	0.07	0.01	7.16	subjects, items
Preposition	-0.03	0.01	-3.29	subjects, items
Block	-0.08	0.01	-8.78	subjects, items
Head * Mismatch * Preposition	-0.02	0.01	-2.85	

Discussion

In Experiment 2, participants completed subject phrases that were presented on the screen with button presses for singular and plural verbs. As in Experiment 1, the items were lexically simple and repetitive. The head and local noun number

matched or mismatched and the preposition was predicted to lead to integrated (*with*) and unintegrated interpretations (*next to*). Picture verification trials were added to encourage participants to activate mental models of the referents. The experiment was designed to test whether in such semantically impoverished circumstances asymmetrical attraction could be replicated, and whether effects of semantic integration would be seen.

The results of Experiment 2 showed that there was an attraction effect in both agreement errors and response times. For the agreement errors, however, the attraction effect was only reliable for the singular heads and not for the plural heads. This replicates the findings of Experiment 1, where attraction was reliable only for singular heads in the agreement errors, whereas in the response times, there was no such asymmetry. The two experiments suggest that there is an asymmetry in the strength of attraction: singular heads combined with plural local nouns more often yield agreement errors than plural heads combined with singular local nouns. Nevertheless, the response time results also show that singular and plural local nouns are equally capable of influencing the agreement generation process.

Similar to Experiment 1, this experiment did not yield a straightforward semantic integration pattern, as there was an overall detrimental effect of the *with*-items. The introduction of picture verification trials in the present study was designed to encourage people to generate a more complete mental model than in Experiment 1. A rudimentary mental model of the subject phrase was necessary to judge the picture in the picture verification trials. Participants were aware of the meaning of the subject phrase to a certain degree, as they were generally successful in verifying whether the picture matched the sentence. Despite the likelihood that participants had a stronger

mental model in this experiment, this did not lead to effects of semantic integration that have been observed in earlier studies.

As in Experiment 1, it is possible that the *with*-items were still more difficult than the *next to*-items because of their ambiguity. An item such as *the star with the circle* was intended to be interpreted with an integrated meaning, making the circle a characteristic of the star, analogous to a print on a sweater. However, when presented with the linguistic stimulus only, *with* could very well be interpreted as *close to*, or *next to*, even. Items with an ambiguous interpretation may take more time to respond to, and increase error rates, hence the overall main effect of Preposition. In addition, there might be even more ambiguity in the plural head noun/singular local noun items containing *with*: A sentence such as *the stars with the circle* might refer to multiple stars each containing one circle, or to multiple stars sharing one and the same circle. Again, having multiple interpretations may slow down and weaken the agreement process.

The picture verification trials may not have been sufficient in distinguishing the *with*- from the *next to*-items. Although this distinction was present in all of the 128 pictures, in only 12.5% of these trials the mismatching feature was the preposition. Looking at the accuracy of those 16 picture verification trials separately, the average error rate of 23% (*SD* = 20%) seems to confirm the uncertainty about the interpretation. More specifically, in 12 of these trials, the sentence contained the ambiguous *with* in combination with a picture of objects next to each other. These trials yielded 30% errors and an average response time of 1582 ms. In the remaining mismatching trials, where the sentences contained the unambiguous *next to* in combination with a picture of objects inside one another, we observed an average error rate of 3.6% and an average response time of 1320 ms. Compared to the error

rates and response times of other mismatching picture verification trials (11.7%; 1337 ms) and of matching picture verification trials (5%; 1337 ms), the error rates and response times for the *with*-items are higher. Clearly, the feedback provided after an incorrect response did not disambiguate the interpretation of *with*, although unlike Experiment 1, the effect of Preposition did become weaker over the course of the experiment.

The results of Experiment 2 highlight that in language production research it is very important to control the message of a target utterance (Bock, 1996). This was also emphasized by a study by Veenstra & Acheson (2014), who showed that notional effects on subject-verb agreement were stronger when the subject phrase was accompanied by a picture. Therefore, the final experiment used a newly developed picture description task. The pictures (similar to the pictures used in the picture verification trials) should evoke unambiguous interpretations. If the items provide sufficient semantic context for semantic integration information to be included in the mental model, semantic integration effects might be observed in the error rates. On the other hand, even with the ambiguity of the *with*-items being solved, it remains possible that no preposition effects will be seen using lexically simplified items.

Experiment 3

The final experiment was a speeded picture description task. Unlike sentence completion tasks, in this task participants were not provided with subject phrases, and had to construct the message themselves from a picture. The goal was to investigate whether this task was able to replicate the key findings from the agreement literature (asymmetrical attraction and possibly an effect of semantic integration). Additionally, we tested whether the picture description task might be a useful tool to study

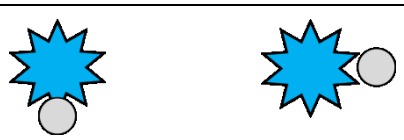
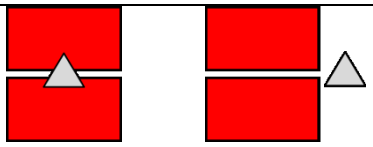
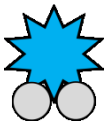
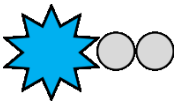
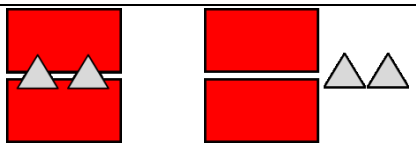
grammatical attraction; it does not involve linguistic comprehension, it enables participants to generate the message of their utterance themselves, it focuses on the grammatical attraction effect, and the simple items could make the task appropriate for participants from different age groups, languages, and populations.

Method

Participants. Twenty-nine native speakers of Dutch participated after giving written informed consent. Data from one participant were excluded because they did not use verbs in their description. Of the remaining 28 participants, 22 were female (mean age = 20.7 years).

Materials. The design and items were identical to Experiments 1 and 2; however, pictures were used instead of subject phrases. No catch trials or filler trials were used in this paradigm. A pilot study which used the pictures from Experiment 2 (see Table 4 above) indicated that participants very rarely provided the target sentence (such as *the rectangles with the triangle*) in the plural head combined with an integrated singular local noun condition (most participants used a plural local noun, rather than a singular local noun). Therefore, slightly different pictures were used, see Table 7:

Table 7
An Example of Pictures in eight Conditions in Experiment 3

	Singular Head		Plural Head	
	with	*next to*	*with*	*next to*
Singular Local				
	The star with/next to the circle is blue		*The rectangles with/next to the triangle are red*	
Plural Local				
	The star with/next to the circles is blue		*The rectangles with/next to the triangles are red*	

In the new materials, there was only one local noun shape in the picture for the singular local noun condition. In the plural head condition, the singular local noun shape had to be part of both head shapes, and was drawn to overlap with both head noun shapes. This contrasts with the pictures used in Experiment 2, where the head noun shapes each contained one local noun shape (i.e., there were two local noun shapes in total for plural heads), which likely contributed to non-target utterances with plural local nouns in the pilot study.

Procedure. Participants were tested individually in a soundproof booth. The experiment started with instructions and two practice blocks of 20 trials each. The participants were instructed to give descriptions of the pictures with the following construction: *the (colored shape, head noun) with/next to the (grey shape, local noun) is/are (color)*. First, a fixation cross was presented 200 pixels left from the center of the screen at 0.4° visual angle for 500 ms, followed by a blank screen of 150 ms. Then the picture was presented in the center of the screen for 2750 ms. Pictures varied in size from 224 x 224 pixels to 256 x 509 pixels, viewed with a 6 to 13° visual angle. Descriptions had to be given within a time limit of 2750 ms, which was indicated at the top of the screen with a timer. After 2750 ms, the picture disappeared and a blank

screen appeared for another 500 ms. Responses were recorded for 3900 ms from the onset of the picture until the onset of the next picture. Participants were told that their focus should be on the correct names for the shapes.

Scoring and analysis. The participants' responses were scored online by the experimenter. Responses were coded for errors, such as a wrong head noun, the wrong number of the head noun, a wrong preposition, a wrong local noun, the wrong number of a local noun, an agreement error on the verb, and the wrong color. Errors other than agreement errors (including missing and incomplete responses) were excluded from the analyses (18.7% of the data). Statistical analyses were the same as in Experiments 1 and 2.

Participants' response times were not analyzed, as the critical part of the sentence (the verb) did not appear sentence-initially and the difficulty of the agreement processes was unlikely to be reflected in the sentence onset latencies.

Results

Figure 5 shows the percentage of agreement errors in each condition. There were clear attraction effects for both singular and plural heads.

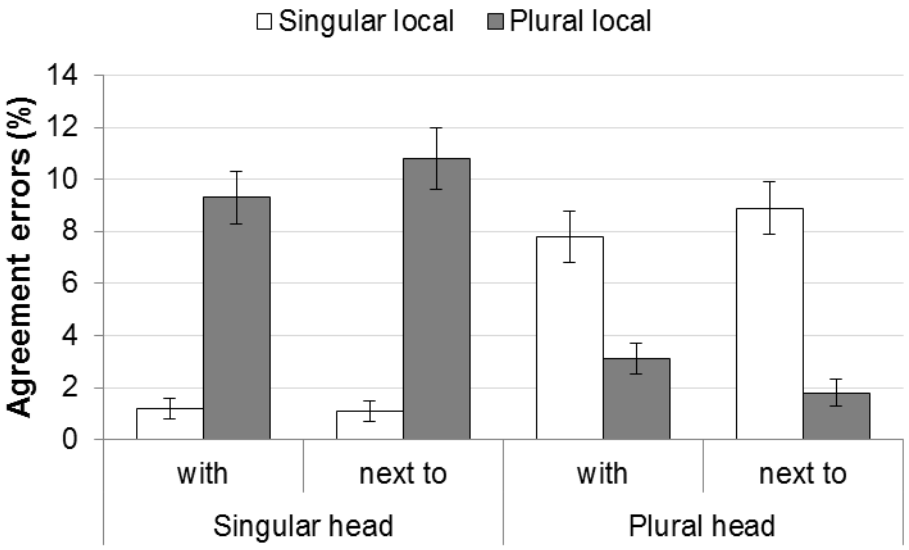


Figure 5. Agreement errors in Experiment 3. Error bars show the *SE* of the mean across participants, for illustrative purposes.

This pattern was confirmed by the statistical analysis. The regression model (see Table 8) showed main effects of Head Noun Number, Mismatch, and Block. The main effect of Head Noun Number showed that more errors were made for plural heads than for singular heads, whereas the main effect of Mismatch indicated that more errors were made when the head and local noun number mismatched than when they matched. Over the course of the experiment, participants made fewer errors, indicated by the main effect of Block. There was an interaction between Head Noun Number and Mismatch, and follow-up analyses showed that attraction was stronger for singular heads than for plural heads: Singular heads combined with mismatching local nouns yield more agreement errors than those combined with matching local nouns (β = 2.51, *SE* = 0.38, p <.001), this effect was reliable, but weaker, for the plural heads (β = 0.77, *SE* = 0.15, p <.001). There was no main effect of Preposition.

Table 8
Logistic Mixed-Effects Model predicting Agreement Errors in Experiment 3

Variable	Coefficient	*SE*	*z*-value	Pr(>|*z*|)	Random Slope
(Intercept)	-4.08	0.20	-20.19	<.001	subjects, items
Head Noun Number	0.38	0.13	2.83	.005	subjects, items
Mismatch	1.28	0.15	8.45	<.001	subjects, items
Block	-0.20	0.05	-3.75	<.001	subjects, items
Preposition	-0.03	0.07	0.38	.706	
Head Number * Mismatch	-0.52	0.13	-4.16	<.001	

Note. Coefficients correspond to Logits.

Discussion

Experiment 3 used a novel agreement production task in which participants described simple pictures with singular and plural head and local nouns in integrated and unintegrated settings. There are two distinct advantages to this paradigm relative to the sentence completion paradigm used in Experiments 1 and 2. First, the paradigm allowed speakers to generate their own messages and provided a more natural way to produce agreement. Second, the picture description task contained an unambiguous message, whereas in Experiments 1 and 2, items containing the preposition *with* were ambiguous with regards to semantic integration, and led to increased error rates and response times.

Experiment 3 replicated the attraction asymmetry from the literature: More errors were made when the head and local noun numbers mismatched relative to when they matched. Similar to the previous experiments, this effect was weaker for the plural heads with singular local nouns than for the singular heads with plural local nouns. Unlike many previous experiments using the sentence completion paradigm, however, a reliable attraction effect was observed for plural head nouns paired with singular local nouns.

In Experiments 1 and 2, the items containing the preposition *with* made the agreement process more difficult than the items containing *next to*. In Experiment 3,

no such effect was seen. The most parsimonious account to explain this discrepancy refers to the ambiguity of *with*. The sentence fragments in the first experiments allowed for multiple interpretations, whereas the pictures in the final experiment were unambiguous. When the ambiguity did not play a role, there was no effect of preposition.

The lack of an effect of semantic integration suggests that in a lexically impoverished context, in which only four different nouns are used repeatedly, semantic integration effects on the agreement process may not be observed. The speeded description task assessed grammatical attraction without confounding semantic influences. This paradigm could thus prove useful in assessing grammatical agreement in clinical and illiterate populations.

General Discussion

The current study looked at the production of subject-verb agreement with lexically simple items in Dutch, using a forced-choice task (Experiments 1 and 2) and a speeded picture description task (Experiment 3). In the forced-choice task, participants completed subject phrases by choosing between a singular and a plural verb phrase with a button press. In the picture description task, participants described pictures such that the target sentence was the same as in the forced-choice task. Lexically simple materials were used to assess the grammatical aspects of agreement.

Although the forced-choice task has been informative in earlier studies on agreement (Staub, 2009, 2010; Veenstra, Acheson, Bock, & Meyer, 2014), these studies have used lexically rich materials. This makes it difficult to distinguish between lexical and grammatical contributions to agreement. A picture description task using a limited vocabulary has been used before to study agreement (Gillespie &

Pearlmutter, 2011a). However, the task employed in this study was fairly complex as a colored outline indicated which preposition speakers had to use in their description. For the current study a novel simple description task was designed in which the use of prepositions was more straightforward.

The goal of the study was to develop a production task that assesses grammatical subject-verb agreement processes in absence of strong influences from lexical-semantics. Researchers in word production typically reduce the difficulty and variability of grammatical encoding processes to a minimum to get to the pure, lexical processes. By contrast, grammatical encoding processes and, more specifically, agreement processes have typically been studied in paradigms with significant variability in lexical difficulty across items. There are, of course, many reasons to use rich lexical contexts. For instance, it is natural in real life language to produce language with a large lexical variability. Additionally, rich lexical contexts can help disguise research questions and prevent participants from developing ad hoc strategies in experimental settings.

However, using rich lexical contexts has its drawbacks as well. There is much inter-item variability, which means that the split-half reliability of a set of items is likely to be low. In addition, in rich lexical contexts, lexical and grammatical skills are difficult to separate, which is especially problematic for individual differences studies. Speakers with limited vocabularies may perform poorly on such tasks, incorrectly suggesting poor grammatical skills. Similarly, in sentence completion tasks, reading ability is very likely to play a role. Poor performance on a grammatical task due to reading ability may incorrectly be interpreted as poor grammatical skills. Another drawback arises in studies investigating grammatical processes across languages: Materials need to be translated, although translation equivalents are not always

available. As a consequence, the materials require norming in all languages involved, and even after this norming, the items may still not be directly comparable.

