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Distinct Mechanisms Underlie Attraction Errors and Agreement with Coordination

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**DISTINCT MECHANISMS UNDERLIE ATTRACTION ERRORS
AND VARIABLE AGREEMENT WITH COORDINATION**

A Thesis Presented

by

LAP-CHING KEUNG

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ABSTRACT

DISTINCT MECHANISMS UNDERLIE ATTRACTION ERRORS AND VARIABLE AGREEMENT WITH COORDINATION

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Previous research has suggested that attraction errors are not due to the proximity of the local noun and verb, as a more distant local noun can result in more errors than a nearer one (e.g., **The helicopter for the flights over the canyon are* vs. **The helicopter for the flight over the canyons are*; Franck, Vigliocco, & Nicol, 2002). However, the verb tends to agree in number with the nearer noun of a disjoined subject, suggesting that linear order can indeed play a role in agreement computation (e.g., *The horse or the clocks are* vs. *The horses or the clock is*; Haskell & MacDonald, 2005). In the present study, two experiments using a two-alternative forced-choice production paradigm and one experiment using eyetracking during reading directly compared agreement computation in the classic attraction configuration and when the subject is a coordinate phrase. The 2AFC experiments replicated both the lack of a linear distance effect in classic attraction and the presence of a linear order effect in disjunction agreement, which was also extended to conjunction agreement; when the second conjunct was singular, subjects frequently selected a singular verb. This order effect was also modulated by the presence or absence of additional material between the subject and verb. In the eyetracking experiment, a singular second conjunct both facilitated processing of a singular verb and inhibited processing of a plural verb. These results suggest that variable agreement with coordinate subjects is not a form of agreement attraction and that distinct theoretical treatments are required for two distinct phenomena.

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CHAPTER 1

INTRODUCTION

Agreement is a syntactic phenomenon whereby one word (or phrase) in the sentence controls the morphological form that another word (or phrase) can take. A well-studied example in English involves grammatical number agreement between subject and verb. In the most basic sense, a singular noun in subject position (commonly termed the *controller*) must co-occur with a singular verb (the *target*) like in (1), and a plural subject must co-occur with a plural verb like in (2).

(1) The key is rusty.

(2) The keys are rusty.

Despite how quickly and effortlessly language users compute number agreement, they still produce errors like in (3).

(3) *The key to the locks are rusty.

Over the past couple of decades, much psycholinguistic work has focused on exploring the factors underlying such agreement behavior. In (3), the presence of the plural local noun (*locks*, also called an *attractor*) intervening between the singular controller (*key*) and target (*be*) elicits errors in production (e.g., Bock & Eberhard, 1993; Bock & Miller, 1991; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996) and makes an ungrammatical verb less salient in comprehension (e.g., Pearlmutter, Garnsey, & Bock, 1999; Wagers, Lau, & Phillips, 2009). One important and counterintuitive finding is that attraction errors arise not when the local noun is linearly close to the target verb, but when the local noun is hierarchically close to the controller. Franck, Vigliocco, and Nicol (2002) showed that errors like (4a) occur more often than errors like (4b), despite the local noun *canyons* being linearly closer to the verb.

(4) a. *The helicopter for the flights over the canyon are safe.

b. *The helicopter for the flight over the canyons are safe.

A related, but not as well-studied (at least in psycholinguistics), type of variable agreement behavior occurs with coordinate structures. Here, we use “coordination” to refer to structures with

and, or, but, etc., “disjunction” to refer to structures with *or* (denoted by |), and “conjunction” to refer to structures with *and* (denoted by &). Haskell and MacDonald (2005) found that, with disjunctions, speakers strongly prefer the verb form that agrees in number with the closer disjunct. If the verb occurs after the subject like in (5), then it tends to agree with the second disjunct, but if it occurs before the subject like in (6), then it tends to agree with the first one.

(5) The horses or the clock is red.

(6) Are the horses or the clock red?

This preference was taken as evidence that linear order does play a role in computing number agreement. This, however, is simply a preference and not a clear rule, as some grammar handbooks (e.g., Fowler & Aaron, 2007) instruct the user to appeal to “awkwardness” when determining proper agreement, particularly in the case of plur|sing preverbal disjuncts, as illustrated in (7). If the singular verb sounds awkward, then reorder the disjuncts so as to make it sing|plur with plural agreement. Errors, then, as characterized by Haskell and MacDonald (2005), are constructions like in (8) in which the verb form does not agree with the closer disjunct. Such “errors” are considerably more common in the case of plur|sing disjuncts, but it is unclear whether they are true errors or whether they reflect grammatical differences between speakers.

(7) ?The horses or the clock is red. => The clock or the horses are red.

(8) *The horses or the clock are red.

Haskell and MacDonald’s (2005) account of variable agreement with disjunction, that it is sensitive to linear order, assumes that this phenomenon and classic agreement attraction are two manifestations of the same underlying mechanism of agreement computation. This is an assumption that we directly address in the present study. We further investigate these two phenomena, along with a previously neglected phenomenon (though see Lorimor, 2007), namely, variable agreement with conjunction, where there is a clear agreement rule: A plural verb is almost always required¹,

¹ Fowler and Aaron (2007) list one exception to the “and-requires-plural-agreement” rule: “When the parts of the subject form a single idea or refer to a single person or thing, they take a singular verb” (p. 307).

regardless of the grammatical number of the conjuncts, as illustrated in (9) and (10). It is unlikely that the number feature comes from only the individual conjuncts, given that two singular conjuncts most often require a plural verb (Gleitman, 1965). Although outside the scope of this thesis, it has been proposed that the plural number feature comes from notional plurality and semantic number resolution (Farkas & Zec, 1995; Johannessen, 1998), from the “and” itself or from the structure of the phrase as a whole (Soltan, 2007), or from a null appositive-like marker that restates the subject, e.g., *The horse and the clock, (they) are red* (Citko, 2004). Errors, then, as stated in most grammar handbooks (e.g., Fowler & Aaron, 2007), are constructions like in (11) in which the verb form is singular. Lorimor (2007) showed that such errors are considerably more common when the second/closer conjunct is singular, a finding that the present work replicates and extends. To preview, we will show that a singular second conjunct behaves like a plural attractor: Both are number-mismatching nouns that immediately precede the verb, eliciting the wrong form in production or making illicit agreement less salient in comprehension. However, on the basis of data from both production and comprehension experiments, we will claim that variable agreement with coordination is in fact theoretically distinct from classic agreement attraction.

(9) The horse and the clock are red.

(10) The horse and the clocks are red.

(11) *The horse and the clock is red.

In this thesis, we directly investigate whether these two phenomena, classic agreement attraction and variable agreement with coordination, reflect similar or different underlying causes. We report three experiments (two production, one comprehension) that reveal a number of qualitative differences and discuss whether existing accounts of agreement attraction can be

Depending on the referent(s), a subject phrase such as *The psychologist and the linguist* can take singular agreement if the psychologist is also the linguist (although the presence of the second determiner might make that reading less accessible), but it can also take plural agreement if it refers to two distinct people. Similarly, *bacon and eggs* takes singular agreement when referring to the breakfast dish as a unit. These are cases of semantic agreement.

extended to explain the effects observed with coordination. In the end, we present a single controller mis-retrieval mechanism that can account for the effects observed in both configurations, as long as we make appropriate assumptions about the representation of number on a coordinate phrase.

Section 1.1 summarizes the effects that linear distance (adjacency), hierarchical structure, and linear order have on agreement computation. The first difference between the two phenomena is revealed here: Agreement attraction is sensitive to hierarchy, while agreement with coordination is sensitive to linear order (and linear order as observed in Experiment 1b). Much of the current literature suggests that attraction arises not because the local noun is linearly close to the target, but because the local noun is hierarchically close to the controller (e.g., Franck, Vigliocco, & Nicol, 2002). Section 1.2, however, describes one case in English where a noun that is linearly close to the verb does control agreement: when part of a disjunction (Haskell & MacDonald, 2005). In the present work, we extend this finding to conjunctions as well. This question is important because in the case of conjunction, as opposed to disjunction, there is a clear agreement rule. If the effect of linear order emerges only when the subject is a disjunction, this would suggest that the phenomenon is likely due simply to the lack of grammatical clarity. On the other hand, if the phenomenon is also present with conjoined subjects, this would suggest that it is the structure of coordinate phrases, how number is represented in these phrases, or some combination of these factors that gives rise to this sensitivity to the number of the closer noun.

Sections 2-4 report three experiments designed to directly compare the two phenomena, classic agreement attraction on the one hand, and variable agreement with coordinate subjects on the other. Experiment 1 (Section 2) has two goals. The first is to assess the reliability of both the Franck et al. (2002) and Haskell and MacDonald (2005) results. This experiment tested the same manipulations used in these previous studies, but in the two-alternative forced-choice production paradigm developed by Staub (2009, 2010). In this paradigm, participants do not verbally produce a sentence, but instead select a verb form with a button press to continue a sentence displayed word-by-word using rapid serial visual presentation (RSVP; Potter, 1984). Independent studies (e.g. by

Veenstra, Acheson, Bock, & Meyer, 2014) have validated this paradigm as replicating production results. One motivation for using this paradigm is the ability to collect response times (RTs), which is important for Experiment 2. The second and third goals are theoretical: To distinguish the effect of linear distance between a noun and target from the effect of linear order of potential controller nouns, and to assess whether effects of linearity on agreement with disjointed subjects also hold with conjoined subjects. Experiment 2 (Section 3) again uses Staub's production paradigm to directly compare a plural attractor to a singular conjunct. Both are found to increase overall error rates as well as RTs on trials on which the correct verb form is chosen. We then fit the correct RTs to the ex-Gaussian distribution in order to assess the scope of their effects, i.e., whether increased RT is due to interference on a subset of trials or on all trials. Lastly, Experiment 3 (Section 4) uses an eyetracking while reading paradigm to directly compare a singular attractor to a singular second conjunct. The latter not only makes an ungrammatical verb seem less salient in comprehension, but also makes a grammatical verb seem ungrammatical. This symmetric effect on grammaticality has not been reported in attraction (Wagers et al., 2009).