To separate the grammatical encoding skills from the lexical encoding skills needed for agreement, the current study used materials that minimized lexical difficulty and variability. To some extent this is analogous to the nonce-probe tasks inspired by the "wug" test (Berko, 1958). In these tasks, participants were given non-existing words which they had to inflect intuitively. This enabled researchers to assess the participants' knowledge of abstract grammatical rules, such as regular and irregular past tense inflection, without interference from lexical factors (Albright & Hayes, 2003; Bybee & Moder, 1983; Prasada & Pinker, 1993). Experiments 1 and 2 were designed to study agreement, with similar limited interference from lexical factors.

The main goal of Experiments 1 and 2 was to assess whether the asymmetry in the attraction effect that has been reported widely in the early agreement literature (e.g., Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock & Miller, 1991; Eberhard, 1997; Vigliocco & Nicol, 1998) and which formed the basis of the Marking and Morphing account (e.g., Eberhard, Cutting, & Bock, 2005), could be replicated using lexically simplified materials. A replication of the asymmetry would validate the forced-choice paradigm. Alternatively, the reduced lexical context might have focused participants' attention more on the grammatical aspects of attraction, thereby eliminating the attraction effect overall. The results validated the paradigm, as the attraction effect and its asymmetry were replicated in both experiments. For error rates, the attraction effect was reliable for singular head nouns combined with plural local nouns, but not for plural head nouns combined with singular local nouns. This result is consistent with a plural markedness account.

Experiment 3 was conducted to assess whether the attraction asymmetry could be replicated once more, using a picture description task. Again, attraction errors occurred and more so after singular head nouns combined with plural local nouns than after plural head nouns combined with singular local nouns. As both the forced-choice task and the picture description task replicated the attraction asymmetry, it can be concluded that these paradigms are able to assess the production of subject-verb agreement.

The main results replicated an attraction asymmetry; however, the asymmetry was less pronounced as one might have expected. The plural markedness account does not predict agreement errors after plural heads, as they are already marked for number. This pattern was seen in Experiments 1 and 2, but not in Experiment 3. In the picture description task, attraction was asymmetrical in that the effect was stronger for singular than for plural heads. However, the attraction for plural heads was reliable, suggesting that the picture description task may be more sensitive than the sentence completion task.

Less asymmetry was also found in the response times in Experiments 1 and 2. Although the response times were predicted to pattern with the error rates (e.g., Staub, 2009), response times in the current study showed a different pattern than error rates. In both Experiment 1 and 2, the response times showed reliable attraction effects, with longer response times for mismatching head and local nouns relative to matching head and local nouns. However, an asymmetry was not observed. Response times, which have been shown to be sensitive to agreement difficulties on trials where no agreement errors are made, may be more sensitive in general, including sensitivity to attraction from singular local nouns (see also Haskell & MacDonald, 2003, for a similar argument concerning response time sensitivity). The current lack of

asymmetry has implications for models of agreement, such as the Marking and Morphing model.

The Marking and Morphing model is a mathematical model that predicts the proportion of plural verbs given weighted number specifications of the constituents in a subject phrase (Eberhard, et al., 2005). In this model, the notional number of a subject phrase is reconciled with the grammatical number features of the head and local noun (for instance, when a notionally plural referent, such as family is referred to with the grammatically singular word *family*, or in the case of unintegrated referents that have a singular head noun). The head noun weight is always larger than the local noun weight, as the head noun typically determines the grammatical number of the subject phrase, and not the local noun. Singulars have an unmarked number specification of 0, whereas plurals are marked with a value of 1. Thus, because of the marked status of plurals, the Marking and Morphing model predicts the attraction effect only for singular head nouns combined with plural local nouns and not for plural head nouns combined with singular local nouns. A strict interpretation of the Marking and Morphing model does not predict any agreement errors for sentences with plural head nouns at all. The current results clearly diverge from this predicted pattern.

However, when we look at attraction asymmetries in recent studies with a rich lexical context, the results are rather mixed. First of all, many studies only included singular head noun conditions and not plural head noun conditions, because singular heads yield robust attraction effects (e.g., Barker, Nicol, & Garrett, 2001; Brehm & Bock, 2013; Gillespie & Pearlmutter, 2011a; Gillespie & Pearlmutter, 2011b, Haskell & MacDonald, 2003; Solomon & Pearlmutter, 2004; Veenstra, et al., 2014). Results from studies of agreement with disjunctions (e.g., *the horses or the clock*), suggest

weaker attraction effects when the last noun is singular compared to plural (Haskell & MacDonald, 2005). Using the same forced-choice paradigm as in the present study, Staub (2009, 2010) found asymmetries in the response times with clearer attraction effects after singular than plural heads. Although many studies using the more traditional sentence completion task have found asymmetries in error rates (Bock, Eberhard, & Cutting, 2004; Franck, Bowers, Frauenfelder, & Vigliocco, 2003; Lorimor, Bock, Zalkind, Sheyman, & Beard, 2008), others have failed to find a clear asymmetry or have even found a reverse asymmetry (Franck, Lassi, Frauenfelder, & Rizzi, 2006; Franck, Vigliocco, & Nicol, 2002). Such a variety in attraction patterns raises the question how tenable a plural markedness account is.

It should be noted, however, that the Marking and Morphing model was based on data from 17 studies, all using a sentence completion task and lexically rich items. Ten of those studies included a plural head noun condition and found an asymmetry (Bock, et al., 2006; Bock, Carreiras, & Meseguer, 2012; Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock, & Miller, 1991; Bock, Nicol, & Cutting, 1999; Eberhard, 1997; Middleton, Bock, & Verkuilen, 2010; Thornton & MacDonald, 2003; Vigliocco & Nicol, 1998). Experiments 1 and 2 also used a sentence completion task and indeed showed an attraction asymmetry with non-reliable effects for plural heads in the error rates. Experiment 3 used a different task which did show an asymmetry, but with reliable effects for both singular and plural heads.

Unlike the Marking and Morphing studies, the items in the current study were reduced in lexical richness. Such items may have put more of a focus on the grammatical features of the subject phrases. Therefore, the local noun number may have received more weight in the determination of the number of the subject phrase than in other contexts, thus increasing the influence of singular local nouns. The

combination of lexically-simple items with a picture description task, where the local noun number is activated through the visual representation, rendered the attraction effect for plural heads reliable. In terms of parameters in the Marking and Morphing model, both lexical richness of the items and the task used may influence the weighting of the local noun relative to that of the head noun. The fact that our results show an asymmetry in the error rates, but not in the response times, suggest that singulars might not be as unmarked as previously assumed. Depending on measure, lexical context, and task, asymmetries might increase, disappear, or even reverse. More research is needed to establish the effects of these factors on agreement processes.

The current study also explored the effect of prepositions on the agreement process. We compared subject phrases in which the head and local noun were linked through the prepositions *with* and *next to*. Whereas *next to* denotes a clear spatial separation, *with* is more likely to express spatial (and possibly semantic) integration (e.g., *the sweater with the dogs*). However, *with* can also be interpreted as *next to*. This ambiguity had an effect on the agreement process: In Experiments 1 and 2, *with* created additional difficulty, leading to more errors and longer response times. In Experiment 3, however, where the interpretation of *with* was not ambiguous due to the configuration of the pictures, no effect of preposition was seen. These results demonstrate how tasks using different types of input can yield different results, and highlight how the ambiguity in the forced-choice task can lead to a misleading pattern. The implications of the results are that the spatial integration manipulated in Experiment 3 did not affect the agreement process. Whether spatial integration is comparable to semantic integration is debatable. The current study cannot be taken to

contribute to the understanding of semantic integration effects that were observed in other studies.

Although no semantic integration effect was found, we did replicate the attraction effect. One may ask why healthy adult speakers make errors in agreement at all given that they are very familiar with the grammatical rule for the implementation of agreement: Singular subjects require singular verbs, and plural subjects require plural verbs. Nevertheless, errors arise regularly during the application of the rule, and response times reflect the time required to resolve interference while applying this rule. The Marking and Morphing account (Eberhard, et al., 2005) provides one approach to how the "rule" is implemented. First, the number of the subject needs to be established, before it can be passed on to the verb. The notional number of the message is marked onto the nouns that will be used for the subject phrase. This is a stage where the first difficulties may arise, as sometimes the notional number and the grammatical number clash. For instance, when talking about collectives (e.g., *family*, *furniture*), which are notionally plural but grammatically singular (e.g., notional number effects), this clash needs to be resolved. Next, the words that have been chosen are put in the right order for the utterance. This is another place where difficulties may arise, as, even though the subject phrase has a certain number overall, the number of the word closest to the verb may interfere with the number eventually passed on to the verb (e.g., attraction). The tasks in the current study thus picked up on difficulties that arise during the implementation of a grammatical rule, rather than knowledge about the rule itself.

Having established that the basic paradigms presented here can be used to assess the grammatical encoding skills needed for the production of agreement, these paradigms allow for use with a broad range of speakers. First, the lexically simple

materials invite cross-linguistic comparison, especially in the description task as the pictures elicit translation equivalents naturally. Second, as attraction was found even with very limited lexical input, the tasks may be well suited for use in populations with limited vocabularies. The materials can be adapted to include specific words that exist in the vocabulary of young children or aphasic patients, thus opening up the possibility to study grammatical skills independent of lexical abilities. In addition, the description task will be useful to assess agreement in speakers with reading difficulties, such as young children or speakers with dyslexia. For some speakers, sentence completion tasks may be too taxing on working memory or comprehension skills, and the picture description task developed here could be used to test agreement skills in such populations. Finally, in addition to its use with a wider range of populations than have previously been studied, the basic paradigm also invites research into additional variables that play a role in subject-verb agreement. For example, one could systematically vary the materials to assess effects of hierarchical or linear distance between nouns or the repetition of materials on agreement, independent of lexical content.

Conclusion

Research into grammatical encoding and individual differences in grammatical encoding should seek converging evidence for widespread phenomena with lexically simple materials. The current study demonstrates that this can be done in a simple picture description paradigm, which replicates patterns of attraction and some asymmetry in attraction—key findings in the agreement literature—using lexically simple materials. Similarly, the current results emphasize the importance of converging evidence from different paradigms (e.g., sentence completion and picture

description tasks). Importantly, the picture description task developed here has potential application in cross-linguistic, acquisition and clinical research.

Chapter 5

Parallel planning and attraction in subject-verb agreement

Abstract

The current study investigated the influence of parallel planning of a head noun and mismatching local noun (e.g., *the apple next to the pears*) on subject-verb agreement. The lexical interference account (Gillespie & Pearlmutter, 2011b; Solomon & Pearlmutter, 2004) predicts more attraction (i.e., agreement errors for subjects in which the head and local noun mismatch in number) for nouns planned in parallel than for nouns that are planned sequentially. In contrast, the Marking and Morphing account predicts no effects of parallel planning (Eberhard, Cutting, & Bock, 2005).

A speeded picture description task with eye tracking was used. The pictures mismatched in number to induce attraction errors. Parallel planning was encouraged by presenting the pictures close together and discouraged by presenting the pictures far apart. Parallel planning was assessed by the amount of semantic interference from semantically related pictures.

Semantic interference was found in the close condition only, suggesting that the head and local nouns were planned in parallel in the close condition, but not in the far condition. There was attraction, with more errors in mismatching than in matching conditions, but in contrast to the predictions from the lexical interference account, attraction was stronger in the far condition and for unrelated pictures. The results suggest that the agreement process may not be affected by the parallel planning of noun phrases.

Introduction

The production of subject-verb agreement can be influenced by syntactic and semantic factors. A robust syntactic influence is the attraction from a local noun that is located between the head noun of a subject phrase and the inflected verb. Attraction—traditionally studied with a sentence completion task—occurs when a plural local noun follows a singular subject head noun, increasing the chance for the verb to obtain an incorrect plural inflection (e.g., *the key to the cabinets **are** missing;* Bock & Miller, 1991, see also Bock & Eberhard, 1993; Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001; Franck, Vigliocco, & Nicol, 2002; Haskell, Thornton, & MacDonald, 2010; Vigliocco, Butterworth, & Semenza, 1995). To a lesser extent the same occurs for plural head nouns combined with singular local nouns (Eberhard, 1997).

Solomon and Pearlmutter (2004) linked the attraction effect to the time course of sentence planning. When nouns are planned in parallel rather than sequentially, their number features are active in working memory simultaneously, giving rise to number interference and agreement errors. This view is supported by the results of experiments varying the degree of semantic integration of the subject noun phrase. Semantic integration is the degree to which a head noun and local noun are related to each other at the conceptual level. *The bowl with the spoons* is an example of a weakly integrated, or unintegrated, subject: The bowl and the spoons coexist, but are independent of each other. *The bowl with the stripes* is an example of a tightly integrated subject: The stripes are part of the bowl. In five sentence completion experiments, Solomon and Pearlmutter found more attraction for integrated than unintegrated subject phrases. They proposed that tight semantic integration

encouraged parallel planning and led to more agreement errors than weak semantic integration.

Gillespie and Pearlmutter (2011a), however, did not replicate these error patterns with a picture description task. Participants described object pairs in noun phrases using prepositions that depended on the color of the outline around the first picture. If the color was blue, *for* had to be used (leading to an integrated phrase, e.g., *the apple for the pie*), if the color was green, *near* had to be used (leading to an unintegrated phrase, e.g., *the apple near the pie*). Gillespie and Pearlmutter found no effect of semantic integration on error rates, but speech onset times were shorter for integrated than unintegrated noun phrases. These results were interpreted to suggest that parallel planning occurred in the integrated phrases and not in the unintegrated phrases (but see Meyer & Konopka, 2011, for an alternative view). The authors suggested that the timing of sentence planning might not have differed sufficiently in the integrated and unintegrated phrases to lead to a reliable effect in the error rates.

The integration effect on error rates seen by Solomon and Pearlmutter (2004) was also not replicated by Brehm and Bock (2013), who found more errors for unintegrated noun phrases, irrespective of whether the head and local noun matched or mismatched in number. They proposed an alternative hypothesis to account for their error patterns, with a focus on the influence that semantic integration has on the notional number of subject phrases. The notional number account claims that integrated subject phrases tend to be perceived as notionally singular, regardless of whether the local noun is singular or plural, whereas unintegrated subject phrases are perceived as notionally plural. With a singular head noun, integrated subject phrases are predicted to yield fewer agreement errors than unintegrated subject phrases. Supporting evidence for the notional number account comes from studies of

agreement in Dutch (e.g., Veenstra & Acheson, 2014; Veenstra, Acheson, Bock, & Meyer, 2014). Veenstra and colleagues found more errors for unintegrated than integrated subject phrases using different sentence completion tasks. Similar to Brehm and Bock, the integration effect in these studies was independent of the attraction effect.

These results cast some doubt on the lexical interference account of Solomon and Pearlmutter (2004). This account is based on two assumptions: (1) that semantic integration leads to parallel planning and (2) that parallel planning leads to increased attraction. Given the inconsistent effect of semantic integration on attraction that has been reported, it could be that semantic integration does not lead to parallel planning, or that parallel planning does not lead to increased attraction. A third possibility is that neither assumption is correct. As the effect of semantic integration is under debate, the current study instead focused on the effect of parallel planning on attraction.

Gillespie and Pearlmutter (2011b) also argued for a lexical interference account of attraction, although they referred to it as a scope of planning account (as both accounts are based on the same assumptions, we will refer to them collectively as a lexical interference account throughout this paper). This account proposes that the strength of the attraction effect is determined by the relative timing of advance planning of the head and local noun. If a local noun that mismatches in number from a head noun is planned simultaneously with the head noun, more attraction errors occur compared to when the nouns are planned sequentially. The likelihood of parallel planning may depend on different factors. For example, parallel planning can be induced by semantic integration, or by short linear distance. Gillespie and Pearlmutter (2011b) conducted two sentence completion experiments, manipulating the hierarchical and linear distance of two local nouns from a head noun and their

semantic integration with the head noun (e.g., *the book with the torn pages by the red pen*). The authors found that more agreement errors were made for mismatching local nouns that were linearly (and not hierarchical) close to the head noun than for nouns that were farther apart. Even more errors occurred when the nouns were both linearly close and semantically integrated. The authors interpreted their findings to suggest that both semantic integration and linear distance to the head noun affect how likely the head and local noun are planned in parallel, which in turn affects the strength of the attraction effect.

Not every account of agreement in production predicts effects of parallel planning on agreement. One such account is the Marking and Morphing model, which is a mathematical model designed to predict the proportion of plural verbs based on weighted number specifications from all constituents of a subject phrase. The Marking and Morphing model can account for the (asymmetrical) attraction effects and notional number effects reported in the literature (e.g., Bock, 2003; Eberhard, Cutting, & Bock, 2005). During the marking stage, the notional number from the message is marked onto the selected nouns for the subject phrase. The grammatical number of the nouns can diverge from the notional number of the message, and additionally, the grammatical number of the nouns themselves may differ. However, during the morphing stage, these different number specifications are reconciled and sent to the verb for number inflection, occasionally leading to agreement errors. This process is independent of the time course of lexical encoding and therefore has the same outcome regardless of whether the nouns in the subject phrase are planned in parallel or sequentially.

The present study tests the contrasting predictions of the effects of parallel planning on subject-verb agreement from the lexical interference and Marking and

Morphing accounts. Earlier studies postulating effects of parallel planning on agreement, however, have not used independent measures to assess whether parallel planning actually occurred. The present study was designed to address this limitation by directly manipulating the amount of parallel processing of head and local nouns. Before relating the error rates to the amount of parallel planning, we first assessed whether parallel planning was occurring. In an object naming task, we used semantic interference between objects that belonged to the same semantic category as a tool to assess parallel planning. This semantic interference was measured in speech onset latencies and eye movements. In the remainder of the introduction we motivate the use of this paradigm and outline predictions for the dependent measures.

The current study used a picture description task, rather than the more traditional sentence completion task. Picture description is a fairly natural way to elicit agreement through the production of whole sentences, whereas in sentence completion tasks speakers only provide a completion (i.e., an inflected verb phrase) to an experimentally-provided noun phrase. One advantage of picture description is that the verbal comprehension that is an unavoidable component of the sentence completion paradigm is eliminated. In the study mentioned above, Gillespie and Pearlmutter (2011a) used a picture description task in which participants produced subject phrases based on pictures and completed those into sentences by providing inflected verb phrases. Although no effects of integration were found in the study, the task did show a reliable attraction effect, suggesting that object naming tasks are suitable for assessing agreement.

Veenstra, Acheson, and Meyer (2014) also used a picture description task to study agreement. In contrast to Gillespie and Pearlmutter's (2011a) task where pictures only yielded a subject phrase (e.g., *the apple for the pie*), in Veenstra et al.'s

task participants based their entire utterance on the pictures (e.g., *the star next to the circle is blue*). The current study used an adaptation of Veenstra et al.'s task, because it allows for tight control over how sentences were to be completed. In addition to being a fairly natural way of eliciting agreement, the picture description task is particularly well-suited to our goals. By manipulating the spatial configuration of the pictures, we could manipulate the amount of parallel planning of noun phrases in a straightforward way that was measurable in speakers' naming times and eye movements.

Earlier studies have shown that when objects are close together, speakers process them in parallel. For instance, Meyer, Ouellet, and Häcker (2008) conducted a naming task in which participants had to name three objects. When they shifted their eye gaze to the second picture, this picture was replaced with a new picture. Facilitation was found when the old and new picture were either identical or homophonous, suggesting that the second (old) picture was already being processed while the participants were still looking at the first picture (see also Mädebach, Jescheniak, Oppermann, & Schriefers, 2011; Malpass & Meyer, 2010; Morgan, Van Elswijk, & Meyer, 2008; Schotter, Ferreira, & Rayner, 2013).

Another study that found effects of parallel processing in picture naming was conducted by Meyer and Konopka (2011), who manipulated the spatial distance between the pictures in a multiple object naming task. Pictures were in a near, middle, or far spatial configuration and either belonged to the same semantic category or were unrelated. Meyer and Konopka found semantic interference in speech onsets and gaze durations for looks at the first picture in the near and middle conditions, but not in the far condition. One account of these semantic interference effects is that the selection of the lemma for the first noun is slowed down by the co-activation of the related

second lemma, leading to longer speech onsets and gaze durations (e.g., Freedman, Martin, & Biegler, 2004; Smith & Wheeldon, 2004).

The results from Meyer and Konopka are relevant for the present study as they indicate that parallel processing can be encouraged by the spatial configuration of pictures, which manifests itself in semantic interference from related pictures. Therefore, in the current study we used pictures that were presented either spatially close (encouraging parallel planning) or far apart (discouraging parallel planning). To assess whether or not parallel planning occurred, the pictures were either semantically related or unrelated. We predicted that semantic interference would only occur in the close but not in the far condition. This interference would be evidenced in longer speech onsets and longer gaze durations for semantically related pictures. In contrast to earlier studies, the manipulation of semantic interference enabled us to directly assess whether parallel planning was occurring. With parallel planning established, we were then able to address whether parallel planning influences agreement.

To summarize, the key issue addressed in the current study is whether differences in the amount of parallel planning lead to differences in the strength of the attraction effect. Given our manipulations, the lexical interference account (Gillespie and Pearlmutter 2011b; Solomon & Pearlmutter, 2004) predicts stronger attraction in the close than in the far condition, and possibly, stronger attraction for related than for unrelated noun pairs within the close condition (see also Barker, Nicol, & Garrett, 2001). In contrast, the Marking and Morphing model predicts no effects of spatial configuration or semantic similarity (Eberhard, et al., 2005).

Method

Participants. Twenty-four native speakers of Dutch participated, with a mean age of 23 years (*SD* = 5.3). Sixteen participants were female; twenty-two were university students. All gave written informed consent prior to the study and received €8 for their participation. Approval to conduct this study was given by the Ethics Board of the Social Sciences Faculty of Radboud University, Nijmegen.

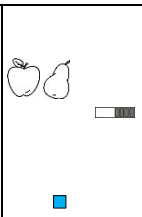
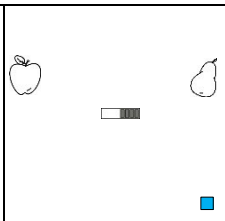
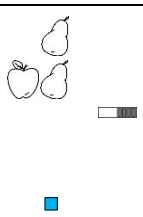
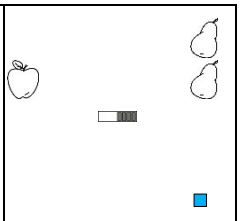
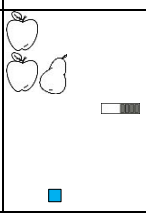
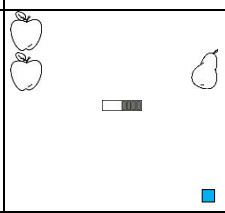
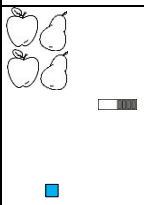
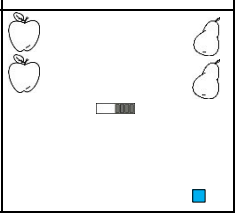
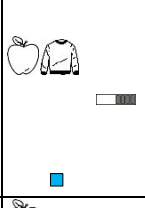
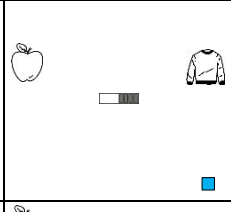
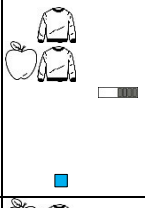
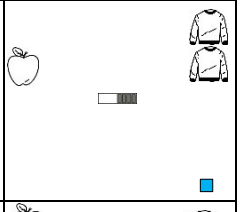
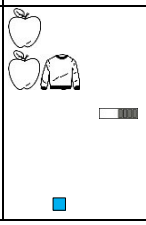
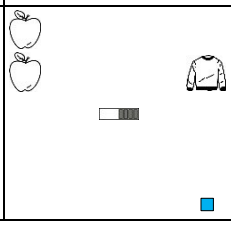
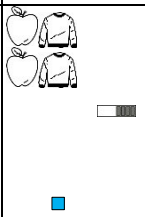
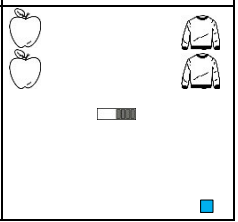
Materials and design. Twenty-eight pictures were used in the experiment. To facilitate picture naming, we used objects with highly frequent names. The average natural log frequency taken from CELEX for the singular forms was 6.3 (*SD* = 1.3); for the plural forms this was 5.4 (*SD* = 1; Baayen, Piepenbrock, & Van Rijn, 1993). The pictures were taken from the Severens picture database and had a mean naming latency of 901 ms (*SD* = 145 ms; Severens, Van Lommel, Ratinckx, & Hartsuiker, 2005). The pictures consisted of simple black line drawings that were all approximately 128 x 98 pixels in size, viewed with 2 x 1.5° visual angle. As the small set of items was presented multiple times (each picture appeared 64 times in the experiment), object identification and naming should be relatively easy (e.g., Francis, Corral, Jones, & Saenz, 2008; Malpass & Meyer, 2010).

The experiment had a 2 (Head Noun Number: singular/plural) by 2 (Number Mismatch: match/mismatch) by 2 (Semantic Similarity: related/unrelated) by 2 (Spatial Distance: close/far) within-subjects design. Fourteen noun pairs were constructed, consisting of two related nouns belonging to the same semantic category. These pairs were recombined to form an additional fourteen unrelated pairs. For example, the related pairs *apple/pear* and *pants/sweater* were recombined into the unrelated pairs *apple/sweater* and *pants/pear*. Similarly, *boat/canoe* and *scarf/hat*

were recombined into *boat/hat* and *scarf/canoe*; see Tables A1 and A2 in the appendix for a list of items and item pairs.

The head noun picture always appeared in the top left corner of the computer screen. The local noun picture was 100 pixels to the right (1.5° visual angle) of the head noun picture in the close condition, and 800 pixels to the right (12° visual angle) in the far condition. A colored box was positioned 400 pixels below the local noun picture (6° visual angle) at the bottom of the screen. See Table 1 for an example item.

Table 1
An Example Item and its Picture Displays in Sixteen Conditions

	Close SG local noun	Far SG local noun	Close PL local noun	Far PL local noun
SG head related				
PL head related				
SG head unrelated				
PL head unrelated				

Note. The target sentence for this item is "*the apple(s) next to the pear(s)/sweater(s) is/are blue*". The color box is relatively large for illustration purposes.

Meyer, Van Der Meulen, and Brooks (2004) conducted an eye-tracking study with similar target sentences (e.g., *the chair next to the star is brown*). Using a colored

first picture, they found that participants often looked back to the first picture when they produced the color word (47%). In our study it was important that participants did not look back to the first picture after naming it, as they may re-activate the number information, thus decreasing the chance of attraction. Therefore, in addition to the black line drawings, a separate picture of a small colored box of 23 x 23 pixels (0.3° visual angle) was used, which was positioned at the bottom of the screen underneath the local noun picture. The colors used were very pale versions of green, blue, yellow, and red. Because of the large distance from the previous picture, the small size and paleness of the color, the colored box was difficult to be extrafoveally identified, which encouraged participants to initiate an eye movement and fixate the color picture before naming it.

Each item was combined with four colors, which resulted in a total of 896 items, divided over four experiment lists. Twenty additional trials were created as practice trials.

Apparatus. Participants' eye movements were recorded with an SR Research Eye Link 1000 eye tracker with chin rest. The right eye was tracked for all participants at a sampling rate of 1000 Hz. Before each block a 9-point calibration was performed, to link the position of the eyes with a location on the screen. To control for head movements between trials, a drift correction was performed before each trial. The experiment was programmed with Experiment Builder software, and the eye-tracking data were quantified with Data Viewer, both from SR Research.

The experiment was stored and run on a Dell Precision desktop computer and presented on an Acer AL2023 20-inch LCD monitor (16.6 ms refresh rate, 60 Hz). Participants' responses were recorded with a Sennheiser microphone.

Procedure. Participants were tested individually in a quiet room. At the beginning of the session, they were given a booklet with the pictures used in the experiment with their names written underneath. To reduce the rate of naming errors, participants were asked to study the names for the pictures and use them in the experiment.

The experiment started with a practice block of 20 trials, followed by four experimental blocks of 56 trials each. Participants were allowed to take short breaks between blocks. The experiment lasted approximately 30 minutes.

On each practice and experimental trial, a fixation cross appeared in the top left corner of the screen for 500 ms or until the drift correction was performed. This fixation cross served as a fixation point for the drift correction, but also made sure that the participants' first gaze would be on the location of the head noun picture. After a blank screen of 150 ms, the pictures appeared, with the head noun picture always appearing in the top left corner in the location of the fixation cross. Along with the pictures, a small timer appeared in the center of the screen. The timer counted down in eight steps from 2.5 seconds. Participants were instructed to have finished producing their description before the timer ran out. Trials proceeded automatically with an intertrial interval of 500 ms.

Scoring and analyses. Participants' responses were recorded from the onset of the pictures for a maximum of 3900 ms until the presentation of the pictures in the next trial. Responses were transcribed and scored for non-agreement errors (e.g., wrong words, numbers, or incomplete responses) and agreement errors. Agreement errors were included in the analysis only if the remainder of the sentence was correct.

Speech onset latencies were measured with Praat speech analysis software (Boersma & Weenink, 2010). Each sentence started with the same determiner, and

this determiner might be produced before the rest of the noun phrase was encoded; onsets for the determiner would therefore not be informative about parallel planning. As such, speech onsets were coded at the first noun rather than the determiner. In addition, onset times for the local noun and the verb were determined.

Finally, the eye movements were used to identify the gaze patterns and determine the first pass gaze duration for the head noun picture. In order to quantify participants' eye movements and fixation patterns, interest areas were drawn around the pictures, approximately one cm larger than the size of the pictures. First pass gaze durations were calculated by subtracting the start time of the eye gaze from the end time of the eye gaze to an interest area, such that both fixations and saccades within one picture would be included.

Statistical analyses were run using linear mixed effects models with crossed effects of subjects and items using the lme4 package in R (Bates, 2005; R Development Core Team, 2011). Factors were centered before entering the models treating participants and items as random effects (Baayen, 2008). Backwards elimination was used for the fixed effects, starting with a full model and leaving out non-significant interactions. Models were run with the maximal random structure justified by the data when possible (Barr, Levy, Scheeper, & Tily, 2013).

The first analysis investigated whether attraction occurred in the agreement error rates, and used a logistic linking function (Jaeger, 2008). Variables included were Head Noun Number (coded as -1 for singular, and 1 for plural), Mismatch (coded as -1 for matching number, and 1 for mismatching number), and Block (coded as -2 through 2 for blocks 1 to 4).