Section 5 then describes two dominant accounts of classic agreement attraction – *feature mis-valuation* (by means of feature percolation (Franck et al., 2002) and marking and morphing (Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001)) and *controller mis-retrieval* (Wagers et al., 2009) – and discusses whether they can also account for variable agreement with coordination (mainly conjunction, which has a clear agreement rule, unlike disjunction). Feature mis-valuation asserts that the representation of a controller's singular number can be overwritten/morphed by a local noun's plural feature. To explain the mismatch asymmetry, in which a singular local noun does not overwrite a plural controller, theorists have appealed to a markedness asymmetry: A singular noun has no number feature, and so it cannot interfere with agreement computation. The second difference between the two phenomena is revealed here: Agreement attraction is driven by a plural local noun, while variable agreement with conjunction is driven by a singular second conjunct. While feature mis-valuation does not easily extend to the latter, we believe that controller

mis-retrieval does. We make additional claims not about the mechanism, but about the representation of number (or lack thereof) on a conjoined subject phrase. To preview, we follow Farkas and Zec (1995) who proposed that it is syntactically undefined for number, and that it must acquire its number feature from semantics. Variable agreement then arises when syntactic agreement occurs with an individual conjunct instead of semantic agreement with the entire subject phrase. Such a theoretical account, together with a retrieval-based mechanism, would explain the coordination effects observed in both production and comprehension.

Section 6 concludes.

1.1. Hierarchical relations in classic agreement attraction

One intuitive explanation for classic attraction effects emphasizes the linear distance between the controller and target. This was first proposed by Jespersen (1924, p. 345), who wrote that “if the verb comes long after the noun, there is no more mental energy left to remember what was the number of the subject.” Franck et al. (2002) suggested a more articulated linear distance hypothesis that also takes into account the linear distance between the local noun and target. Under this account, one might expect errors like (4b), in which the local noun *canyons* is linearly next to the target, to occur more often than errors like (4a), in which the local noun *flights* is linearly more distant. Franck et al. (2002) showed the opposite to be true: The local noun more distant from the target is the stronger attractor. Franck et al. (2002) rejected the linear distance hypothesis in favor of a hypothesis based on syntactic hierarchy. This hypothesis asserts that attraction effects are strong when the local noun is hierarchically close to the controller in terms of the number of syntactic nodes that intervene (see also Eberhard, Cutting, & Bock, 2005; cf. Gillespie & Pearlmutter, 2011, 2013).

Franck et al.’s (2002) results, however, do not arbitrate between accounts emphasizing hierarchical or linear distance between the local noun and controller. The local noun *flights* in (4a) may elicit more attraction errors simply because it is linearly closer to the controller than the local noun *canyons* in (4b) is. Evidence against this view comes from Bock and colleagues. The

adjectives in (12) increase the linear distance between the local noun and controller, but have little influence on the attractor strength of the local noun, as errors like (12) occur just as often as errors like (3) (Bock & Cutting, 1992; Bock & Miller, 1991). Thus, it appears that neither linear distance between the local noun and target, nor linear distance between the local noun and controller, can account for attraction effects.

(12) *The key to the ornate Victorian cabinets are rusty.

However, the local noun in the embedded relative clause in (13) and the local noun in the complement clause in (14) are as linearly far from the controller as is the local noun within the prepositional phrase in (12), but because they are syntactically more deeply embedded, errors like (13) and (14) do occur less often than errors like (12) (Bock & Cutting, 1992; Bock & Miller, 1991; see also Nicol, 1995).

(13) *The mechanic who repaired the tires are getting tired.

(14) *The report that they controlled the fires are accurate.

Moreover, attraction can arise even when the attractor does not linearly intervene between the controller and target, as in errors like (15) and (16) (Bock & Miller, 1991; Staub, 2010; Vigliocco & Nicol, 1998), suggesting that linear intervention is not even necessary for attraction errors.

(15) *The cabinets that the key open are on the second floor.

(16) *Are the helicopter for the flights safe?

Taken together, these findings suggest that the local noun's syntactic distance to the controller matters in determining its strength as an attractor, while its linear distance to either the controller or target does not. Across these studies, however, the role of linear distance between the local noun and target has not been fully investigated. Franck et al.'s (2002) results suggest that when two local nouns follow a controller, the first local noun (i.e., the one hierarchically closer to the controller) influences agreement more than the second one. In their study, the first local noun also happens to be more distant from the target, but their design does not address the question of whether linear distance between the local noun and target has an independent effect. A critical

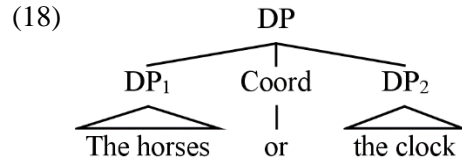
comparison to detect a linear distance effect is given in (17), in which the local noun *flights* varies in its distance from the target. Evidence for such an effect would be observed if the presence of material between the local noun and target – either a second prepositional phrase like in (17a), or material that contains no number information, such as the adverb in (17b) – reduces the strength of the attraction effect relative to a condition in which the local noun and target are adjacent. We investigate this issue in Experiment 1a of the present study.

- (17) a. *The helicopter for the flights over the canyon(s) are safe.
b. *The helicopter for the flights apparently are safe.
c. *The helicopter for the flights are safe.

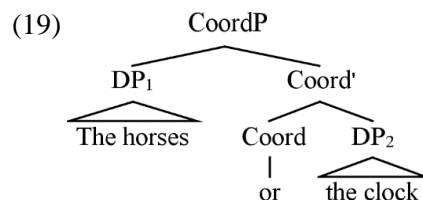
1.2. Linear relations in variable agreement with coordination

An important qualification to the conclusion that the linear order of nouns plays no role in agreement computation comes from Haskell and MacDonald (2005). They suggested that the structural configuration of classic attraction sentences like those used by Franck et al. (2002), in which there is a clear structural hierarchy between the relevant local noun positions, would mask any effect of linear order or distance. Haskell and MacDonald (2005) tested for a linear order effect by using disjoined subjects such as *The horses or the clock*. They assumed a structural representation for disjunction in which the two nouns are hierarchically equidistant from the verb and can be reversed without a change in hierarchical relations, while one of them is linearly closer to the verb than the other. This claim necessarily assumes a flat, symmetric, and multi-headed structure like that in (18) (e.g., Lakoff & Peters, 1966; Peters, 1966), which is neither the more recently proposed nor more widely accepted syntax for coordination in the theoretical literature. Syntacticians (e.g., Jackendoff, 1977; Kayne, 1984) have since argued for \bar{x} -theory, that all phrase structures are subjected to binary branching and are headed by only a single element. The coordinate determiner phrase (DP) in (18) follows neither generalization; it involves ternary branching and two heads (i.e., two DPs).

Despite this outdated characterization of coordination, Haskell and MacDonald (2005) found a strong preference for the verb to agree with the closer of the two disjuncts, that is, a linear order effect, and took this result to be evidence that though hierarchical relations are primary in the agreement computation process, linear order can play an observable role when the effect of hierarchy is neutralized.



It is surprising, then, that the observed agreement pattern disregards the more widely accepted, hierarchical, asymmetric, and singly-headed structure like that in (19). This syntax was first introduced by Munn (1993), who asserted that a coordinate phrase (CoordP)² should not be treated as a unique syntactic object (which would allow it to have ternary branching and multiple heads), but that it should conform to the \bar{x} schema. As in all headed phrases, the coordinating conjunction head (*or*, *and*, *but*) projects to its maximal projection CoordP. The first constituent (DP₁) occupies the specifier position, and the other one (DP₂) is the complement to the head. This structure, however, wrongly predicts that only the first constituent is accessible as an agreement controller: The specifier position is hierarchically closer to the verb and dominates (i.e., c-commands) the complement position. This structure fails to explain why the second, more deeply embedded constituent seems to be the one controlling agreement when the verb follows the disjoined subject.



² Munn (1993) originally termed this phrase as a Boolean phrase (BP). Throughout this thesis, it is referred to as a coordinate phrase (CoordP).

An important test is whether there is also a linear order effect with conjunctions, for which there is a clear agreement rule: A plural verb is required, regardless of the grammatical number of the individual conjuncts. The only exceptions are in cases where the conjunction has a singular referent (see Note 1). Outside of these exceptions, (20) would be considered an agreement error. By Haskell and MacDonald's (2005) reasoning, a linear order effect might also be present here, with the number of the second noun having an effect on verb number, on the assumption that the structures of disjunction and conjunction are similar. In fact, a study by Lorimor (2007) has suggested that agreement errors are considerably more common when the second conjunct is singular, a finding that we replicate and extend in Experiment 1b.

(20) *The horses and the clock is red.

It is notable, however, that such an effect would represent an influence of a singular noun on agreement. As we discuss below, in the classic number attraction configuration, a plural local noun is typically a potent attractor, while a singular noun is not.

In the upcoming sections, we show in Experiment 1b that the pattern of agreeing with the closer constituent is similar for both disjointed and conjoined subjects. These effects of linear order necessitate an account of coordination agreement that is independent of hierarchical structure, i.e., not feature mis-valuation (see Section 5.1). We further reveal in Experiments 2 and 3 a number of other asymmetries between variable agreement with coordination and classic agreement attraction. After presenting the experimental results, we discuss whether existing accounts of number attraction can be extended to explain the effects observed with coordination (see Sections 5.1-5.2), and conclude with representational differences between classic agreement attraction and variable agreement with coordination (see Section 5.3). By following Farkas and Zec (1995) who proposed that a coordinate subject phrase is syntactically undefined for number, we can model the production and comprehension effects observed in coordination agreement with a controller mis-retrieval mechanism that is identical to that of attraction effects.