A second analysis investigated the effects of spatial configuration of the pictures and the semantic similarity between them on agreement error rates, again

using a logistic linking function. Because of the extremely low error rates in the matching condition (see Results), only mismatching trials were included in this analysis. Trials in which the head noun picture was fixated between production of the local noun and the verb were excluded. The variables included were Head Noun Number, Block, Spatial Distance (coded as -1 for the Far condition, and 1 for the Close condition), Semantic Similarity (coded as -1 for unrelated pictures, and 1 for related pictures), and the interaction between Spatial Distance and Semantic Similarity. Because of its importance with regard to our experimental hypotheses, this interaction remained in this and the subsequent analyses regardless of whether it was significant or not.

A third analysis investigated the effects of spatial configuration of the pictures and the semantic similarity between them on speech onset latencies for the first noun. Incorrect trials and those in which speech onsets exceeded three standard deviations above the participants' mean were excluded. The remaining speech onsets were natural log-transformed before analysis. Variables included were Head Noun Number, Mismatch, Spatial Distance, Semantic Similarity, and Block. The inclusion of random slopes in the analysis meant that resampling methods for calculating statistical probability were not available. In accordance with Baayen (2008), absolute *t*-values exceeding 2 were interpreted as statistically significant.

The final analysis investigated the effects of spatial configuration of the pictures and the semantic similarity between them on gaze durations for the first picture. Only correct trials were included and the gaze durations were natural log-transformed before analysis. Variables included were Head Noun Number, Mismatch, Spatial Distance, Semantic Similarity, and Block. As with the analysis of reaction times above, absolute *t*-values exceeding 2 were interpreted as statistically significant.

Results

Error rates. Non-agreement errors (n = 512, 8.5%) included incorrect head nouns, prepositions, local nouns, or colors, incorrect numbers for the head noun or local noun, or incomplete utterances. These errors were divided over the conditions as seen in Figure 1.

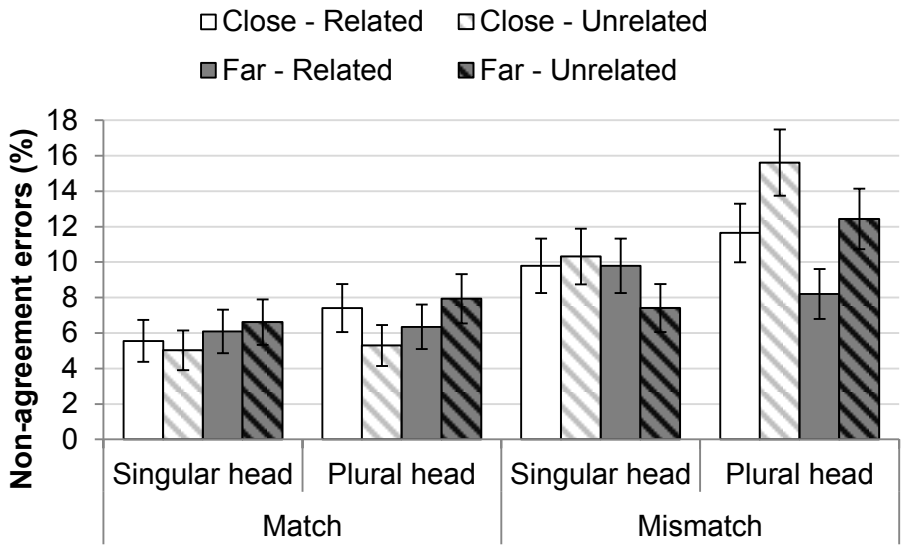


Figure 1. Non-agreement error rates for items with singular and plural heads in close and far conditions with related and unrelated word pairs in matching and mismatching conditions. Error bars represent the *SE* of the mean across participants for illustrative purposes.

As agreement errors can only be established in sentences that are otherwise correct, non-agreement errors were removed from subsequent analyses. After removal of these errors each cell in the design still included at least 319 observations. The first analysis was meant to confirm that attraction occurred, with the prediction that there would be more agreement errors in mismatching condition than in matching condition. The agreement errors made for matching and mismatching head and local nouns are shown in Figure 2.

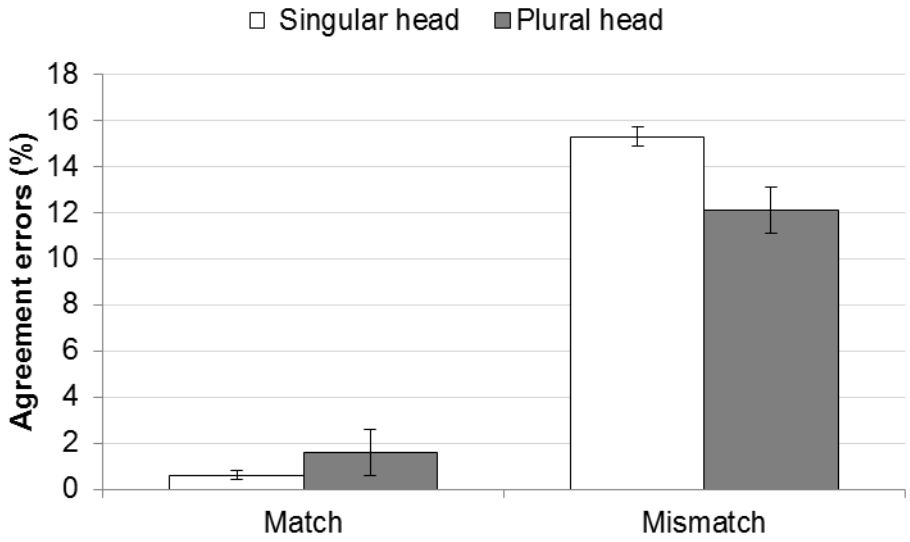


Figure 2. Agreement error rates for items with singular and plural heads in matching and mismatching conditions. Error bars represent the *SE* of the mean across participants for illustrative purposes.

As the figure shows, the error rates in the matching condition were extremely low. The statistical analysis revealed main effects of Mismatch and Block (see Table 2). More agreement errors were made when the number of the local noun mismatched with the number of the head noun compared to when they matched, confirming that attraction occurred. Over the course of the experiment, the error rates decreased. There was also an interaction between Head Noun Number and Mismatch, which came from the fact that the attraction was stronger for the singular heads ($\beta = 2.17$; $SE = 0.35$; $z = 6.81$; $p < 0.001$) than for the plural heads ($\beta = 1.22$; $SE = 0.20$; $z = 5.97$; $p < 0.001$).

Table 2
Logistic Mixed-Effects Model predicting Attraction

Variable	Coefficient	*SE*	*z*-value	Pr(>|*z*|)	Random Slope
(Intercept)	-3.75	0.22	-17.10	<.001	subjects, items
Head Noun Number	0.19	0.14	1.31	.192	subjects
Mismatch	1.59	0.19	8.42	<.001	subjects
Block	-0.15	0.05	-3.12	.002	subjects
Head Number * Mismatch	-0.34	0.12	-2.80	.005	

Note. Coefficients correspond to Logits.

There were very few errors in the matching condition, ranging from 1 single error to a maximum of 7 errors in a cell of the experimental design. Given that our primary research question concerned the magnitude of the attraction effect (which is only found in the mismatching condition), the following analysis was restricted to the mismatching condition. The lexical interference account predicts stronger attraction in the Close condition, as those nouns are more likely to be planned in parallel than in the Far condition.

Trials in which participants looked back at the head noun picture after producing the local noun, but before producing the verb, were removed from the analysis (n = 110, 4.6%). On these trials, participants might have been able to check for the number of the head noun, thereby reducing the chance of an agreement error. Figure 3 shows the agreement error rates in the mismatching conditions.

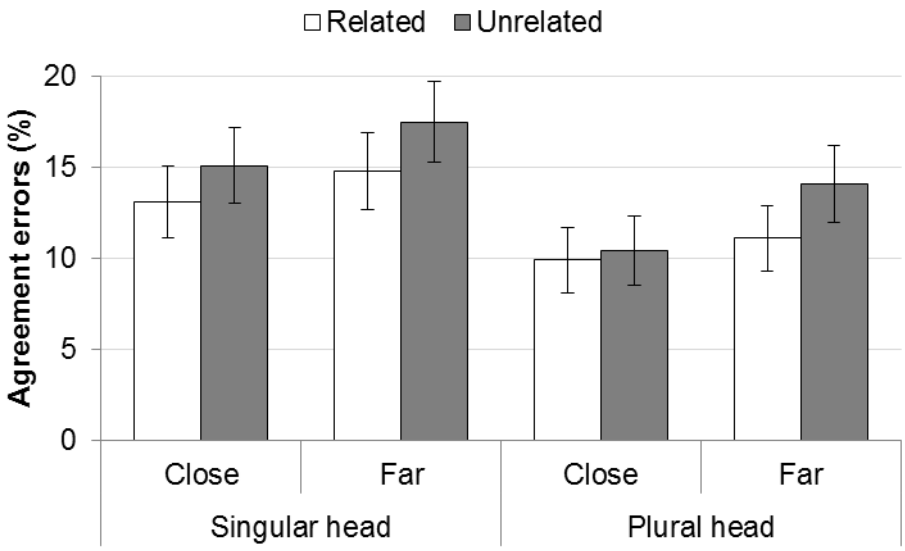


Figure 3. *A*greement errors rates for items with singular and plural heads in close and far conditions with related and unrelated word pairs (mismatching conditions only). Error bars represent *SE* of the mean across participants for illustrative purposes.

The statistical analysis revealed only a main effect of Block (see Table 3). Participants made fewer attraction errors over the course of the experiment (18% in

block 1, 13% in block 2, 10% in block 3, and 12% in block 4). The main effects of Head Noun Number and Spatial Distance approached significance. There was a trend of more errors being made for singular head noun items than for plural head noun items. In addition, marginally more errors were made when the pictures were far apart than when they were close together. The effect of Semantic Similarity did not reach significance, but was trending in the direction of more errors being made for semantically unrelated pictures than for related pictures.

Table 3
Logistic Mixed-Effects Model predicting Agreement Errors

Variable	Coefficient	*SE*	*z*-value	Pr(>|*z*|)	Random Slope
(Intercept)	-2.281	0.211	-10.801	<.001	subjects, items
Head Noun Number	-0.198	0.110	-1.794	.073	subjects, items
Spatial Distance	-0.152	0.083	-1.842	.066	subjects, items
Semantic Similarity	-0.112	0.075	-1.493	.135	subjects, items
Block	-0.168	0.053	-3.184	.001	subjects, items
Similarity * Distance	0.020	0.067	0.296	.767	

Note. Coefficients correspond to Logits.

The current results on agreement error rates suggest that they were not affected by the spatial distance and semantic similarity manipulations. If anything, the effects were opposite from the direction predicted by a lexical interference account as more errors should have been observed in the Close condition. It is critical to establish that parallel planning occurred in the Close condition, thus we now turn to the speech onset latencies.

Speech onset latencies. Speech onsets for invalid and incorrect trials and those more than three standard deviations above the participants' mean were excluded from the analysis (n = 933, 17.4%). Planning two nouns in parallel was predicted to lead to longer speech onsets than planning two nouns sequentially. Additionally,

previous research suggests that semantic similarity should lead to longer speech onsets for related than for unrelated nouns. Figure 4 shows the speech onset times.

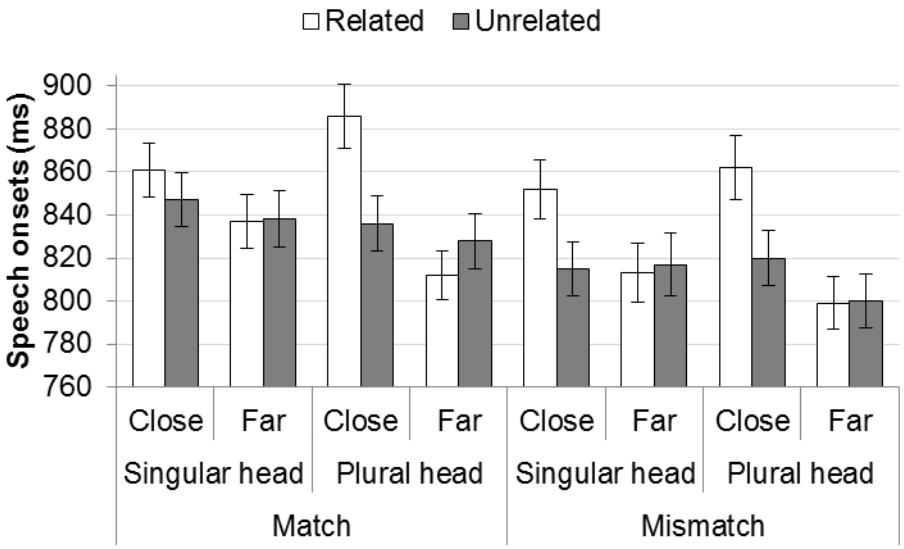


Figure 4. Average speech onset times for items with singular and plural heads in close and far conditions with related and unrelated word pairs in matching and mismatching conditions. Error bars represent *SE* of the mean across participants for illustrative purposes.

The statistical analysis revealed main effects of Spatial Distance and Semantic Similarity (see Table 4). Participants were slower to initiate their response when the pictures were close relative to when they were far apart, suggesting that the Close condition encouraged parallel planning. Additionally, participants were slower when the pictures were related relative to when they were unrelated, indicating semantic interference. There was an interaction between Semantic Similarity and Spatial Distance. Follow-up analyses showed that in the Close condition, speech onsets were slower for related relative to unrelated pictures (β = 0.020; *SE* = 0.004; t = 4.89), whereas there was no semantic interference in the Far condition (β = -0.002; *SE* = 0.005; t = -0.36).

There was also a three-way interaction between Mismatch, Semantic Similarity and Block, which came from the fact that the magnitude of the semantic

interference effect decreased over the course of the experiment in the mismatching condition (β = -0.006; *SE* = 0.003; *t* = -2.44), but increased in the matching condition (β = 0.005; *SE* = 0.002; *t* = 2.25). Specifically, in the matching condition, the onsets for related condition remained stable (β = 0.001; *SE* = 0.005; *t* = 0.18), whereas the onsets for the unrelated condition decreased (β = -0.011; *SE* = 0.005; *t* = -2.39). In the mismatching condition the speech onset latencies for the related condition decreased (β = 0.013; *SE* = 0.006; *t* = -2.21), whereas the onsets for the unrelated condition remained fairly stable (β = 0.001; *SE* = 0.006; *t* = 0.19, see Figure 5). No effect of Head Noun Number or Mismatch was found.

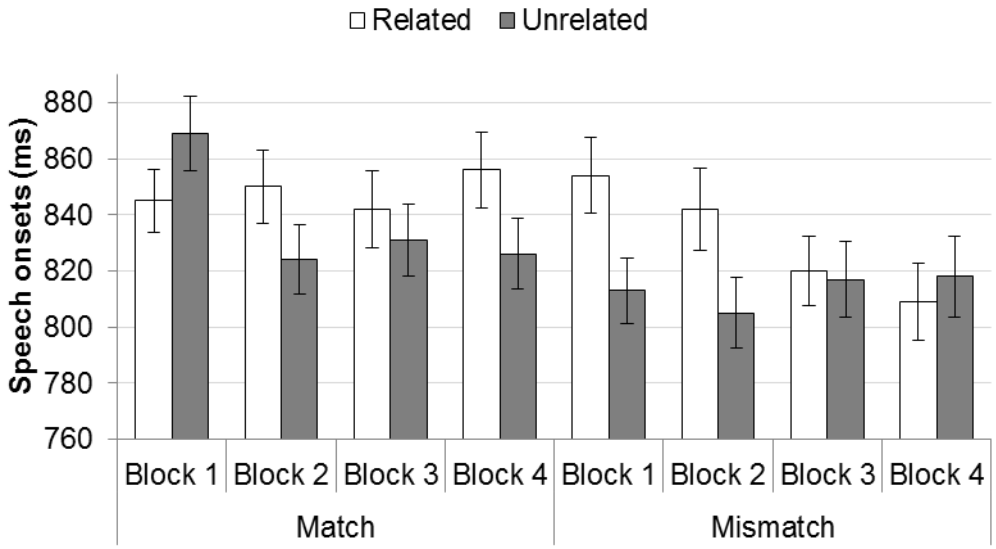


Figure 5. Average speech onset times across different blocks with related and unrelated word pairs in matching and mismatching conditions. Error bars represent *SE* of the mean across participants for illustrative purposes.

Table 4
Mixed-Effects Model predicting Speech Onset Times

Variable	Coefficient	*SE*	*t*	Random Slope
(intercept)	6.705	0.032	209.13	subjects, items
Head Noun Number	-0.002	0.003	-0.63	subjects, items
Mismatch	-0.005	0.004	-1.39	subjects, items
Spatial Distance	0.017	0.004	3.90	subjects, items
Semantic Similarity	0.010	0.004	2.70	subjects, items
Block	-0.005	0.004	-1.26	subjects, items
Similarity * Distance	0.011	0.003	4.00	subjects
Mismatch * Similarity * Block	-0.006	0.002	-3.30	

Note. Coefficients correspond to natural log-transformed speech onsets.

In sum, the speech onsets suggested that parallel planning occurred mostly in the Close condition. Further converging evidence is provided by the eye-tracking measures below.

Eye movements. First, participants' gaze patterns in the mismatching condition were examined. As many earlier studies have shown that speakers typically look at pictures in the order they will mention them (e.g., Griffin, 2001; Griffin & Bock, 2000; Meyer, Sleiderink, & Levelt, 1998), the predicted pattern was that participants would first look at the head noun picture, followed by the local noun picture, and finally at the color box. In the majority of trials, participants indeed started with a head-local-color pattern (89.4%). On the remaining trials, sometimes no fixations were recorded to the head noun picture (0.3%), to the local noun picture (7.1%), or to the color box (0.7%), most often because the participants fixated just outside of the interest area. On many trials the participants looked back to the head or local noun picture after their first inspection of the three areas of interest (77.3%). These second gazes typically occurred well after the onset of the spoken utterances.

Second, gaze durations for the first looks at the head noun picture were measured. Longer gaze durations have been shown to indicate semantic interference (e.g., Meyer & Konopka, 2011). The gaze durations are shown in Figure 6.

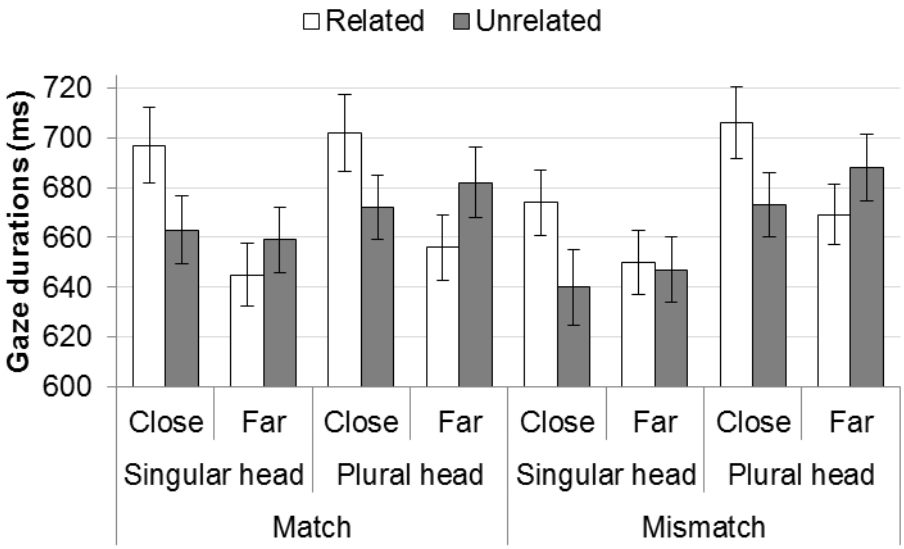


Figure 6. Average gaze durations for items with singular and plural heads in close and far conditions with related and unrelated word pairs in matching and mismatching conditions. Error bars represent *SE* of the mean across participants for illustrative purposes.

Statistical analysis revealed a main effect of Head Noun Number (see Table 5). Participants looked longer at the first picture when it was plural than when it was singular. Similar to the speech onsets, there was an interaction between Semantic Similarity and Spatial Distance in the gaze durations. Follow-up analyses showed that in the Close condition, participants looked longer at the first picture when it was semantically related to the second picture than when it was unrelated (β = 0.019; *SE* = 0.008; t = 2.35), whereas in the Far condition, gazes were longer in the unrelated condition than in the related condition (β = -0.015; *SE* = 0.007; t = -2.17). Also similar to the speech onsets, there was a three-way interaction between Mismatch, Semantic Similarity and Block, which came from the fact that semantic interference slightly decreased over the course of the experiment in the mismatching condition (β = -0.005, *SE* = 0.004, t = -1.10) and increased in the matching condition (β = 0.008, *SE* = 0.004, t = 1.82). A similar interaction was found between Head Noun Number, Semantic Similarity and Block. Semantic interference decreased across blocks in plural head condition (β = 0.005, *SE* = 0.005, t = -1.07), but increased in singular head condition

(β = 0.007, *SE* = 0.005, *t* = 1.62). It should be noted that the effect of Block was not significant in either of the interactions; thus the interactions between Head Noun Number, Semantic Similarity and Block, and between Mismatch, Semantic Similarity and Block were driven by the crossing over of the directions of the Block effects.

Table 5
Mixed-Effects Model predicting Gaze Durations

Variable	Coefficient	*SE*	*t*	Random Slope
(intercept)	6.454	0.029	221.01	subjects, items
Head Noun Number	0.014	0.007	2.11	subjects, items
Mismatch	-0.001	0.006	-0.09	subjects, items
Spatial Distance	0.010	0.007	1.44	subjects, items
Semantic Similarity	0.003	0.006	0.42	subjects
Block	0.005	0.005	0.94	subjects
Similarity * Distance	0.017	0.005	3.50	subjects
Mismatch * Similarity * Block	-0.007	0.003	-2.39	
Head * Similarity * Block	-0.007	0.003	-2.09	

Note. Coefficients correspond to natural log-transformed gaze durations.

Results from both speech onsets and gaze durations demonstrated that there was evidence of semantic interference in the Close condition. In both cases, the semantic interference effect decreased over the course of the experiment, possibly due to the repetition of the materials. These results nevertheless confirm that parallel planning was more likely to be employed in the Close condition than in the Far condition.

Discussion

The current study used a picture description task to investigate whether parallel planning of two nouns with mismatching number would yield higher agreement error rates compared to nouns that are planned sequentially. The lexical interference account of attraction postulates that parallel planning of head and local nouns leads to simultaneous activation of the number features of the nouns. Such

simultaneous activation leads to more number interference and, consequently, more agreement errors relative to when nouns are planned sequentially (Gillespie & Pearlmutter, 2011b; Solomon & Pearlmutter, 2004). The Marking and Morphing account, on the other hand, does not predict any effect of parallel planning compared to sequential planning. As it is not clear from previous studies whether semantic integration increases parallel planning, we manipulated parallel planning in a different way: Following Meyer and Konopka (2011), we used the spatial distance between objects to encourage or discourage parallel planning.

To assess whether our spatial distance manipulation influenced the amount of parallel planning, we measured speech onsets and gaze durations. We had two ways to establish parallel planning. First, following Meyer and Konopka (2011), we hypothesized that pictures in a spatially close configuration would encourage parallel planning as the local noun picture could be extrafoveally processed while the head noun picture was fixated. In a far configuration, parallel planning would be unlikely, as the pictures were too far apart to be processed simultaneously. Therefore, we predicted longer speech onsets and gaze durations in the Close condition than in the Far condition. This main effect of Spatial Distance was indeed seen in the speech onsets, but not reliably in the gaze durations.

The second way of establishing parallel planning was through observing effects of semantic interference. Semantic similarity between objects has a stronger effect when nouns are planned in parallel compared to when they are planned sequentially (e.g., Meyer & Konopka, 2011). Therefore, we expected to see evidence of semantic interference when objects were close together but not when they were far apart. In both speech onsets and gaze durations, there was a significant interaction between Semantic Similarity and Spatial Distance. As predicted, in the Close

condition speech onset latencies and gaze durations were longer for related than for unrelated objects, whereas no such effect was observed in the Far condition. Note that for gazes, extrafoveal-onto-foveal effects (i.e., longer gazes at the fixated object because of interference from an extrafoveal object) can occur only when visual processing is parallel. Taken together, these findings suggest that parallel planning was indeed more likely in the Close than in the Far condition. This confirms earlier findings of extrafoveal processing of objects in object naming studies (e.g., Malpass & Meyer, 2010; Meyer, Ouellet, & Häcker, 2008). Our finding that extrafoveal processing depends on spatial distance is consistent with the results reported by Meyer and Konopka (2011), who argued that spatial configuration influenced the amount of parallel planning.

Having established that the spatial configuration of the pictures affected the amount of parallel planning, we continued by assessing whether parallel planning affected agreement errors. The lexical interference account predicts stronger attraction for mismatching nouns planned in parallel than for nouns planned sequentially. Thus, if parallel planning increases attraction, higher error rates should be seen in the Close condition relative to the Far condition. However, our results did not confirm this prediction. There was a marginal effect of Spatial Distance in the opposite direction: More errors were made in the Far condition relative to the Close condition. Therefore, the current study does not provide evidence supporting the lexical interference account of attraction.

It is important to note that we did find a mismatch effect on error rates, even though it was not modulated by spatial distance. As often reported in the agreement literature, the attraction effect was asymmetrical with regard to the number of the head noun. More errors were found for singular heads combined with plural local

nouns compared to plural heads combined with singular local nouns. This asymmetry has been explained by the markedness of plural forms, which allows marked plural local nouns to exert attraction on singular head nouns, but rarely the reverse (Bock & Eberhard, 1993; Eberhard, 1997). This error pattern shows that the paradigm did tap into agreement processes.

To account for the lack of an effect of parallel processing on error rates, one could argue that parallel processing in our study might have been confined to the visual level. The spatial manipulation primarily affected the visual processing of the objects, and the semantic interference effect may be partially based on the higher degree of visual similarity of related relative to unrelated object pairs. In future research, the contribution of visual and semantic similarity to the interference effects on speech onset latencies and gaze durations could be assessed by using object pairs that are purely visually, but not semantically related or, conversely only semantically, but not visually related. However, regardless of the precise origin of the interference effect, the question remains why relatedness affected speech onset latencies and gaze durations, but not the selection of the correct verb form.

Similar dissociations between grammatical feature mismatches and (lack of) interference have been seen elsewhere in the literature, namely in studies of number and gender interference using the picture-word interference paradigm. Here, speakers typically see to-be-named target pictures accompanied by spoken or written distractors. Typical manipulations include whether the distractor words are semantically related or unrelated, phonologically similar or dissimilar, or match or mismatch with the target in number or grammatical gender (Damian, Vigliocco, & Levelt, 2001; Glaser & Düngelhoff, 1984; Meyer, 1996; Miozzo & Caramazza, 1999; Schriefers, 1993; Schriefers & Teruel, 2000). While phonological and semantic

effects are quite robust, mismatch in grammatical features sometimes leads to interference effects, although this effect is not always observed. In gender interference studies, the results appear to depend on whether or not the grammatical gender has to be specified in the utterance (i.e., whether participants produce determiner noun phrases or bare nouns, La Heij, Mak, Sander, & Willeboordse, 1998; Schiller & Caramazza, 2003, but see Cubelli, Lotto, Paolieri, Girelli, & Job, 2005, and Miozzo & Caramazza, 1999, for alternative views). For instance, Schriefers (1993) found gender interference in Dutch when participants produced nouns with determiners and when they produced nouns with adjectives (in Dutch, determiners and adjectives are inflected for gender). Later studies found the effect only when the noun was accompanied by a determiner and not with bare nouns or nouns with adjectives (e.g., Costa, Kovacic, Fedorenko, & Caramazza, 2003; Janssen & Caramazza, 2002; La Heij, et al., 1998; Schiller & Caramazza, 2003).

One explanation for the lack of an effect when bare nouns are produced is that the locus of the interference is not at the lexical level, where abstract grammatical features are activated, but instead emerge during a later stage, the selection of inflectional morphology (Schiller & Caramazza, 2003). In a series of experiments on Dutch and German, Schiller and Caramazza asked their participants to name singular and plural objects overlaid with distractor words that matched or mismatched in gender with a determiner and a noun. In the Dutch experiments, for instance, a picture of a cat (common gender, takes the determiner *de* for both singular and plural) would be overlaid with the word *blad* (*leaf*, neuter gender, takes the determiner *het* for singular and *de* for plural). Depending on an auditory cue at trial onset, the singular or plural form of the picture had to be named with a determiner and a noun. If gender features compete at the lexical level, gender interference should be found in both the

singular and plural conditions. In Dutch, however, only singular determiners are specified for gender. Thus, if gender features only compete during the selection of the determiner, then gender interference should only be found in the singular condition. Interference was only found in the singular condition, leading the authors to conclude that the selection of grammatical features was not competitive.

Only one study using the picture-word interference paradigm appears to have investigated whether interference arises between nouns differing in number. Schiller and Caramazza (2002) asked German participants to name singular or plural objects (e.g., a picture of one nose or of two noses), which were overlaid with distractor words that matched or mismatched in number (Experiment 1) or words that matched and mismatched in number and were semantically related or unrelated (Experiment 2). Only bare nouns had to be produced. Semantic interference was evidenced by longer speech onsets for trials where the picture and the distractor word were semantically related compared to when they were unrelated. This indicated that the distractor word was processed in parallel with the picture. However, no number mismatch effects were found: Although the plural nouns possessed plural marking (which requires the activation of number features), number mismatch did not delay picture naming. Because no determiners had to be selected, Schiller and Caramazza (2002) concluded that only the abstract grammatical number features were active, and that these features do not compete for selection. Instead, the authors argued that later inflectional processes, such as selecting a determiner, cause interference. Similar conclusions were made by Costa, et al. (2003), who argued that only free morphemes, but not inflectional suffixes, compete for activation.

Previous research using the picture-word interference paradigm has thus shown that interference effects are driven by determiners, but only when these

determiners are specified for gender or number. In the current study, participants did include determiners in their utterance. However, we only used common gender nouns which take determiners that are identical in their singular and plural form, as those have been shown to yield stronger attraction effects (Anton-Mendez & Hartsuiker, 2010; Hartsuiker, Schriefers, Bock, & Kikstra, 2003). These determiners are not informative about number. Therefore, based on results from the picture-word interference studies mentioned above, one would predict similar onsets in the matching and mismatching conditions (e.g., Schiller & Caramazza, 2003). Our results indeed showed similar speech onsets for the matching condition (*m* = 843 ms; *SD* = 225 ms), and the mismatching condition (*m* = 822 ms; *SD* = 208), as well as similar gaze durations for the matching condition (*m* = 672 ms; *SD* = 242 ms), and the mismatching condition (*m* = 662 ms; *SD* = 221 ms). This suggests that mismatch in number and the associated morphological markers of head and local nouns does not delay the selection or morpho-phonological encoding of the nouns.