CHAPTER 2

EXPERIMENT 1

We return to a qualitative difference between classic agreement attraction and variable agreement with disjunction: syntactic hierarchy vs. linear order. Linear order seems to have little to no effect on agreement in attraction configurations like *The helicopter for the flights over the canyons*, but a pronounced effect when the subject is disjoined like *The horses or the clock*. In fact, linear order seems to have a reversed effect in attraction, where the attractor closer to the verb is actually weaker than the more distant one.

Both types of agreement errors were further investigated in Experiment 1, using a two-alternative forced-choice (2AFC) paradigm designed by Staub (2009, 2010). Participants were instructed to read sentence preambles in rapid serial visual presentation (RSVP) format and then select the verb form that would be a grammatical continuation. This experiment contained two intermixed sets of materials, one involving the classic intervening attraction configuration (Experiment 1a) and the other involving coordination (Experiment 1b). To preview the findings, both of the previously reported patterns were replicated with a different production paradigm, and more notably, a robust linear order effect on agreement was observed when the subject was conjoined, similar to that seen when it was disjoined (Haskell & MacDonald, 2005). A singular second/closer conjunct elicited agreement errors about 20% of the time.

A third intermixed set of materials included two conjoined singulars as the object of a PP modifier like in (21), so that *and* was not always associated with the plural response.

(21) *The key to the lock and latch...

Interestingly, the conjoined object of the PP elicited as many plural verbs as a plural local noun, despite the absence of any morphosyntactically plural elements, and the singular second conjunct did not reduce the number of plural responses. This reveals an interesting asymmetry where a singular second conjunct could elicit a singular verb when the conjoined phrase was in subject position, but not when embedded in object position. This suggests a linear order effect that is

distinct from attraction: A conjunct can affect the verb choice, but only when it is a potential controller. This set of materials will not be discussed further as it investigated a separate question.

2.1. Method

2.1.1. Participants

There were 48 participants in Experiment 1. In this and all subsequent experiments, participants were right-handed, monolingual native English speaking undergraduate students at the University of Massachusetts Amherst, with normal or corrected-to-normal vision and no history of speech or hearing disorders. They were compensated with course credit for their time. Two participants were excluded from and replaced in Experiment 1 for having an accuracy rate on unambiguous trials (i.e., conditions SS, SSS, SSA from Table 1; conditions P&P, P&P(), S|S, S|S(), P|P, P|P() from Table 3) that was more than three standard deviations below the accuracy rate on unambiguous trials averaged across all participants (mean = 89.1%; sd = 7.0%; excluded participants = 65.7% and 57.5%).

2.1.2. Procedure

The 2AFC paradigm was essentially identical to that in Staub (2010). The experiment was carried out on a Windows XP computer running the E-Prime experimental software (Psychology Software Tools, Pittsburgh, PA), in a normally illuminated room, with the participant sitting a natural distance from the keyboard and monitor.

To initiate a trial, the participant pressed the spacebar. Then, a fixation cross was presented at the center of the screen for 1000 ms. After a 150-ms blank screen, the preamble was presented one word at a time in the center of the screen in 12-point Times New Roman font. Each word was displayed for 250 ms with a 150-ms interstimulus interval (ISI), for a total stimulus onset asynchrony (SOA) of 400 ms. After the final 150-ms ISI, the words IS and ARE, or WAS and WERE, were presented in uppercase letters on either side of the center of the screen. For a random half of the items, the response options were IS and ARE; for the other half, WAS and WERE. For

half of the IS-ARE items and half of the WAS-WERE items, the singular verb was presented on the left; for the remainder of items, it was on the right.

The participant was instructed to select as quickly as possible the response option that would constitute a grammatical continuation of the sentence, by pressing either the F or J key on the computer keyboard. The correct response was F for 50% of the trials. If the participant did not respond within ten seconds of the onset of the response options, a tone was played, and the words “TOO SLOW” appeared on the screen. If the participant did make a response, feedback – “CORRECT” or “INCORRECT” – was provided in the center of the screen.

Prior to beginning the experiment, the participant read instructions that described the task and emphasized the importance of both speed and accuracy. Each experimental session began with 12 practice trials, followed by an opportunity to ask questions. The entire experiment lasted approximately 60 minutes.

2.2. Experiment 1a

Experiment 1a was a replication and extension of Franck et al. (2002). This experiment assessed the reliability of the pattern in which the plural first local noun in a subject like *The helicopter for the flight(s) over the canyon(s)* is more likely than the second local noun to induce an attraction error. In addition, the present experiment assessed whether the influence of the first local noun is independently modulated by the linear distance between this noun and target.

2.2.1. Materials

Eighty preambles, 32 of which were adapted from Franck et al. (2002), were constructed for this experiment. Each preamble began with the definite determiner and a singular noun (*The helicopter...*), followed by a PP modifier (*...for the flight(s)...*), followed by a continuation (*...Ø / over the canyon(s) / apparently*). These were intermixed with the preambles from Experiment 1b, as well as preambles like the one in (21), designed to prevent strategic responding in Experiment 1b (see below).

Thus, two factors were manipulated: (i) Second noun of the preamble (i.e., the local noun in the first PP modifier): singular vs. plural, and (ii) Continuation: nothing vs. singular noun vs. plural noun (i.e., the local noun in the second PP modifier) vs. non-number-marked adverb (e.g., *apparently, certainly*). The eight conditions of this 2×4 experiment are illustrated in Table 1.

Table 1

Example Preamble Set for Experiment 1a

Cond	Example preambles	Second/local noun	Continuation
SS	The helicopter	for the flight	∅
SP	The helicopter	for the flights	∅
SSS	The helicopter	for the flight	over the canyon
SPS	The helicopter	for the flights	over the canyon
SSP	The helicopter	for the flight	over the canyons
SPP	The helicopter	for the flights	over the canyons
SSA	The helicopter	for the flight	apparently
SPA	The helicopter	for the flights	apparently

Note. S = singular noun, P = plural noun, A = adverb.

2.2.2. Results and discussion

Responses that were shorter than 200 ms or longer than 4000 ms were excluded from analysis, eliminating 0.8% of the experimental trials (31 out of 3840). Because the controller (e.g., *helicopter*) was always singular, the correct response was always the singular verb. Thus, the error rate is equivalent to the proportion of plural responses, which is plotted for each condition in Figure 1. Plural responses occurred more frequently when the second noun (e.g., *flights*) was plural. The continuation had little additional influence, as the proportion of plural responses did not significantly differ whether the plural second noun was the last word of the preamble or was followed by something.

These patterns were supported statistically. The analysis of accuracy was carried out using a mixed-effects logistic regression model (Jaeger, 2008) with the lme4 package (Bates, Mächler, Bolker, & Walker, 2015) in R (R Development Core Team, 2016). Participants and items were crossed random effects, and the two experimental factors (first local noun, continuation) were crossed fixed effects. First local noun number was modeled using sum/deviation coding, with a

plural noun coded as +0.5. Continuation was dummy coded, with singular as the reference level. We started with a model that included all random slopes, but due to a failure to converge, the random effects structure was simplified until the largest converging model was achieved. The final model included only random intercepts by participants and by items.

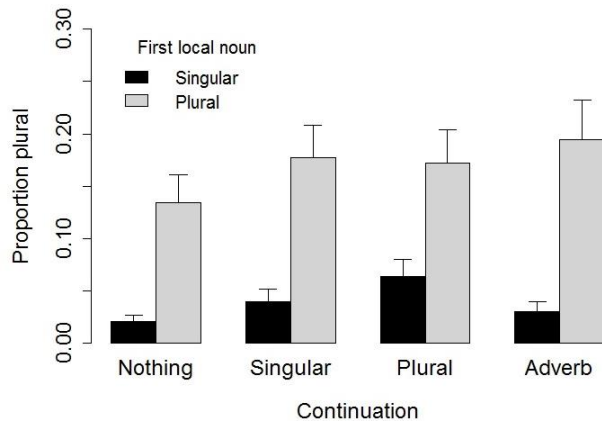


Figure 1. Mean proportion of plural (i.e., error) responses, averaged over participants, in each of the eight conditions in Experiment 1a. Error bars represent standard errors.

The results of this model are shown in Table 2. The estimate of the intercept is the log odds of a correct (i.e., singular) response, averaged across first local noun number, when the continuation is a singular noun (e.g., *The helicopter for the flight(s) over the canyon...*); the fact that this estimate is significant and positive indicates that participants were well above chance performance. The significant negative estimates associated with the first local noun and with the plural continuation indicate that the log odds of a correct response decreased when either of the local nouns was plural. The fact that the estimate is more negative when the first local noun was plural ($\beta = -2.004$) than when the continuation was plural ($\beta = -0.587$) indicates that the first local noun had a stronger influence on accuracy than the second one; that is, linear order does not matter. None of the interactions were significant, indicating that the effect of a plural first local noun did not differ across continuation type; that is, linear distance does not matter.

These results are consistent with Franck et al.'s (2002) study. The 2AFC production paradigm replicated the critical finding that the first local noun, which is hierarchically (and linearly) closer to the agreement controller, was a stronger attractor than the second local noun,

which is linearly closer to the verb. A plural second local noun did have an effect on accuracy, but this effect was smaller than the pronounced effect of a plural first local noun. This confirms that hierarchical distance of the local noun to the controller is the primary determinant of the strength of an attraction effect triggered by a noun that intervenes between the controller and target.