In contrast to the lack of a number interference effect, semantic similarity did lead to interference in the current study. The classic account of semantic interference is based on mutual activation between related concepts and lemmas (e.g., Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992). Co-activation arises because there are "links" in the conceptual and lemma stratum. Whereas the semantic links are present between related concepts and lemmas a priori, number features may only be activated ad hoc based on the conceptual information of the specific utterance. Thus, number links are not present in the lexicon. It is therefore not surprising to find semantic interference but not number interference in our latency measures.

The present results are problematic for the lexical interference account (Gillespie & Pearlmutter, 2011b; Solomon and Pearlmutter, 2004). Although we have

clear evidence that we induced parallel planning, we did not find evidence for lexical number interference. From the picture-word interference literature, we know that number features may not compete during selection. Thus, if there is no lexical number interference during the planning of the subject phrase, number interference should not be expected to persist during verb selection either, regardless of the amount of parallel processing. In fact, if number interference only occurs with the selection of free morphemes that specify number (e.g. Costa, et al., 2003; Schiller & Caramazza, 2002), it is surprising that studies on English found number interference during advance planning, as English determiners are not marked for number.

The current null-results fit well within the Marking and Morphing account (Eberhard, Cutting, & Bock, 2005). First of all, the model does not predict effects of parallel planning on agreement, and we found no effects of parallel planning. In fact, the model does not take into account the timing of production at all, as Eberhard and colleagues (2005) pointed out. The Marking and Morphing model does not predict that there should be effects of semantic relatedness either. In our study, semantic similarity led to semantic interference in the speech onsets and gaze durations, but no effects were found on the agreement process. This contrasts, however, with findings from Barker, Nicol, & Garrett (2001), who found stronger attraction when the head and local noun belonged to the same semantic category compared to unrelated nouns. Finally, the model does not make predictions about the spatial distance between to-be-named objects, and no significant effects of spatial configuration on error rates were found.

Conclusion

The current study showed that parallel planning can be induced by a spatial manipulation of objects during naming, but does not affect the magnitude of attraction in agreement. These results are not consistent with a lexical interference account of attraction. Instead, the results suggest that simultaneously active number features do not compete at the lexical level.

Appendix A

Table A1

Log-transformed Form Frequencies of the Head and Local Nouns

Head noun	Singular	Plural	Local noun	Singular	Plural
koe *(cow)*	6.422	6.729	geit *(goat)*	5.094	5.476
auto *(car)*	8.854	7.410	bus *(bus)*	7.295	5.403
appel *(apple)*	5.717	5.533	peer *(pear)*	5.247	5.142
broek *(pants)*	7.768	5.485	trui *(sweater)*	6.402	4.522
tafel *(table)*	8.991	6.457	stoel *(chair)*	8.509	7.080
kikker *(frog)*	5.215	5.147	slak *(snail)*	4.205	5.063
wortel *(carrot)*	6.295	6.690	tomaat *(tomato)*	4.595	5.663
kaars *(candle)*	5.999	6.080	lamp *(lamp)*	6.772	6.073
leeuw *(lion)*	6.463	5.753	tijger *(tiger)*	5.403	4.248
lepel *(spoon)*	6.174	4.615	vork *(fork)*	6.052	4.263
trommel *(drums)*	6.410	5.176	gitaar *(guitar)*	5.384	3.761
vlieg *(fly)*	5.956	5.900	bij *(bee)*	-	5.727
boot *(boat)*	7.643	5.740	kano *(canoe)*	4.796	4.344
sjaal *(scarf)*	5.598	4.060	muts *(hat)*	5.501	3.989

Note. The CELEX database did not contain the frequency for the singular form of *bij*.

Table A2

Related and Unrelated Noun Pairs

Related pairs		Unrelated pairs	
koe/geit	auto/ bus	koe/bus	auto/geit
appel/peer	broek/trui	appel/trui	broek/peer
tafel/stoel	kikker/slak	tafel/slak	kikker/stoel
wortel/tomaat	kaars/lamp	wortel/lamp	kaars/tomaat
leeuw/tijger	lepel/vork	leeuw/vork	lepel/tijger
trommel/gitaar	vlieg/bij	trommel/bij	vlieg/gitaar
boot/ kano	sjaal/muts	boot/muts	sjaal/kano

General Discussion

Although speakers know the grammatical rule for generating subject-verb agreement, agreement errors are quite common in spontaneous speech. Many studies have investigated the factors influencing the production of agreement. A robust finding is the attraction from a local noun that differs in number from the head noun. However, the extent to which this attraction effect might be modulated by additional factors is under debate. The current studies investigated some of these additional factors. In this thesis, three main issues were addressed. Two issues were theoretical and concerned the effect of semantic integration on agreement errors and the asymmetry in the attraction effect, respectively. The third issue was more methodological in nature and inspired a search for an optimal agreement production task. Below, I summarize the results with respect to these main issues and discuss the implications for the Marking and Morphing model (Eberhard, Cutting, & Bock, 2005).

Semantic Integration

Chapter 2 addressed the debate on the influence of semantic integration on subject-verb agreement. Pearlmutter and colleagues found a detrimental effect of integration on agreement, predicted by a lexical interference hypothesis (Gillespie & Pearlmutter, 2011b; Solomon & Pearlmutter, 2004). This hypothesis proposes that semantic integration leads to parallel planning of head and local nouns, which leads to more attraction in sentences where the nouns mismatch in number. In contrast, Brehm

and Bock (2013) found a facilitatory effect of integration, predicted by the notional number hypothesis. The notional number hypothesis proposes that integrated subject phrases are perceived as notionally singular, facilitating singular agreement.

Using a variant of the constrained preamble completion task introduced by Brehm and Bock (2013) and items adapted from Solomon and Pearlmutter (2004), I investigated the effect of semantic integration on agreement in Dutch. Experiment 1 showed that local noun number mismatches increased error rates and response times, and so did weak integration. The effects were independent of each other. This pattern was replicated in Experiment 2, which used the same items in a metalinguistic judgment task. These results are consistent with the notional number hypothesis, which predicts that notionally plural subjects (weakly integrated phrases) make singular agreement harder than notionally singular subjects (tightly integrated phrases).

Chapter 3 followed up on the independence of the notional semantic integration effect and the grammatical attraction effect. Under the assumption that the notional effect is partly driven by the mental image of a subject, I predicted that enhancing this mental image should increase the integration effect. In addition, given the independence of the effects, an increase in the integration effect should not coincide with an increase in the attraction effect. Using the same metalinguistic judgment task as in Chapter 2, I investigated the effect of pictures on the strength of the integration and attraction effects. In addition to hearing the subject phrase, one group of participants saw a picture illustrating the subject phrase, whereas a second group of participants did not see any pictures. Results showed that there were more errors after unintegrated subjects, relative to integrated subjects, independent of the local noun number, which provides converging evidence for the notional number

hypothesis. Importantly, the integration effect was stronger in the picture group than in the non-picture group, whereas the attraction effect was the same across groups. The results support the idea that semantic integration influences notional number, and that this semantic influence works independently from grammatical number in the production process.

One way of manipulating semantic integration is to use different prepositions to link the same head and local noun. For instance, *the secretary of the governor* is integrated, as *of* makes working for a governor a characteristic of the secretary. *The secretary with the governor* is less integrated, because *with* makes the secretary independent from the governor. However, depending on context, the preposition *with* can also be interpreted as integrated. For example, *the sweater with the dog*, which refers to a sweater with a dog printed on it, is integrated, whereas *the sweater next to the dog* is unintegrated. Chapter 4 investigated whether a semantic integration effect would still be found when items were low in lexical variability (e.g., *the star with the circle* versus *the star next to the circle*). The results showed that the preposition *with* was ambiguous without additional context (Experiments 1 and 2). When the ambiguity was resolved by accompanying pictures of the subject phrase, the prepositions (*with*/*next to*) did not induce effects of semantic integration (Experiment 3). These results suggest that semantic integration may require a certain level of lexical context that was not present in the stimuli.

The results of Chapters 2 and 3 showed that weak integration led to more incorrect plural verbs, consistent with the notional number hypothesis and inconsistent with the lexical interference hypothesis. However, the lexical interference hypothesis is based on two assumptions: (1) semantic integration leads to parallel planning and (2) parallel planning leads to increased attraction. The effect of semantic integration

as found by Pearlmutter and colleagues was not replicated in the previous chapters, suggesting that semantic integration might not have influenced parallel planning of the head and local noun. Nevertheless, parallel planning may still influence attraction. Therefore, Chapter 5 investigated the second assumption. In a picture description task, parallel planning was encouraged, while the attraction effect was measured. In contrast to earlier studies which assumed rather than assessed that parallel planning was induced by semantic integration, parallel planning was actually confirmed by semantic interference in speech onsets and gaze durations. Results showed longer speech onsets and gaze durations in the semantically related than in the unrelated condition in a spatially close configuration, but not in a far configuration. This confirmed that parallel planning was occurring in the close condition. However, parallel planning did not increase attraction error rates.

One possible explanation for why parallel planning did not influence attraction comes from research on the gender congruency effect in the picture-word interference paradigm. Although interference effects have been found when nouns that mismatch in gender features are planned in parallel, several studies have found that this interference might not stem from simultaneously active gender (or number) features (Schiller & Caramazza, 2002, 2003, 2006). Instead, results from these studies suggest that these abstract features do not compete, and that the interference arises at a later stage. So, if the number features do not compete in parallel planning, it is conceivable that the number mismatch effect in agreement tasks is not due to interference during planning, but arises at a later stage, for instance during the grammatical encoding of the verb.

To summarize, the studies in this thesis did not support the lexical interference hypothesis. Neither tight semantic integration nor parallel planning of mismatching

nouns led to stronger attraction. In contrast, the studies provided converging evidence for the notional number hypothesis. Across three experiments, participants made more errors for unintegrated (notionally plural) subjects than for integrated subjects, in addition to the errors made for mismatching local nouns.

Attraction Asymmetry

The asymmetry in attraction, with stronger attraction after singular heads than plural heads, has been explained by the markedness of plurals. Plural nouns often possess a plural marker (e.g., *-s* in English, *-s* or *–en* in Dutch), which singular nouns do not possess. Importantly, studies have suggested that the number feature of a noun is either active or not; an active number feature makes the noun plural, whereas an inactive number feature makes the noun a default singular (e.g., Eberhard, 1997). In case of a singular head noun (with inactive number features), a plural local noun (with active number features) can affect verb number. In contrast, for an already active plural head noun, an inactive singular local noun does not have much of an effect.

The studies by Solomon and Pearlmutter (2004) and Brehm and Bock (2013) on the effect of semantic integration did not include plural head conditions. Part of the reason for this exclusion may be because error rates have typically been low in sentences with plural heads combined with singular local nouns (e.g., Bock & Miller, 1991; Bock & Eberhard, 1993; Eberhard, 1997). As the aim of Chapter 2 was to replicate both studies, I did not include experimental items with plural heads. Plural filler items were used to balance the singular and plural responses, but they were not systematically paired with singular and plural local nouns. Chapters 2 and 3 could therefore not assess the attraction asymmetry.

The experiments in Chapters 4 and 5 did include plural head conditions, which allowed me to study the asymmetry of the attraction effect. In both studies, head and local noun number were crossed. The forced-choice experiments in Chapter 4 (Experiments 1 and 2) both showed the classic asymmetry in the error rates: attraction after singular heads combined with plural local nouns, but not after plural heads combined with singular local nouns. The error rates of the picture description experiments (Experiment 3 in Chapter 4, Chapter 5) were different: although there was an asymmetry in that attraction was stronger after singular heads than plural heads, a reliable attraction effect was present for both singular and plural heads. Perhaps even more surprising, the response times in the forced-choice experiments did not reveal an asymmetry at all: attraction was reliable after both plural and singular heads, without an interaction with head noun number.

These results suggest that attraction might not be as asymmetrical as previously assumed. In fact, other studies have also reported deviating patterns. For instance, Franck and colleagues did not find an asymmetry in their error rates in French and Italian (Franck, Lassi, Frauenfelder, & Rizzi, 2006; Franck, Vigliocco, & Nicol, 2002). Results from the current thesis thus bring into question whether plurals are marked and singulars are not. I propose that singulars and plurals are both marked, with marked plurals (e.g., *three keys*) on one end and marked singulars (e.g., *one key*) on the other end of a continuum. The Marking and Morphing account proposes a similar continuum from -1 for marked singulars to 1 for marked plurals, and places unmarked singulars (e.g., *the key*) at the zero-point in the middle. In contrast, I suggest that unmarked singulars might be below the zero-point, though closer to the zero-point than plurals are to the zero-point. The strength of this singular marking

might either depend on the measure (e.g., response times or error rates) and context (e.g., materials and task), or might have a different fixed value in different languages.

In sum, the results suggest that the influence of singular local nouns is variable, ranging from no reliable attraction, weaker attraction compared to plurals, to equal attraction compared to plurals. Relative to previous research that found a clear asymmetry between singular and plural head nouns, the currents experiments differed both with regard to the type of task that was used and the dependent measures. Results of the current studies show that response times are more sensitive to singular attraction than error rates. In addition, the picture description paradigm is more sensitive to singular attraction than the sentence completion paradigm. Below, I will discuss the implications for the Marking and Morphing model, but first, I discuss the paradigms used in the thesis.

Agreement Production Tasks

Traditionally, the production of subject-verb agreement has been studied with sentence completion paradigms. Following Bock and Miller (1991), many researchers provided their participants with subject phrases that had to be repeated and completed with an inflected verb phrase. Although the paradigm has revealed many factors that play a role during agreement, it also has its disadvantages. In this thesis, I worked towards an alternative tool for assessing attraction.

In Chapter 2, I used different versions of the sentence completion task. Experiment 1 was based on Brehm and Bock (2013), and required participants to provide a spoken verb phrase only, using the adjective given at the start of the trial. Compared to the traditional task, this constrained completion task had two advantages: First, providing participants with an adjective reduced the number of

invalid trials, as the adjective clearly required an inflected verb. It also limited the possibility for non-target responses, such as object-fronted sentences where the verb does not agree with the first noun. Second, because participants' utterances started with the inflected verb, response times could be measured. Response times had been shown to reflect difficulties during agreement generation, perhaps even more clearly than agreement errors (Brehm & Bock, 2013; Haskell & MacDonald, 2003).

The constrained completion task yielded clear results in both error rates and response times. However, each utterance had to be manually coded for errors (agreement errors and non-agreement errors) as well as speech onsets, which rendered the paradigm quite laborious. Therefore, in Experiment 2, I used the simpler forced-choice paradigm designed by Staub (2009, 2010). Participants only had to provide the completion by choosing between a singular and plural verb. Button presses registered both agreement errors and response times. The results were was much faster to analyze, and showed similar, though slightly weaker effects compared to the constrained spoken sentence completion task of Experiment 1.

I used the forced-choice paradigm again in Chapter 3. In previous experiments the subject phrases were rapidly presented in writing on the computer screen. However, as the aim of Chapter 3 was to study the influence of pictures on people's mental images of the subject phrases, the subject phrases were presented auditory at a normal speed. Clear effects of number mismatch were found in the error rates, but not in the response times. One possible reason that response times were not sensitive to noun mismatch in this study is that participants may have prepared their answers while the subject phrase was still unfolding. Critically, there was an effect of pictures on agreement, which provided support for the independence of semantic and syntactic

influences. However the results also pointed out a weakness of the completion paradigm, namely the potential ambiguity of the subject phrase.