Table 2

Coefficient Estimates in Log Odds, and Associated Standard Errors and p-values, for the Fixed Effects in the Mixed Logistic Regression Model of Accuracy in Experiment 1a

	Estimate	Std. error	p
(Intercept)	3.259	0.288	<.001
Second noun: Plural	-2.004	0.283	<.001
Continuation: None	0.121	0.208	.560
Continuation: Plural	-0.587	0.226	.009
Continuation: Adverb	-0.261	0.185	.158
Second noun: Plural × Continuation: None	-0.460	0.417	.270
Second noun: Plural × Continuation: Plural	-0.285	0.452	.528
Second noun: Plural × Continuation: Adverb	0.600	0.370	.105

Note. Green rows are significant at $\alpha = .05$.

The present study also directly assessed whether the presence of material between the first local noun and verb had any influence on its strength as an attractor. Accuracy did not significantly vary depending on whether a plural first local noun was followed by a prepositional phrase containing a singular or plural noun, an adverb, or no material at all. Notably, the error rate was numerically lowest when no material intervened between a plural first local noun and the verb; this trend is in the opposite direction from the prediction of a linear distance hypothesis. In sum, Experiment 1a strengthens Franck et al.’s (2002) conclusion that the strength of an attractor depends only on its hierarchical distance to the controller.

2.3. Experiment 1b

Experiment 1b was a replication and extension of Haskell and MacDonald (2005). This experiment assessed how strongly the first or the second disjunct in a disjointed subject like *The horses or the clock* influences agreement (i.e., a linear order effect) in the 2AFC paradigm, and tested whether similar patterns would be obtained for conjuncts in a conjoined subject. This further

question is important, because in the case of conjunction, as opposed to disjunction, there is a clear grammatical rule: Plural agreement is correct regardless of the number of either constituent in the conjunction, except in cases where the conjunction has a singular referent. In the present experiment, the stimuli were constructed so as to rule out a single-referent interpretation. If the second constituent tends to control agreement only when the subject is a disjunction, but not when it is a conjunction, this would suggest that the phenomenon is likely due simply to the lack of grammatical clarity in the former case. On the other hand, if the phenomenon is also present with conjoined subjects, this would suggest that it is the structure of coordinate phrases, how number is represented in these phrases, or some combination of these factors that gives rise to this sensitivity to the number of the closer constituent.

In addition, the present experiment assessed whether the influence of the second constituent in either disjunction or conjunction is modulated by the presence or absence of material between this noun and target. Experiment 1a showed that in the classic attraction configuration, linear distance between the local noun and target seems to play no role whatsoever in inducing agreement errors. Given that linear order appears to play a role in coordination agreement, it is possible that linear distance plays a role here too.

2.3.1. Materials

One hundred sixty preambles were constructed for this experiment. Each preamble began with the definite determiner and a noun (*The maid(s)...*), followed by a coordinator (*...and / or...*), followed by a second definite determiner and noun (*...the butler(s)...*). Constituents were chosen to be highly semantically related, but distinct (e.g., *maid-butler*, *duke-prince*, *gun-sword*, *church-steeple*, *entrance-exit*) such that they would be unlikely to refer to the same referent. The second determiner was included based on the intuition that it further suppresses the same-referent reading. Having a singular referent is more common when deverbal or mass nouns are conjoined (e.g., *The singing and dancing*, *The wind and rain*) (Lorimor, 2007; Lorimor, Jackson, Spalek, & van Hell, 2016), so only count nouns were used in this experiment. In half of the experimental conditions,

this coordinate phrase was followed by non-number-marked material. Half of them continued with a reduced relative clause (...*laboring away*), while the other half continued with an adverb (...*obviously*).

Thus, four factors were manipulated: (i) First/farther constituent: singular vs. plural, which should be ignored by participants because it provides no information about correct agreement; (ii) Coordinator: *and* vs. *or*, which determines agreement with respect to conjunctions only (*and* = plural; *or* = may depend on closer noun); (iii) Second/closer constituent: singular vs. plural, which tends to control agreement with disjunctions, but never with conjunctions; and (iv) Non-number-marked intervening material after the second/closer constituent: present vs. absent. The 16 conditions of this 2×2×2×2 experiment are illustrated in Table 3. These items were intermixed with the preambles from Experiment 1a, as well as preambles like the one in (21), so that *and* was not always associated with the plural response.

Table 3

Example Preamble Set for Experiment 1b

Cond	Example preambles	Cond	Example preambles
S&S	The maid and the butler	S S	The maid or the butler
S&P	The maid and the butlers	S P	The maid or the butlers
P&S	The maids and the butler	P S	The maids or the butler
P&P	The maids and the butlers	P P	The maids or the butlers
S&S()	The maid and the butler laboring away	S S()	The maid or the butler laboring away
S&P()	The maid and the butlers laboring away	S P()	The maid or the butlers laboring away
P&S()	The maids and the butler laboring away	P S()	The maids or the butler laboring away
P&P()	The maids and the butlers laboring away	P P()	The maids or the butlers laboring away

Note. & = conjunction, | = disjunction, () = intervening material.

2.3.2. Results and discussion

Responses that were shorter than 200 ms or longer than 4000 ms were excluded from analysis, eliminating 1.1% of the experimental trials (85 out of 7680). The normatively correct response for the conjunction conditions, regardless of constituent number, was always the plural verb. Thus, the error rate is equivalent to the proportion of singular responses, which is plotted for each condition in Figure 2 (bottom panel). Although there is no clear agreement rule for the

disjunction conditions, the proportion of singular responses is also plotted (top panel, note difference in scale) to parallel the conjunction conditions. (Because there is no clear agreement rule for the disjunction conditions, a response was given “CORRECT” feedback when the number of the selected verb matched the number of the closer disjunct.)

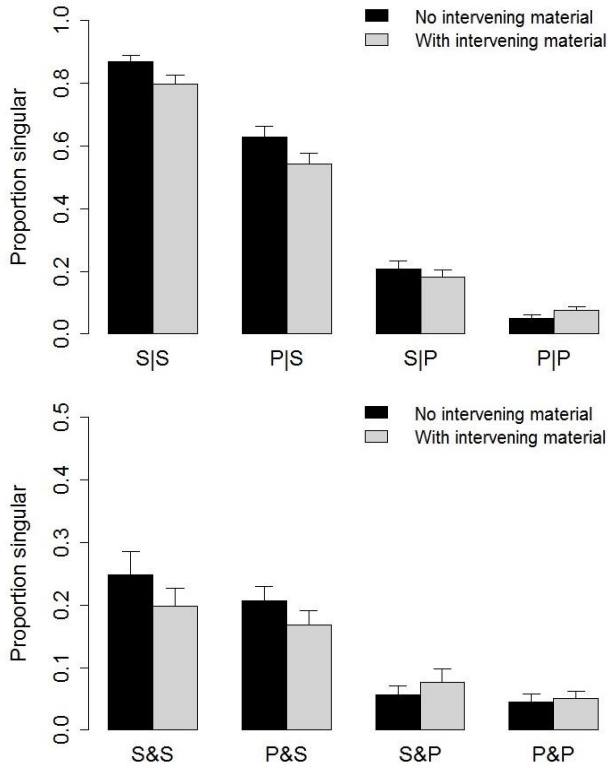


Figure 2. Mean proportion of singular responses, averaged over participants, in each of the disjunction (top) and conjunction (bottom, note difference in scale) conditions in Experiment 1b. Error bars represent standard errors.

Importantly, the same patterns can be seen in both types of coordination. Singular responses occurred most frequently when both constituents were singular, slightly less frequently when only the second/closer constituent was singular, and even less so when only the first/farther one was singular. The presence of intervening material also decreased the proportion of singular responses, but only when the second constituent was singular.

These patterns were supported statistically. Like in Experiment 1a, the analysis of the proportion of plural responses was carried out using a mixed-effects logistic regression model. Participants and items were crossed random effects, and the three experimental factors (first

constituent, second constituent, intervening material) were crossed fixed effects. The disjunction and conjunction conditions were analyzed separately. The fixed factors were modeled using sum/deviation coding, with plural first noun, plural second noun, and presence of intervening material coded as +0.5. We started with a model that included all random slopes, but due to a failure to converge, the random effects structure was simplified until the largest converging model applicable to both disjunction and conjunction was achieved. The final models included random intercepts by participants and by items, and a random slope for the second constituent by participants only.

The results of these models are shown in Table 4. The estimates of the intercept are the log odds of a plural response averaged across the other three factors; the fact that these estimates are significant and positive indicates that participants produced the plural verb at a rate well above chance. The significant positive estimates associated with the first and second constituents indicate that the log odds of a plural response increased when each of these factors (averaged across the other factors) was plural. Accordingly, singular responses were more likely with a singular constituent. The fact that the estimates are more positive when the second constituent was plural ($\beta = 3.37$ for disjunction; $\beta = 1.93$ for conjunction) than when the first constituent was plural ($\beta = 1.39$ for disjunction; $\beta = 0.26$ for conjunction) indicates that the second constituent had a stronger influence on response proportion than the first one. These two main effects were additive (no interaction), indicating that the effect of one constituent was constant regardless of the other constituent. Finally, the significant negative estimate for the interaction of second constituent number and intervening material indicates that the effect of the second constituent was reduced when intervening material was present.

The disjunction results are consistent with Haskell and MacDonald's (2005) study. The 2AFC production paradigm replicated the critical finding that linear order has a robust effect on agreement when the subject is a disjunction, as participants tended to choose the verb form that agreed with the linearly closer noun. More importantly, the present experiment revealed a similar

influence of the linearly closer noun when the subject is a conjunction. This is a construction that has a clear agreement rule, yet a singular second noun elicited a singular response (i.e., an error) close to 20% of the time. For both disjunctions and conjunctions, the first noun also had an influence on participants' selection of a verb form, though this influence was relatively weak.