In a completion task, the subject phrase is typically given verbally to the participant. This means that the phrase first has to be comprehended, and in some paradigms, stored in working memory for repetition. In addition to requiring comprehension rather than production, this stage replaces the message formulation stage that precedes an utterance in natural language production (Levelt, 1989). One could argue that the general process of agreement does not depend on how the subject phrase is generated. However, the results from Chapter 3 showed that the inclusion of a picture of the subject phrase increased notional effects. The forced-choice tasks in Chapter 4 (Experiments 1 and 2) showed that ambiguous prepositions can lead to a misleading pattern in error rates. These effects might not have been observed if speakers had formulated their own message.

To test agreement in situations in which participants do generate their own messages, I developed a picture description paradigm. Gillespie and Pearlmutter (2011a) had previously used a picture description task in which participants based their subject phrase on two objects presented on a screen. Participants were free in their completion, which may have induced invalid responses. Therefore, in the new description task I constrained participants in their completion by encouraging them to base their completion on the pictures. In Experiment 3 of Chapter 4, participants saw a large colored object and a small gray object and had to describe the color and position of the large object with respect to the small object, eliciting utterances such as *the star next to the circles is blue*.

The picture description task did not show the effects of preposition ambiguity as the completion experiments in Chapter 4 had done. The preposition *with* was

ambiguous between integrated and unintegrated interpretations in the completion experiments (Experiments 1 and 2), whereas in the picture description experiment (Experiment 3) no ambiguity was present because of the pictures. This direct comparison between a completion task and a description task using the same materials suggests that the meaning of subject phrases might be more tightly controlled in a description task than in a completion task. In earlier studies, effects of difficulties with the comprehension of the subject phrase and difficulties in generating agreement might have been confounded. Nevertheless, picture description tasks have limitations as well. Materials are limited to depictable items, which may vary heavily in factors such as frequency, name agreement, or visual complexity.

Another methodological issue that arose in Chapter 4 concerned the lexical variability of stimulus materials. Previous studies have typically used materials that were rich in lexical variability, which yields natural sentences. To get to the core grammatical processes of agreement, however, I eliminated lexical factors. Inspired by nonce-probe tasks (e.g., Berko, 1958; Bybee & Moder, 1983), I used only four nouns that were lexically very simple: *circle*, *star*, *triangle*, and *rectangle.* Results using these materials showed attraction effects both in a forced-choice completion and a picture description task.

In addition to isolating grammatical factors in agreement, the use of lexically-reduced materials opens up the possibility of testing agreement in populations with limited vocabularies, such as children, language learners, and patients. As the subject phrases are based on pictures, it is easy to conduct cross-linguistic studies. In contrast to most sentence completion paradigms, there is no reading involved in the description task. Again, this benefits testing in children, but also speakers with

dyslexia, and low-literates. Further research is needed to validate the paradigm in different populations.

Finally, in Chapter 5, I used a picture description task with slightly more lexical variability while measuring eye movements. The increased lexical variability of the materials was necessary to induce semantic interference from objects that belonged to the same semantic category. The task showed clear semantic interference effects and attraction effects. Ultimately, this task might be preferred over sentence completion tasks because of its finer-grained measures including eye movements and speech onsets. In further research one might use this paradigm to look at the timing of verb planning in more natural situations (e.g., when the adjective that belongs to the first object is actually a characteristic of the picture, and not a separate color box as in the current experiment).

Implications for the Marking and Morphing Model

The Marking and Morphing account (Bock, 2003; Eberhard, Cutting, & Bock, 2005) was the starting point for my thesis work. This account not only predicts agreement error patterns on a theoretical basis, it is also the only account of agreement to date that has been translated into a mathematical model that yields quantitative predictions. Over the course of this thesis, however, it became clear that the model could not account for all results I have found. Here I will discuss how the model accounts for the current findings of notional number, attraction that is not always asymmetrical, and task effects, as well as offering suggestions about how the model might be adapted to account for these results.

The Marking and Morphing model predicts the proportion of plural verbs, taking into account the number specifications of the different constituents in a subject

phrase, using $S(r) = S(n) + \sum_j w_j \times S(m_j)$. In this formula, S($r$) is the root number of the subject phrase, which is calculated by adding the notional number S(n) to the weighted grammatical number of a head and local noun. How much the number specifications S(m) of the head noun and the local noun contribute to the overall number specification is determined by their respective weights w: $[w_H \times S(m_H)] + [w_L \times S(m_L)]$. The numbers of the head and local nouns are controlled for the frequency of their singular and plural forms, by $S(m) = Specification \times \frac{log_{10}(frequency_{singular} + frequency_{plural})}{log_{10}(frequency_{plural})}$. The eventual number of the subject phrase $S(r)$ predicts the proportion of plural verbs through the transformation $\frac{1}{\{1-[S(r)-3.42]\}}$, in which -3.42 is a free parameter to make sure that there is a bias towards singular.

Following studies that did not find attraction after plural heads, plural marking was set to 1 and default singular marking to 0 (e.g., Bock & Cutting, 1992; Bock & Miller, 1991; Eberhard, 1997). The values for the weighting of the head and local nouns were set to be able to account for results from 17 agreement studies. The best fit was found with a weighting for the head noun of 18.31 and for the local noun of 1.39. The head noun is weighted much more heavily than the local noun, emphasizing the strong influence of the grammatical number of the head noun, which is most typically the subject of a sentence that drives verb agreement.

The present studies suggested that the notional number of a subject phrase can be influenced by the degree of semantic integration between the head and local noun. The Marking and Morphing model accounts for the additive effect of notional number when it reconciles the notional number with the grammatical number in the marking

stage. If the notional number is plural, but the grammatical number is singular, there is an increased risk of producing a plural verb. The model predicts additive effects of notional number and grammatical local noun number because the notional number S(n) is simply added to the weighted sum of grammatical properties of the nouns in the subject phrase: $S(n) + \sum_j w_j \times S(m_j)$. This independence of notional and grammatical effects was supported by the lack of Integration by Local Noun Number interactions in Chapters 2 and 3, and by the findings in Chapter 3 that the notional effects can be boosted while the attraction effect remained constant in Chapter 3.

The model is less successful, however, in accounting for the attraction patterns found in some of the current experiments. Specifically, the asymmetry of attraction predicted by the model was not always observed. A strict interpretation of the Marking and Morphing model does not predict any errors after plural heads, as they are already specified for number. In terms of the Marking and Morphing equations, a number specification that has a value of 1 (i.e., marked plural) will never turn into a 0 (i.e., unmarked singular) when a 0 is added. In contrast to this prediction, I found evidence for errors after plural heads combined with singular local nouns in each experiment that included plural head conditions. However, the magnitude of the attraction for plural heads varied (see Figure 1).

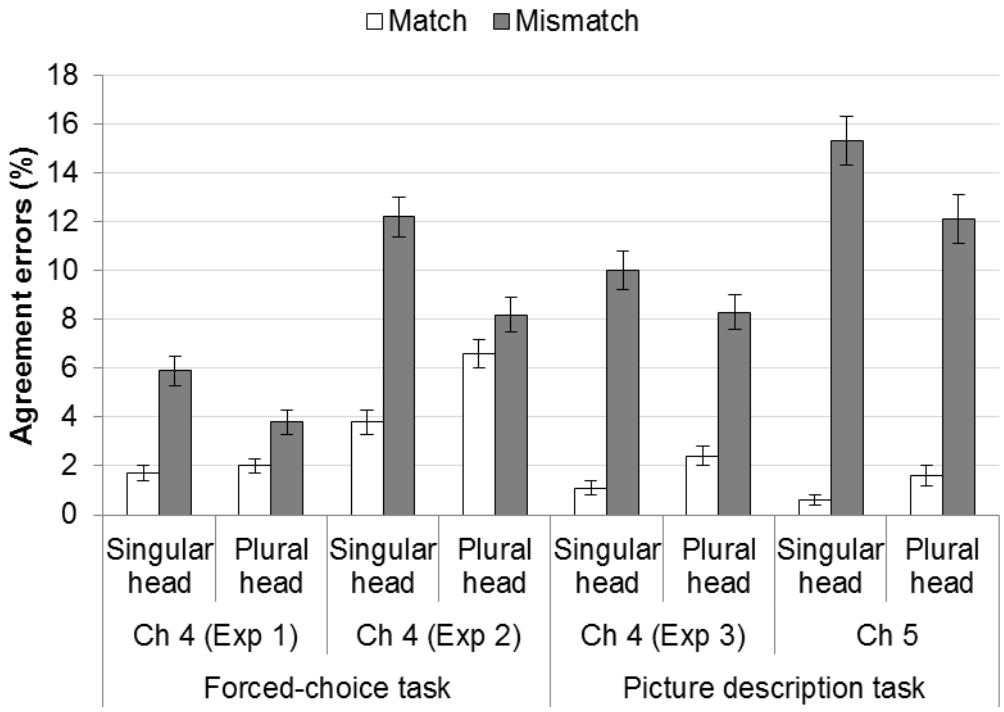


Figure 1. Attraction after singular and plural heads in Chapter 4 (Experiments 1, 2, and 3) and Chapter 5. Error bars represent *SE* from the mean across participants.

These results raise a question about the conditions under which attraction from singular local nouns for plural heads can occur. To investigate these conditions, I ran a number of model simulations (see Figure 2). Note that my intention in running these simulations was not to falsify the Marking and Morphing model, but rather to determine which configuration of parameters would predict attraction patterns similar to the current studies. These parameter changes have theoretical implications for the generation of agreement, and are discussed below. Each simulation was bound by two assumptions. First, based on grammatical theory, the head noun is more important in controlling agreement than the local noun, and should therefore outweigh the local noun. Second, based on previous and the current studies, the attraction effect for singular heads should be stronger than for plural heads with mismatching local nouns.

Each simulation yielded a percentage of agreement errors in each condition. The model is designed to predict the proportion of plural verbs. For the plural head

conditions, I converted the proportion of plural verbs to agreement errors (thus, proportion of singular verbs) by subtracting the proportion of plural verbs from 1. Figure 2 shows examples from the simulations and Table 1 shows the parameter values of these simulations.

Using the original parameters from the Eberhard et al. (2005) paper, the Marking and Morphing model does not predict any agreement errors after plural heads, as the left panel in Figure 2 shows. The predicted error rates are relatively low due to the fact that the head noun number is weighted more strongly than the local noun number (18.31 versus 1.39). The asymmetrical attraction patterns found in earlier studies are achieved with a singular value of 0 and a plural value of 1. The present results, however, were not consistent with such a pattern.

It might be that the context of the current experiments, which had materials that were reduced in lexical variability and included picture description tasks, increased the influence from the local noun. Therefore, in the first simulation, I changed the weight of local noun, while keeping the weight of the head noun constant. The local noun weight was originally 1.39. To simulate increased weighting of the local noun, a series of simulations were run where the local noun weight was increased in steps of 2 up to the point before it would exceed the head noun weight (i.e., 17.39). For each of the steps, 0% agreement errors were predicted for plural head nouns combined with singular local nouns (see Figure 2). This comes from the fact that even though the weighting of the local noun increased, it was always multiplied by zero, and a zero marking does not yield attraction. The error rates for the singular heads combined with plural local nouns were extreme: from a weighting of 9.39 onwards, 100% errors were predicted. The pattern of errors generated by this model simulation clearly does not pattern according to the results in this thesis. Therefore, it

seems unlikely that the plural head attraction was simply driven by an increased importance of the local noun number.

For attraction to occur, two requirements must be met: (1) there must be a local noun that is capable of exerting attraction and (2) there must be a head noun that is vulnerable to attraction. Changing the weight of the local noun did not increase attraction for plural heads. Thus, in a second simulation I investigated whether decreasing the weight of the head noun might drive the current patterns of attraction instead. In the second simulation the head noun weight was decreased in steps of 2, beginning at the original weighting of 18.31. To preserve the rule that the head noun typically controls number agreement, only values which exceeded the local noun value of 1.39 were included (16.31 to 2.31). The steps up to 6.31 predicted 0% errors for plural heads combined with singular local nouns. At 6.31, 2% errors were predicted, whereas at 4.31, 13.1% agreement errors were predicted. However, this error rate for plural heads was higher than the 11.6% predicted for singular heads, which does not adhere to an attraction asymmetry. Finally, going down to a head noun value of 2.31, this yielded at least 30% errors in all conditions, including the matching conditions, where one would not typically predict agreement errors. This is not a likely scenario either. The head noun weight of 6.31 yielded a very small attraction effect for plural heads, see Figure 2. Given that singular marking in these models is still 0, this begs the question of where singular attraction might come from. The answer lies in the constant parameter that biases the model to produce singular verbs, and not in a number mismatch effect. The current results however, strongly suggest that agreement errors in plural head conditions were due to attraction, and not to a singular bias, as error rates up to 12% were observed in the experiments.

As discussed in the section above, another possible explanation for singular attraction is that singulars might actually be more marked than previously assumed. A marked singular local noun would necessarily be more capable of exerting attraction than an unmarked singular local noun given that the latter is set to 0 in the original model. In addition, a slightly less marked plural head noun might be more vulnerable to attraction than a fully marked plural head noun. Therefore, in Simulation 3, I simulated all number values of the head and local noun from -1 to 1 with steps of 0.1 using the original weightings of head and local noun (see Table 1). Plural heads ranged from values of 0.5 to 1. Values above 0.5 were chosen here because they are mainly plural, whereas lower values would indicate the rather unlikely situation where plural marking is closer to singular zero. These plural marking values were combined with every value for singular local nouns ranging from 0 to -1. These configurations of parameters yielded only 0% to 0.5% agreement errors in the plural head condition. An example simulation where singulars were marked -0.2 and plurals 0.8 is provided in Figure 2 and shows that hardly any errors were predicted. The reason for this error pattern lies in the strong weighting of the head noun, which is not vulnerable to attraction from weakly marked local nouns. This pattern of results suggests that when the head noun is weighted so strongly, changing the marking values of singular and plural nouns alone does not affect the likelihood of attraction for plural heads

The results of the above simulation thus suggest that in order for singular marking to lead to attraction for plural heads, the weighting parameters might need to be changed as well. It is conceivable, for instance, that in some circumstances the singular marking is increased and the head noun weight is decreased, which may lead to attraction after plural heads. Therefore, Simulation 4 combined the adaptations from Simulation 2 and 3. This simulation was not designed to exhaustively search all

possible configurations of parameters. Instead, it simply serves to illustrate that under certain circumstances, attraction for plural heads can occur. The requirements for this simulation based on the literature were that the head noun number would be weighted stronger than the local noun number and that there would be an asymmetry in the attraction effect. As can be seen in Figure 2, when the head noun number is weighted 6.31, the local noun number is weighted 1.39, singulars are marked -0.1, and plurals are marked 0.9, a pattern arises in which plural heads show an attraction effect, and importantly, this effect is weaker than the attraction effect for singular heads.

Table 1
Model Parameters for the Model Simulations depicted in Figure 2

Model	W_H	W_L	Marking Plural	Marking Singular
Original model	18.31	1.39	1	0
Simulation 1	18.31	9.39	1	0
Simulation 2	6.31	1.39	1	0
Simulation 3	18.31	1.39	0.8	-0.2
Simulation 4	6.31	1.39	0.9	-0.1

Note. The contrastive frequency was not modeled, because this was counterbalanced across conditions in the current experiments.