Table 4

Coefficient Estimates in Log Odds, and Associated Standard Errors and p-values, for the Fixed Effects in the Mixed Logistic Regression Model of Proportion of Plural Responses in the Disjunction (top) and Conjunction (bottom) Conditions in Experiment 1b

Disjunction conditions	Estimate	Std. error	p
(Intercept)	0.552	0.077	<.001
First cons: Plural	1.387	0.100	<.001
Second cons: Plural	3.365	0.204	<.001
Inter mater: Present	0.184	0.099	.062
First cons: Plural × Second cons: Plural	-0.102	0.200	.610
First cons: Plural × Inter mater: Present	-0.382	0.198	.054
Second cons: Plural × Inter mater: Present	-0.612	0.198	.002
First cons: Plural × Second cons: Plural × Inter mater: Present	-0.440	0.396	.266
Conjunction conditions	Estimate	Std. error	p
(Intercept)	2.608	0.182	<.001
First cons: Plural	0.263	0.120	.028
Second cons: Plural	1.925	0.210	<.001
Inter mater: Present	0.012	0.120	.917
First cons: Plural × Second cons: Plural	0.141	0.239	.557
First cons: Plural × Inter mater: Present	0.084	0.239	.726
Second cons: Plural × Inter mater: Present	-0.532	0.239	.026
First cons: Plural × Second cons: Plural × Inter mater: Present	0.228	0.479	.634

Note. Green rows are significant at $\alpha = .05$.

The presence of intervening material between the second noun and verb reduced the influence of a singular second noun on participants' selection of a verb form, again for both disjunctions and conjunctions. This is evidence for a linear distance effect. In sum, it appears that the same factors influenced agreement with both disjunctions and conjunctions, and in the same way.

In summary, Experiment 1a replicated and extended Franck et al.'s (2002) finding that, in the classic attraction configuration, it is hierarchical distance between a local noun and the

controller that drives attraction, while Experiment 1b replicated Haskell and MacDonald's (2005) finding that the number of the noun that is closer to the verb in a disjoined subject tends to determine verb number. Experiment 1b further revealed that disjunction agreement is sensitive not only to the order of the two nouns, but to linear distance as well, as evidenced by the fact that intervening material reduces the influence of a singular second disjunct. Moreover, these order and distance effects are not limited to a construction where grammatical agreement is not clearly defined, because the same effects appear with conjunction agreement, which has a clear agreement rule. Thus, it appears that the effects of linear order and linear distance are due to the structure of coordination, or to number representation in a coordinate structure, rather than to the uncertainty about grammatical agreement that arises with disjunctions.

CHAPTER 3

EXPERIMENT 2

Experiment 2 extended the findings of Experiment 1 in a couple of ways. Again using Staub's (2009, 2010) 2AFC production paradigm, we directly compared classic intervening attraction errors to conjunction agreement errors using the same items within a single experiment. In addition to analyzing the proportion of correct responses, we analyzed response time (RT) data and fit the ex-Gaussian distribution to the data in order to assess the scope of a plural attractor and singular second conjunct, i.e., whether effects on RT were due to interference on a subset of or on all trials.

This paradigm and analysis has³ been used to provide RT evidence suggesting that classic intervening and non-intervening attraction errors have different processing characteristics. Staub (2009) observed that, when an intervening plural attractor was present, the error rate increased, as has been shown many times before, but critically, the latency of making a correct response also increased, compared to when there was no attractor. Errors were neither faster nor slower than correct responses. Following that, Staub (2010) replicated the RT effects and additionally fit the ex-Gaussian distribution to each participant's correct RT data. When an intervening plural attractor was present, the distribution of correct RTs was shifted rightward (μ shift) with an increased right skew (τ effect), compared to when there was no attractor. The μ shift indicates that the increase in correct RT was not limited to a small subset of long trials getting longer, but that the effect was present across the entire distribution. Together, these findings suggest that interference from a plural attractor had a general effect, making agreement computation slower and harder on all trials, regardless of whether an error was made or not.

In contrast, non-intervening attraction errors (e.g., **The locks that the key are*) displayed a different RT profile, suggesting that the two types of attraction have distinct underlying

³ "Paradigm and analysis" is being treated as a single unit, hence singular agreement.

mechanisms, as originally proposed by Bock & Miller (1991) and more recently by Eberhard et al. (2005). When a non-intervening plural attractor (i.e., *locks*) was present, the error rate increased, as did the latency of making a correct response, but to a smaller degree, so errors remained reliably slower than correct responses. When the ex-Gaussian was fit to the RT data, the distribution of correct RTs in the attractor condition exhibited a τ effect, but no μ shift, compared to when there was no attractor. This indicates that the increase in correct RT was not a general effect that slowed down every trial. Instead, a non-intervening attractor led to pronounced slowing on only a subset of the correct trials.

In the present experiment, the 2AFC paradigm was essentially identical to that in Staub (2010). We directly compared the effects of a classic intervening attractor to the effects of a singular second conjunct. Experiment 1 revealed qualitative differences between the two configurations, which could, in theory, be demonstrated as distinct RT profiles. This would provide evidence that classic agreement attraction and variable agreement with conjunction have distinct underlying mechanisms.

3.1. Method

3.1.1. Participants

There were 32 participants in Experiment 2, none of whom participated in Experiment 1. The same inclusion criteria as Experiment 1 were used. One participant was excluded and replaced for having an accuracy rate on unambiguous trials (i.e., SS, PP, P&P from Table 5) that was more than three standard deviations below the accuracy rate on unambiguous trials averaged across all participants (mean = 94.0%; sd = 4.4%; excluded = 72.5%).

3.1.2. Materials

One hundred sixty preambles were constructed for this experiment. Each one began with the definite determiner and a noun (*The maid(s)...*), followed by a “connector” (...*behind / and...*), followed by a second definite determiner and noun (...*the butler(s)*). The nouns matched in animacy so that both of them could be plausible subjects of the same predicate (more important for

Experiment 3). They were semantically related, but distinct/non-identical such that (i) the two could not refer to the same referent (for the conjunction conditions) and (ii) the second noun could be a plausible modifier of the first noun (for the PP conditions).

Three factors were manipulated: (i) First noun number: singular vs. plural, (ii) Configuration type: intervening attraction (i.e., PP modifier, replication of Experiment 1a) vs. conjunction (replication of Experiment 1b), and (iii) Second noun number: singular vs. plural. For design simplicity, no PP continuations or intervening material were included. Each participant viewed two versions of each of the 160 preambles, for a total of 320 experimental trials, 40 per condition. The eight conditions of this 2×2×2 experiment are illustrated in Table 5.

Table 5

Example Preamble Set for Experiment 2

Cond	Configuration	1 st noun	2 nd noun	Example preambles
SS	Attraction	S	S	The maid behind the butler
SP	Attraction	S	P	The maid behind the butlers
PS	Attraction	P	S	The maids behind the butler
PP	Attraction	P	P	The maids behind the butlers
S&S	Conjunction	S	S	The maid and the butler
S&P	Conjunction	S	P	The maid and the butlers
P&S	Conjunction	P	S	The maids and the butler
P&P	Conjunction	P	P	The maids and the butlers

Note. S = singular, P = plural, & = conjunction.

These preambles were combined with 80 fillers, with examples like those in (22).

- (22) a. The man with the pail and shovel...
- b. The chef with the desserts and wines...
- c. The dragon guarding the cave and dungeon...
- d. The farmer picking apples and oranges...
- e. The billboard that the name...
- f. The cars that the recall...

They were included (i) to preclude the presence of *and* from always co-occurring with the plural response, (ii) to require attention to different nouns, as with fillers like (22e-f), it is not necessarily

the first noun that controls agreement with the subsequent verb, and (iii) to help balance the proportion of singular and plural responses. The correct response was singular for all 80 fillers; therefore, in the experiment as a whole, the correct response was singular for 40% of the preambles. The 400 total trials were presented to each participant in an individually randomized order, following 12 practice trials.

3.1.3. Procedure

The procedure was identical to Experiment 1.

3.2. Results

3.2.1. Accuracy

Responses that were shorter than 200 ms or longer than 4000 ms were excluded from analysis, eliminating 0.2% of the experimental trials (20 out of 10240). The error rate in each condition is plotted in Figure 3. As expected, error responses occurred more frequently when a number-mismatching noun, i.e., a plural attractor (SP) and a singular second conjunct (P&S, S&S, S&P to a smaller extent), was present. Surprisingly, though, there were more errors than expected when the first noun was plural in the attraction configuration (PP, PS). This remains unexplained, but a singular attractor crucially did not affect the rate of errors. Figure 3 also depicts a seemingly additive effect of two singular conjuncts, with the first conjunct having a smaller effect on agreement than the second one. When only the first conjunct was singular, the error rate slightly increased (from P&P 2% to S&P 4%). It increased slightly more when only the second conjunct was singular (to P&S 9%) and even more when both were singular (to S&S 13%).

These patterns were supported statistically. Like in Experiment 1, the analysis of accuracy was carried out using a mixed-effects logistic regression model. Participants and items were crossed random effects, and the three experimental factors (first noun, configuration type, second noun) were crossed fixed effects. The fixed factors were modeled using sum/deviation coding, with plural first noun, conjunction, and plural second noun coded as +0.5. We started with a model that included all random slopes, but due to a failure to converge, the random effects structure was

simplified until the largest converging model was achieved. The final model included random intercepts by participants and by items, and a random slope for configuration type by participants.

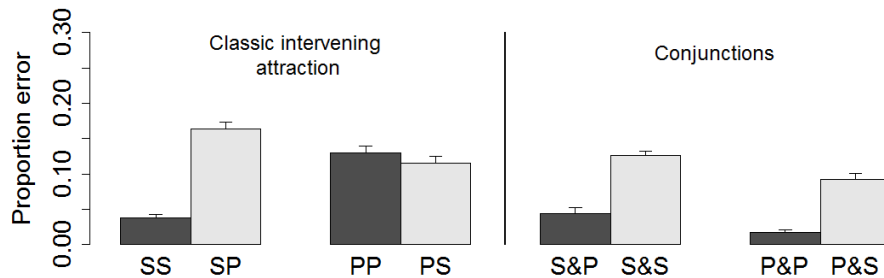


Figure 3. Mean proportion of error responses, averaged over individual trials, in each of the eight conditions in Experiment 2. The first set of bars is equivalent to the proportion of plural responses. The other three sets are proportions of singular responses. Error bars represent standard errors.

The results of this model are reported in Table 6. Critically, there is a significant main effect of and significant interactions involving configuration type, indicating that the first and second nouns have distinct effects in classic attraction and conjunction agreement errors. The estimate of the intercept is the log odds of a correct response averaged across all conditions; the fact that this estimate is significant and positive indicates that participants were well above chance performance. The significant positive estimates associated with the conjunction configuration and with the plural second noun indicate that each of these manipulations (averaged across the other factors) increased the log odds of a correct response.

Table 6

Coefficient Estimates in Log Odds, and Associated Standard Errors and p-values, for the Fixed Effects in the Mixed Logistic Regression Model of Accuracy in Experiment 2

	Estimate	Std. error	P
(Intercept)	2.737	0.124	<.001
First noun: Plural	0.097	0.088	.269
Config: Conjunction	0.698	0.134	<.001
Second noun: Plural	0.298	0.088	<.001
First noun: Plural × Config: Conjunction	1.162	0.175	<.001
First noun: Plural × Second noun: Plural	1.068	0.175	<.001
Config: Conjunction × Second noun: Plural	2.417	0.175	<.001
First noun: Plural × Config: Conjunction × Second noun: Plural	-0.936	0.350	0.008

Note. Green rows are significant at $\alpha = .05$.

These main effects are qualified by a significant three-way interaction, which is the most informative result. To resolve this interaction, separate models were fit for the two configuration types, to directly explore the effects of the first and second nouns. These models showed a significant interaction of the two nouns in both the attraction ($\beta = 1.530$, $SE = 0.206$, $p = .001$) and conjunction ($\beta = 0.604$, $SE = 0.280$, $p = .03$) configurations. Further resolving these interactions fully revealed the asymmetry reported in Experiment 1. In the attraction configuration, a plural second noun decreased the log odds of a correct response only when the first noun was singular ($\beta = -1.943$, $SE = 0.280$, $p < .001$). This is the classic effect of a plural attractor, reflected by a large difference in proportion correct between the SP and SS conditions (12%). In contrast, with a plural first noun, the log odds of a correct response did not differ whether the second noun was singular or plural ($\beta = -0.166$, $SE = 0.155$, $p = .283$; accuracy differed by 1%). In the conjunction configuration, a plural second noun increased the log odds of a correct response regardless of whether the first noun was singular ($\beta = 1.129$, $SE = 0.245$, $p < .001$) or plural ($\beta = 2.200$, $SE = 0.477$, $p < .001$). Note that when both nouns were singular, the effect of singulars was at its greatest, reflecting the lowest accuracy rate in the S&S condition (87%). The small but significant interaction indicates that accuracy was lower than what would be predicted by combining the effect of each noun (singular first noun: P&P – S&P, 2% errors; singular second noun: P&P – P&S, 7% errors). This interaction was not observed in Experiment 1b.

In summary, we showed that configuration type greatly influenced the effect that a second noun had on verb production (or choice). A plural attractor increased error rates, while a plural second conjunct did not. Conversely, a singular attractor had no effect on error rates (no difference between PP and PS), while a singular second conjunct had a sizable effect (larger difference between _&P and _&S). A singular second conjunct increased error rate more than a singular first conjunct did (i.e., a linear order effect), and having two singular conjuncts increased error rate more than what the two individual conjuncts could account for.

3.2.2. Response time

The mean RTs of correct responses and errors in each condition are plotted in Figure 4. Correct responses were fastest in the conditions in which errors were relatively rare (SS, P&P) and were longer when a number-mismatching noun was present (e.g., SP, P&S). Consistent with the proportion of correct responses, Figure 4 depicts the smaller effect of the first conjunct compared to the second one. Correct RT increased slightly when only the first conjunct was singular (from P&P 758 ms to S&P 815 ms) and more so when the second conjunct was singular (P&S 863 ms). There was no additional slowdown when both conjuncts were singular (S&S 849 ms).

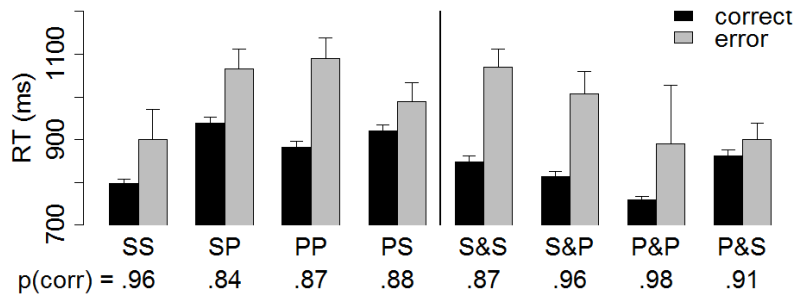


Figure 4. Mean correct (black bars) and error (gray bars) RTs, averaged over individual trials, in each of the eight conditions in Experiment 2. Error bars represent standard errors. Proportion correct is provided beneath the condition labels.

These patterns were supported statistically. The analysis of the log-transformed RTs of correct trials was carried out using a mixed-effects linear regression model. The same random effects, fixed effects, and coding scheme as in the previous analysis were used. The final model included random intercepts by participants and by items, and random slopes for all fixed effects except the first noun by items and the interactions.

The results of this model are reported in Table 7. Again, there is a significant main effect of and significant interactions involving configuration type, suggesting two distinct empirical patterns. The estimate of the intercept is the log RT of a correct trial averaged across all conditions (i.e., the grand mean). The significant negative estimate associated with the conjunction configuration indicates that correct responses were generally faster with a conjoined subject.

Table 7

Coefficient Estimates in Log Milliseconds, and Associated Standard Errors and t-scores, for the Fixed Effects in the Mixed Linear Regression Model of Correct RT in Experiment 2

	Estimate	Std. error	T
(Intercept)	6.653	0.040	165.11
First noun: Plural	-0.004	0.012	-0.33
Config: Conjunction	-0.072	0.014	-5.30
Second noun: Plural	-0.013	0.012	-1.07
First noun: Plural × Config: Conjunction	-0.059	0.014	-4.06
First noun: Plural × Second noun: Plural	-0.115	0.014	-7.99
Config: Conjunction × Second noun: Plural	-0.123	0.014	-8.54
First noun: Plural × Config: Conjunction × Second noun: Plural	0.116	0.029	4.01

Note. Green rows are significant at $\alpha = .05$.

The main effect is qualified by the significant three-way interaction, which is the most informative result here. Resolving it showed a significant interaction of the first and second noun in both the attraction ($\beta = -0.175$, $SE = 0.029$, $t = -6.00$) and conjunction ($\beta = -0.057$, $SE = 0.026$, $t = -2.18$) configurations. Further resolving these interactions fully revealed the differences between configurations. In the attraction configuration, a plural second noun significantly increased correct RT only when the first noun was singular ($\beta = 0.141$, $SE = 0.019$, $t = 7.58$). This is the classic effect of a plural attractor, reflected by a large difference in correct RT between the SP and SS conditions (139 ms). When the first noun was plural, a plural second noun resulted in slightly faster RTs, indicating that a singular attractor numerically slowed down correct trials (PS – PP, 38 ms), though this did not reach significance ($\beta = -0.038$, $SE = 0.022$, $t = -1.73$). In the conjunction configuration, a plural second noun significantly decreased correct RT regardless of whether the first noun was singular ($\beta = -0.046$, $SE = 0.019$, $t = -2.45$) or plural ($\beta = -0.103$, $SE = 0.022$, $t = -4.78$). The significant interaction indicates that when both nouns were singular, the increase in correct RT (S&S – P&P, 91 ms) was smaller than what would be predicted by combining the effect of each noun (singular first noun: S&P – P&P, 57 ms; singular second noun: P&S – P&P, 105 ms).

These results are consistent with the results from the analysis of the proportion of correct responses. This is illustrated in Figure 5 by the linear relationship between accuracy and

production/choice latency. Across the two dependent measures, we showed that configuration type influenced the effect that the second noun had. A plural attractor resulted in lower accuracy and slower correct RT, while a plural second conjunct resulted in higher accuracy and faster correct RT. Conversely, a singular attractor had little effect, while a singular second conjunct had a sizable effect on both measures. Furthermore, a singular second conjunct increased correct RT more than a singular first conjunct did (linear order effect), but having two singular conjuncts did not increase correct RT as much as would have been expected from two individual conjuncts. A reversed interaction was observed in accuracy: two singular conjuncts resulted in an accuracy lower than what the two individual conjuncts could account for.

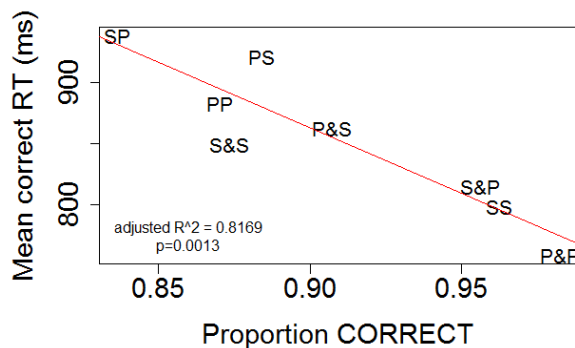


Figure 5. Mean correct RT as a function of the mean proportion of correct responses in each of the eight conditions in Experiment 2. The red line corresponds to be best-fitting regression line.