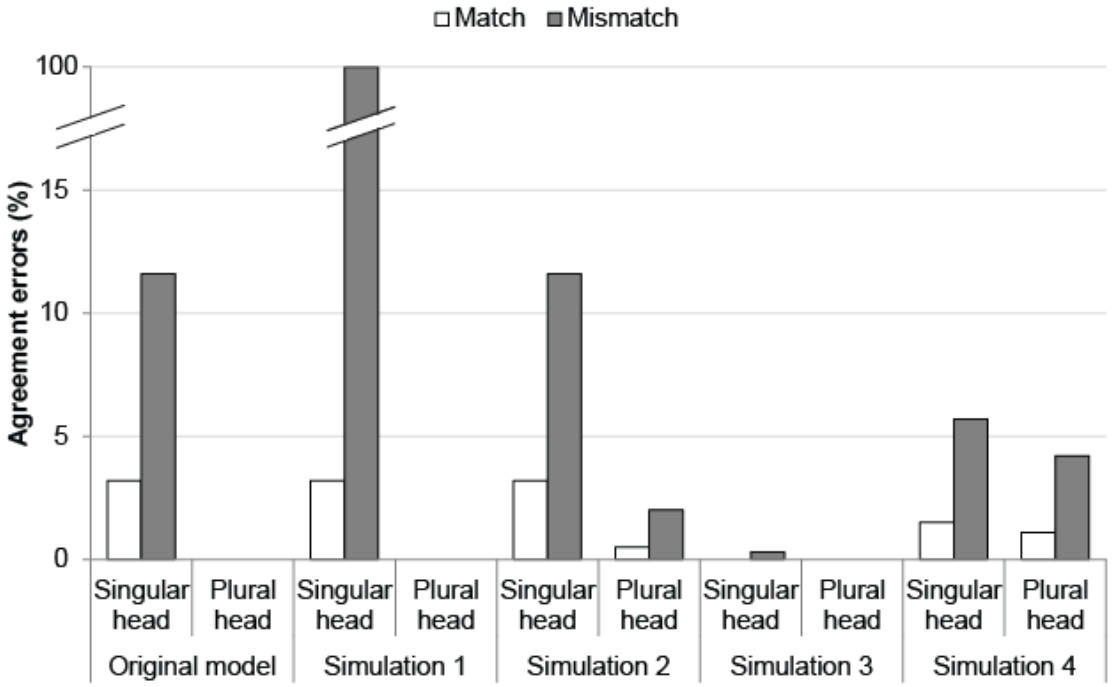


Figure 2. Predicted error rates following the model simulations. Simulation 1 increased the local noun weight; Simulation 2 decreased the head noun weight; Simulation 3 varied number marking; Simulation 4 varied both head noun weight and number marking.

To summarize, in Simulation 1 only the local noun weight was increased, which did not yield attraction for plural heads. In Simulation 2, only the head noun weight was decreased, which yielded very low error rates, due to the singular bias in the model, but not due to attraction. In Simulation 3, the number marking was varied, but did not yield any attraction for plural heads, because of the strong weighting of the head noun. Finally, in Simulation 4, both the head noun weight and the plural marking were decreased and the singular marking increased. This yielded a pattern similar to the results in the current studies. The combination of results across these simulations demonstrates that the influence of local nouns and marking of singulars might be variable in natural language production. One way in which the Marking and Morphing model could account for the flexibility in relative head and local noun number weighting would be to add a parameter that changes the relative weighting depending contextual factors. This has implications for theories of agreement production.

Natural language production occurs in many different contexts. For instance, speakers may be given sufficient time to prepare their utterance, or might need to have to trade accuracy for speed. In some contexts the referents for the local nouns are more salient than in others. The results in this thesis suggest that the computation of number for subject-verb agreement is likely to be more flexible than previously theorized. Similarly, the simulations in this section show that the relative influence from head and local nouns may be flexible. Additionally, the simulations support the suggestion made in Chapter 4 that singulars might be more marked than assumed by the Marking and Morphing model. Again, this marking might depend on context, or might be fixed but vary between different languages. Further research is needed to disentangle the exact role that task and materials play in the flexibility of generating agreement.

Conclusions

Generating subject-verb agreement is a complex process. Although the grammatical rule is clear, speakers do make occasional agreement errors. Studies on agreement have tried to locate the different factors triggering agreement errors, often using sentence completion tasks. In this thesis, new methods for assessing agreement have been developed which may be suitable for testing a wide range of populations, and future research should be conducted to validate these measures. The studies reported in this thesis contributed to a deeper understanding of the factors that trigger agreement errors, having provided evidence for notional number effects and against effects of parallel planning. One important conclusion drawn from this thesis is that the computation of number for subject-verb agreement is greatly dependent on the context in which agreement is generated.

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Nederlandse Samenvatting

In het Nederlands is het gebruikelijk dat het getal van het finiete werkwoord (enkelvoud of meervoud) overeenkomt met het getal van het onderwerp in de zin. De grammaticale regel is eenvoudig: een enkelvoudig onderwerp gaat samen met een enkelvoudig werkwoord en een meervoudig onderwerp gaat samen met een meervoudig werkwoord. We passen deze regel toe in bijna elke zin die we produceren en vaak zonder er bij na te denken. Toch komt het af en toe voor dat een werkwoord niet hetzelfde getal heeft als het onderwerp en maken we een congruentiefoutje.

Het is erg onwaarschijnlijk dat deze congruentiefouten het gevolg zijn van het even vergeten van de grammaticale regel. In mijn promotieonderzoek ben ik op zoek gegaan naar de oorzaak van congruentiefouten. Bock en Miller (1991) merkten eerder al op dat het vaak mis gaat als er twee nomina met een verschillend getal voorkomen in het onderwerp, zoals in **de tekening van de bloemen zijn mooi*. In dit soort zinnen met meerdere nomina is het wenselijk dat het hoofdnomen *tekening* in overeenstemming is met het werkwoord, en niet het plaatselijke nomen *bloemen*, waardoor het werkwoord dus een enkelvoudsvorm zou moeten krijgen. Gebeurt dit niet, en wordt ten onrechte de meervoudsvorm van het plaatselijke nomen in het werkwoord overgenomen, dan spreken we van ‘attractie’.

In hoofdstuk 2 werd getest of het congruentieproces alleen gevoelig is voor grammaticale factoren, zoals het meervoudige plaatselijke nomen, of ook voor semantische factoren, zoals semantische integratie. Semantische integratie tussen twee nomina is wellicht van belang, omdat het het conceptuele getal van een onderwerp

beïnvloedt. Het conceptuele getal van een onderwerp kan verschillen van het grammaticale getal. Een voorbeeld hiervan is *meubilair*, dat grammaticaal enkelvoudig is, maar conceptueel meervoudig. In *de tekening van de bloemen* zijn de twee nomina zeer geïntegreerd, de bloemen maken immers deel uit van de tekening. Hierdoor refereert het gehele onderwerp naar één voorwerp en is het daardoor conceptueel enkelvoudig. Echter, in een onderwerp als *de tekening naast de bloemen*, zijn de nomina niet geïntegreerd en refereren zij naar twee of meer verschillende voorwerpen. Nu bestaat de kans dat sprekers het onderwerp interpreteren als conceptueel meervoudig. In dit laatste geval, wanneer een onderwerp grammaticaal enkelvoudig is, maar conceptueel meervoudig, kan er ook een soort attractie ontstaan.

Om te onderzoeken of zowel grammaticale als semantische factoren het congruentieproces beïnvloeden, werden er twee verschillende aanvultaken uitgevoerd. In het eerste experiment lazen proefpersonen een zinsfragment, een enkelvoudig onderwerp zoals *de tekening van de bloemen*, waarna zij een gesproken vervolg van de zin moesten produceren, zoals *is mooi*. In het tweede experiment lazen nieuwe proefpersonen een onderwerp (dezelfde als in experiment 1) en konden zij door middel van twee knoppen aangeven of ze de voorkeur hadden voor een vervolg met een enkelvoudig werkwoord of een meervoudig werkwoord. In beide taken werden congruentiefouten en reactietijden gemeten. Er werden meer fouten gemaakt en er werd langer gewacht met antwoorden wanneer het hoofdnomen en het plaatselijke nomen verschilden in getal. Onafhankelijk van dit grammaticale effect, waren de foutpercentages ook hoger en reactietijden langer wanneer het onderwerp ongeïntegreerd was (en het conceptuele meervoud dus verschilde in getal van het grammaticale enkelvoud). Deze resultaten laten zien dat het congruentieproces gevoelig is voor zowel grammaticale als semantische factoren. Deze factoren hebben

onafhankelijk van elkaar invloed op het aantal congruentiefouten en de tijd die nodig is om de congruentie uit te voeren.

In hoofdstuk 3 werd de onafhankelijkheid van de grammaticale en semantische factoren verder onderzocht. Eén groep proefpersonen deed een aanvultaak waarbij zij een plaatje van een onderwerp zagen en tegelijkertijd een gesproken versie van het onderwerp hoorden. Na afloop konden zij door op één van twee knoppen te drukken aangeven of zij de zin met een enkelvoudig werkwoord of een meervoudig werkwoord aan wilden vullen. Een andere groep proefpersonen onderging hetzelfde experiment met als enige verschil dat zij geen plaatjes zagen, maar alleen het voorgelezen onderwerp hoorden. Uit de resultaten bleek dat de aanwezigheid van visuele stimuli tot meer semantisch gerelateerde congruentiefouten leidde, terwijl het aantal grammaticaal gerelateerde congruentiefouten hetzelfde bleef. Deze uitkomst bevestigt de onafhankelijkheid van de grammaticale en semantische factoren, maar benadrukt ook dat de invloed van bepaalde factoren experimenteel versterkt kunnen worden.

In hoofdstuk 4 heb ik een congruentietaak te ontwikkeld die meer op spontane taalproductie lijkt dan de gebruikelijke aanvultaken. In de gebruikelijke aanvultaken krijgen proefpersonen een onderwerp aangeboden die eerst begrepen moet worden (door middel van luisteren of lezen) en vervolgens vanuit het werkgeheugen herhaald moet worden. Behalve dat de prestaties op deze taak afhankelijk zijn van de begripsvaardigheid en het werkgeheugen van de spreker, wordt ook de gehele fase van het formuleren van een boodschap, de eerste fase in het spraakproductieproces, overgeslagen. Ik onderzocht of de foutenpatronen die gevonden waren met aanvultaken, konden worden gerepliceerd met een meer natuurlijke taak.

In de nieuwe beschrijftaak beschreven proefpersonen eenvoudige plaatjes, wat zinnen opleverde als *de cirkel naast de sterren is rood*. Ook met deze nieuwe taak werden patronen van attractie in de congruentiefouten gevonden. Twee aanvultaken waarin dezelfde onderwerpen werden gebruikt (hier lazen proefpersonen zinsfragmenten als *de cirkel naast de sterren* en maakten zij deze af door middel van een druk op de knoppen) lieten hetzelfde patroon zien en bevestigden daarmee dat een beschrijftaak ook geschikt is om congruentie mee te testen. Verder maakten de resultaten in dit hoofdstuk duidelijk dat er in de aanvultaak meer ruimte is voor ambigue interpretaties van het onderwerp dan in de beschrijftaak, en dat congruentiefouten ook voorkomen als een meervoudig hoofdnomen gecombineerd wordt met een enkelvoudig plaatselijk nomen. Dit laatste is verrassend, omdat men op basis van de bestaande literatuur zou verwachten dat hoofdnomina in de meervoudsvorm minder gevoelig zijn voor attractie vanwege de gemarkeerdheid van het meervoud. Het voordeel van de beschrijftaak is dat er geen kant-en-klaar onderwerp aangeboden hoeft te worden, waardoor proefpersonen geen woorden hoeven te lezen of te onthouden voordat ze aan hun aan hun productie beginnen. Een dergelijke taak biedt de mogelijkheid om congruentie in diverse populaties te onderzoeken, zoals kinderen, laaggeletterden of patiënten.

In hoofdstuk 5 werd opnieuw een beschrijftaak ontwikkeld, dit keer om het effect van spraakplanning op congruentie te onderzoeken. De Planning Hypothese van Pearlmutter en collega's (Gillespie & Pearlmutter, 2011b; Solomon & Pearlmutter, 2004) voorspelt dat wanneer een hoofdnomen en een plaatstelijk nomen met een ander getal tegelijkertijd gepland worden, er meer congruentiefouten ontstaan dan wanneer deze nomina één voor één worden gepland. Proefpersonen beschreven plaatjes door middel van zinnen als *de appel naast de peren is blauw*. Door het meten

van oogbewegingen werd vastgesteld dat proefpersonen bij plaatjes die dicht bij elkaar geplaatst waren, het onderwerp in één keer—dus het hoofdnomen en het plaatselijke nomen tegelijk—planden, voordat ze begonnen met hun productie. Wanneer de plaatjes verder uit elkaar geplaatst waren, werd het onderwerp vaker in gedeeltes gepland, dus woord voor woord. In tegenstelling tot de voorspellingen van de Planning Hypothese maakten proefpersonen niet méér congruentiefouten wanneer zij het onderwerp in één keer planden, dan wanneer zij het onderwerp in gedeeltes planden. Het lijkt er dus op dat congruentiefouten pas ontstaan wanneer het werkwoord gepland wordt, en niet wanneer het onderwerp van de zin gepland wordt.

Tot slot werd in hoofdstuk 6 onderzocht in hoeverre de resultaten uit dit onderzoek verklaard kunnen worden met behulp van het Marking & Morphing model (Eberhard, Cutting, & Bock, 2005). Dit computationele model voorspelt het aantal congruentiefouten aan de hand van de verschillende getallen van de nomina in een onderwerp. Het model is in staat om de effecten van semantische integratie te voorspellen door de waarden van het conceptuele getal (geïntegreerd is conceptueel eenvoudig en ongeïntegreerd is conceptueel meervoudig) aan te passen. Het model voorspelt echter geen congrentiefouten na meervoudige hoofdnomina, terwijl deze wel gevonden werden in hoofdstukken 4 en 5. Door de gemarkeerdheid van de meervoudsvorm af te zwakken en de invloed van het plaatselijke nomen te versterken, kan het model ook attractie na meervoudige hoofdnomina voorspellen.

De resultaten in dit onderzoek laten zien dat de productie van werkwoordscongruentie niet zo eenvoudig is als dat het lijkt. Het proces wordt bemoeilijkt door verschillende factoren, maar gelukkig zijn we ons van de meeste niet bewust.

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(Bowie, 1972)

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Curriculum Vitae

Alma Veenstra was born in 1984 in Giekerk, Tietjerksteradeel. After obtaining her Gymnasium diploma in 2002, she started studying Psychology at the University of Groningen. After two years she switched to English Language and Culture, for which she received her BA in 2008. Having taken up a passion for experimental linguistics and language acquisition, she continued to do an MA in Applied Linguistics (on referring expressions in L2 learners) and a research MA in Linguistics (on the acquisition of implicatures) in Groningen. At the end of 2009 she did an internship at the University of Cambridge to work with Napoleon Katsos. Alma's ReMA degree was awarded cum laude in 2010. Later that year, she started her PhD project at the Max Planck Institute in the Psychology of Language department with Antje Meyer and Dan Acheson, to study the production of subject-verb agreement.

Publications

Veenstra, A., & Acheson, D. J. (2014). *Boosting the notional number effect in the production of subject-verb agreement*. Manuscript in preparation.

Veenstra, A., Acheson, D. J., & Meyer, A. S (2014). *Subject-verb agreement in a lexically-reduced context: A tool for assessing grammatical attraction.* Manuscript in preparation.

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