3.2.3 Correct vs. error RTs

In Staub’s (2009, 2010) studies, interference from an intervening attractor (SP, PS) yielded error RTs that were neither faster nor slower than correct RTs, and when there was no attractor (SS, PP), error RTs were significantly slower. These slow errors likely resulted from relatively rare external processes that would be expected to increase RT, e.g., yawning, coughing, or not paying attention. The present experiment contained the same four attraction conditions (with different items), so we expected to replicate this pattern of results. Figure 4, however, shows a slightly different pattern. The SS, PP, and PS conditions were consistent with those from Staub’s studies,

but a potential anomaly lies in the SP condition, in which error RT was expected to be about equal to correct RT, but was in fact numerically slower (though not statistically significant).

The analysis of the difference between the mean correct RT and the mean error RT in each condition, for only those participants who made errors in that condition, was carried out using within-participants *t*-tests. Many participants did not make errors in the SS condition (11 out of 32), resulting in large variability and low power.

In the no-attractor SS condition, the participants who made errors averaged 967 ms for errors and 837 ms for correct responses, though due to the small number of errors, this sizeable difference was not significant ($t(20) = 1.245, p = .227$). In the no-attractor PP condition, error RT was significantly slower than correct RT, as expected (1160 ms vs. 883 ms; $t(30) = 3.863, p < .001$). In the two conditions with a number-mismatching attractor, error RTs were slower than correct RTs (SP: 1064 ms vs. 958 ms; PS: 1061 ms vs. 911 ms), but in neither condition was this difference statistically significant, as expected (though it was marginal; SP: $t(27) = 1.899, p = .068$; PS: $t(29) = 1.991, p = .056$). These results, along with those from the previous sections, replicated Staub (2009, 2010). There is strong evidence that an intervening plural attractor increased error rate and slowed correct responses. While error RT did not differ significantly from correct RT, the numerical difference should not be disregarded. For some reason (see Section 4.3), the plural attractor in the present experiment had smaller effects on RT than in previous studies. The low power in the correct vs. error RT analyses makes it difficult to make a clear determination though.

Importantly, we observed that interference from a singular second conjunct (P&S, though not S&S) patterned like that from a plural attractor and yielded error RT that was not different from correct RT, and when the second conjunct was plural (P&P, S&P), error RTs were significantly slower. The statistical significance of these patterns was assessed using *t*-tests similar to above. Many participants did not make errors in the P&P condition (21 out of 32), again resulting in large variability and low power.

In the high accuracy P&P condition, the participants who made errors averaged 833 ms for errors and 690 ms for correct responses, though due to the small number of errors, this sizeable difference was not significant ($t(10) = 1.198, p = .259$). In the almost-as-accurate S&P condition, error RT was indeed significantly slower than correct RT (994 ms vs. 800 ms; $t(23) = 3.123, p = .005$). Results diverged in the conditions with a singular second conjunct (i.e., the conditions with lower accuracy). In the P&S condition, correct and error RTs did not differ from each other, as expected (857 ms vs. 847 ms; $t(27) = 0.208, p = .837$), but in the S&S condition, error RT was significantly slower (1051 ms vs. 879 ms; $t(28) = 3.321, p = .003$). Surprisingly, participants took the longest to respond ‘singular’ when both conjuncts were singular.

Across these RT results, there are no consistent patterns regarding a plural attractor and singular second conjunct. In the SP condition, errors were numerically slow, but the difference did not reach significance; in the S&S condition, errors were slow, and the difference did reach significance; and in the P&S condition, correct and error RTs were nearly identical. It becomes difficult, then, to claim that the two configurations are truly distinct on the basis of these correct vs. error RTs.

3.2.4. Ex-Gaussian fit

Lastly, as in Staub’s (2010) study, each participant’s correct RT data in each condition were fit to the ex-Gaussian distribution using the QMPE software developed by Cousineau, Brown, and Heathcote (2004). The ex-Gaussian is a unimodal and positively skewed distribution that is often used to model the shape of empirical RT data. It is a combination of the Gaussian and exponential distributions and can be described with three parameters: (i) the mean μ and (ii) the standard deviation σ of the Gaussian, as well as (iii) $1/\text{rate}$ of the exponential, τ . Per Cousineau et al.’s (2004) recommendation, the maximum number of possible quantiles, i.e., with each data point in a separate bin, were used in the fits. The fitting procedure used maximum likelihood estimation to determine the distributional parameters, while allowing all three parameters to vary freely, that came closest to producing the correct quantile boundaries.

Staub (2010) found that the μ (and τ) parameter was substantially larger in the SP compared to the SS condition. This suggests that the plural attractor generally interfered with agreement computation, leading to a general increase in RT even on the trials where a correct response was made. In contrast, neither μ nor τ were larger in the PS compared to the PP condition (i.e., no effect of a singular attractor). Because the present experiment contained the same four attraction conditions (different items), we expected to replicate this critical pattern of results.

The mean values of the three ex-Gaussian parameters in each condition are shown in Figure 6, which illustrates that the attraction conditions did not replicate those in Staub (2010). The large increase in correct RT when an intervening plural attractor was present (SP – SS, 139 ms) was due to an effect only on the τ (143 ms) parameter. This indicates that the attractor interfered with agreement computation on only a subset of trials, rather than having the expected general effect. In other words, the intervening SP condition in this experiment patterned like the non-intervening SP condition from Staub (2010) (see Section 4.3). Consistent with Staub (2010), however, there were no parameter differences between the PS and PP conditions.

These patterns were mostly supported statistically. The analysis for each of the three parameter values was carried out using a repeated measures analysis of variance. Two experimental factors (first noun, second noun) were crossed fixed effects, with the attraction and conjunction configurations analyzed separately. The reported analyses included only the participants whose convergence tolerances in the ex-Gaussian fits were satisfied in all conditions, which means that the parameter estimates and their standard errors were “trustworthy” (Cousineau et al., 2004). However, this excluded 9 out of 32 participants in the attraction configuration (5 in the SP condition, 2 in SS, 4 in PP, and 3 in PS) and 6 in the conjunction configuration (3 in the P&S condition, 1 in each of the others), resulting in large variability and low power.

In the attraction configuration, there were no significant effects on μ and σ . On τ , however, there was a significant main effect of the second noun ($F(1,22) = 18.920, p < .001$), which was qualified by a significant interaction of first and second noun ($F(1,22) = 15.350, p < .001$). As seen

in Figure 6, the difference in τ was much larger between the SS and SP conditions than between PP and PS where τ 's were not significantly different from each other.

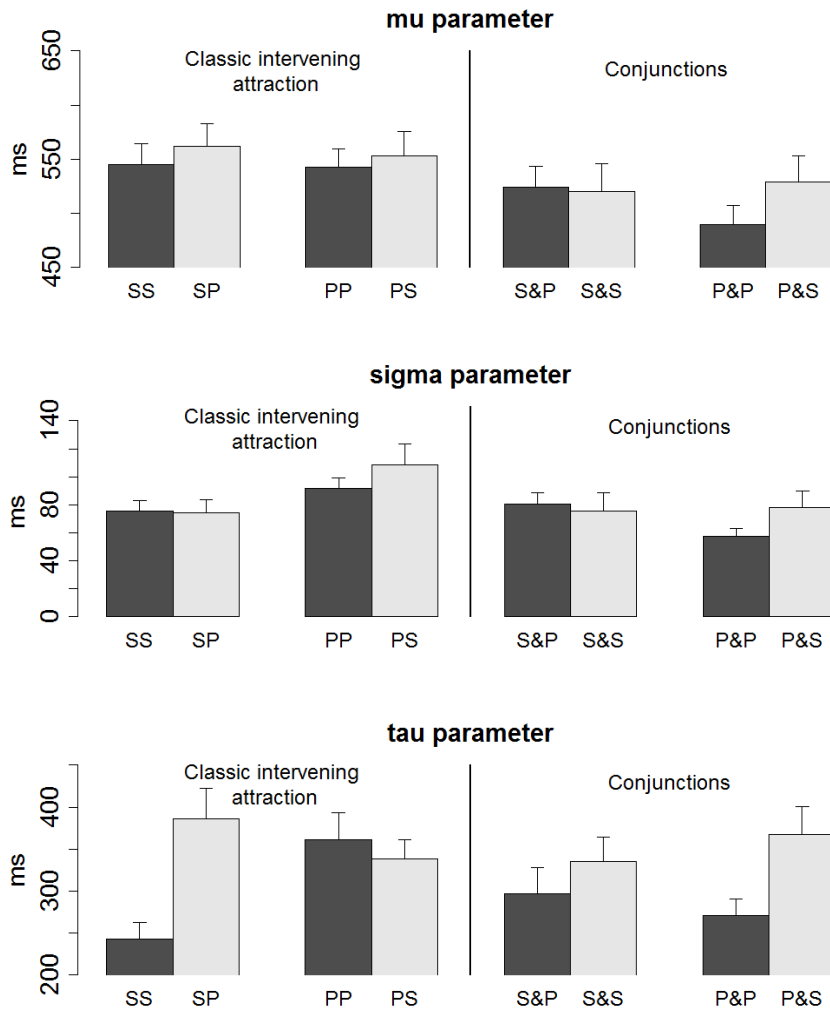


Figure 6. Mean μ (top panel), σ (middle), and τ (bottom) ex-Gaussian parameters, averaged over participants, in each of the eight conditions in Experiment 2. Error bars represent standard errors.

In the conjunction configuration, the increase in correct RT due to a singular conjunct was attributed to effects on both the μ and τ parameters. The effects on μ , regardless of whether the first or second conjunct was singular, were nearly equal compared to the P&P condition (S&P: 34 ms; P&S: 39 ms; S&S: 30 ms). In contrast, the effects on τ were graded depending on which conjunct was singular. The small increase in correct RT due to a singular first conjunct (S&P – P&P, 57 ms) was due to a small effect on τ (26 ms). Consistent with a linear order effect, the larger increase in

correct RT due to a singular second conjunct (P&S – P&P, 105 ms) was due to a larger effect on τ (69 ms). Lastly, the comparable increase in correct RT due to two singular conjuncts (S&S – P&P, 91 ms) was due to a comparably sized effect on τ (64 ms).

These patterns were mostly supported statistically. There was a marginal interaction of first and second noun on μ ($F(1,25) = 3.138, p = .088$) and σ (because σ often varies with μ ; $F(1,25) = 3.632, p = .068$). As seen in Figure 6, μ and σ were lowest in the P&P condition than in any other. On τ , there was a significant main effect of the second noun ($F(1,25) = 27.550, p < .001$), which was qualified by a marginal interaction of first and second noun ($F(1,25) = 3.253, p = .083$). The difference in τ was larger between the P&P and P&S conditions than between S&P and S&S; in both comparisons, τ 's were significantly different from each other.

3.3. Discussion

In Experiment 2, we confirmed in a single experiment that the coordination results of Experiment 1 were indeed empirically distinct from the classic attraction results. A singular attractor after a plural controller (PS) had no influence on verb choice, as participants made a similar number of errors in the PP and PS conditions, and had a small effect of increasing the latency of a correct response. Fitting the correct RTs to the ex-Gaussian distribution revealed that the small increase in correct RT was attributed to non-significant differences in the μ and τ parameters between the PP and PS conditions.

In contrast, a singular second conjunct after a plural first conjunct (P&S) displayed a pattern of results that was similar to that of a plural attractor (SP). It increased error rate, slowed down correct responses, and resulted in error and correct RTs that were nearly equal. The increase in correct RT was due to both a μ shift and a τ effect compared to the P&P condition, suggesting that a singular second conjunct generally interfered with agreement computation. This pattern of results was mostly the same when both conjuncts were singular (S&S); the only difference was that error RT was significantly slower than correct RT, which was not expected.

The plural attractor (SP) in the present experiment similarly increased error rate, slowed down correct responses, and resulted in error and correct RTs that were not significantly different from each other, all of which are consistent with Staub (2010). The failure to observe a μ shift, however, could be explained by low power (9 out of 32 participants were excluded from the ex-Gaussian analyses), but also by how (un)informative each noun was across the experimental and filler stimuli. The first noun in Staub's (2010) experiment was the controller in 50% of the trials (i.e., in the intervening attraction conditions), and the second noun was the controller in the other 50% (i.e., in the non-intervening conditions). Therefore, participants needed to consider both nouns as the controller equally as often. In the present experiment, however, the second noun was the true controller in only 10% of the trials (i.e., in the non-intervening attraction fillers). Because participants did not have to consider the second noun as often (in fact, never in the intervening attraction configuration), the effect of the plural attractor (i.e., the second noun) might not have affected every trial, as explained by a strong τ effect but no μ shift. This is further supported by the low accuracy rate (69%) in the non-intervening SP fillers (e.g., *The clubs that the advertisement are*), in which participants mistook the first noun as the controller. In the conjunction configuration, the second noun was also never the true controller, so in theory, it could have been ignored. However, that was not always the case. Previewing Section 5.3, the agreement mechanism usually searches for a controller that is a DP. A conjoined subject phrase is not a DP though; it is a CoordP, making it less attractive as a controller. This allows a singular second conjunct, which is a DP and thus provides a partial match with the targeted properties, to interfere with agreement computation whenever it is present.

In summary, we observed in this production experiment (i) typical effects of a plural attractor (except for the lack of a μ shift), (ii) typical null effects of a singular attractor, (iii) robust effects of a singular conjunct patterning like a plural attractor, and (iv) linear order effects where a singular second conjunct was more influential than a singular first conjunct. While classic agreement attraction and variable agreement with coordination are sensitive to different qualitative

factors (hierarchical structure vs. linear order/distance, weak vs. strong singular influences), the finding that conjunct number influences correct RT is a strong indication that coordination agreement, like attraction (according to Staub, 2009, 2010), should be modeled in a way that involves general competition (see Sections 5.2-5.3). Before we describe what such a model might look like, we first report one more experiment, which employs an eyetracking while reading paradigm to directly compare a singular local noun to a singular second conjunct. In fact, our proposed mechanism can be applied to both production and comprehension.

CHAPTER 4

EXPERIMENT 3

It is clear from the results of Experiments 1 and 2 that a singular second conjunct can elicit an erroneous singular verb in a production-like paradigm. Experiment 3 assessed whether comparable effects arise in comprehension. In addition, this experiment directly contrasted the effect of a singular second conjunct with the effect of a singular local noun in the classic attraction configuration.

Few studies have used eyetracking while reading to investigate the effect of an attractor on subject-verb number agreement, and even so, results have been mixed (Deutsch, 1998 in Hebrew; Dillon, 2011 and Dillon, Mishler, Sloggett & Phillips, 2013 with subject relative clause modifiers; Pearlmutter et al., 1999). Moreover, eyetracking has not been used (as far as we are aware) to look at conjunction agreement. The current experiment, which directly compares the two types of agreement, thus contributes to both bodies of literature.

The grammaticality effect is characterized by longer reading times on and increased regression probability out of the verb when the number of that verb (usually plural) mismatches the number of its controller (singular). This effect has been replicated across all four eyetracking studies, though its timing has been inconsistent, sometimes as early as first pass time on the verb and persisting into total time (Deutsch, 1998; Dillon, 2011; Dillon et al., 2013), or only in total time on the spillover (Pearlmutter et al., 1999). The one measure in which this effect emerged reliably is the increased likelihood of a regression from the ungrammatical verb.

The attraction effect is characterized by an attenuated grammaticality effect when a number-mismatching local noun (usually plural) intervenes between controller (singular) and verb (plural). Deutsch (1998) showed that, in first pass and total times, the grammaticality effect disappeared when a modifier phrase separated controller and verb. She claimed that the extra distance allowed semantic processes to take place, which made syntactic cues less important. A finding this strong (i.e., the grammaticality effect completely disappearing) has not been replicated

in eyetracking, as studies have since shown a robust, but reduced, grammaticality effect even in the presence of intervening PP modifiers and relative clauses. Dillon and colleagues (2011, 2013) and Pearlmutter et al. (1999) have reported illusions of grammaticality induced by a plural local noun. With a singular controller, an ungrammatical plural verb preceded by a plural local noun (e.g., **The key to the locks are*) showed a smaller grammaticality effect, compared to when it was preceded by a singular noun (e.g., **The key to the lock are*) – that is, faster reading times on the verb and spillover, and fewer regressions out of the verb. As in production, there exists a *mismatch asymmetry* in which a singular local noun again has little if any effect (Dillon, 2011; Pearlmutter et al., 1999; Wagers et al., 2009). The present experiment tested whether a singular second conjunct induces an illusion of grammaticality, whereas a singular local noun in the classic attraction configuration does not.

Experiment 3 also investigated the effect of a singular second conjunct in grammatical sentences. Notably, attraction effects in comprehension have generally been limited to ungrammatical sentences, a pattern that has been termed the *grammaticality asymmetry* (Dillon et al., 2013; Wagers et al., 2009; cf. Engelmann, Jager, & Vasishth, under review). No study (self-paced reading or eyetracking) has shown that a plural local noun significantly disrupts the processing of a grammatical singular verb (e.g., *The key to the cabinets is*) (cf. Pearlmutter et al., 1999, whose illusion of ungrammaticality on the spillover region in self-paced reading can be explained as an extended plural complexity effect; see Wagers et al., 2009). Thus, to the extent that the effect of a singular second conjunct is an attraction-like phenomenon, it would be expected to have an effect only on the comprehension of ungrammatical sentences.

4.1. Method

4.1.1. Participants

There were 56 participants in Experiment 3, none of whom participated in Experiments 1 and 2. The same inclusion criteria as Experiment 1 were used. Seven participants were excluded

and replaced for track loss on more than 25% of the trials (see Section 4.2 for the criteria for track loss). No participants were excluded on the basis of low comprehension accuracy.

4.1.2. Materials

Eighty items were constructed for this experiment, all of which were adapted from Experiment 2 with two changes: (i) A predicate (e.g., *is/are laboring away in the huge mansion*) was added to the end of the preamble, and (ii) The first noun was always plural (fillers excepted).

Thus, three factors were manipulated: (i) Configuration type: classic attraction vs. conjunction, (ii) Second noun number: singular vs. plural, and (iii) Grammaticality: grammatical vs. ungrammatical, which was manipulated by varying the number feature of the agreeing verb. In all conditions, the grammatical verb was always plural, so that interference would be from a singular “attractor”. Each participant viewed a total of 80 experimental preambles, 10 per condition. The eight conditions of this 2×2×2 experiment are illustrated in Table 8.

Table 8

Example Stimulus Set for Experiment 3

Configuration	2 nd noun	Grammaticality	Example sentences
Attraction	S	Grammatical	The maids behind the butler are laboring...
Attraction	P	Grammatical	The maids behind the butlers are laboring...
Attraction	S	Ungrammatical	*The maids behind the butler is laboring...
Attraction	P	Ungrammatical	*The maids behind the butlers is laboring...
Conjunction	S	Grammatical	The maids and the butler are laboring...
Conjunction	P	Grammatical	The maids and the butlers are laboring...
Conjunction	S	Ungrammatical	*The maids and the butler is laboring...
Conjunction	P	Ungrammatical	*The maids and the butlers is laboring...

Note. S = singular noun, P = plural noun, * = ungrammatical.

These experimental sentences were combined with 76 fillers. Examples of 40 of them are provided in (23).

- (23) a. The man with the pail and shovel is digging sand...
 b. The chef with the desserts and wines is preparing...
 c. The dragon guarding the cave and dungeon is slumbering...
 d. The farmer picking apples and oranges is standing on...

These were included to preclude the presence of *and* from always co-occurring with the plural verb in grammatical sentences. The subject phrase was always singular in order to balance the number of singular and plural subjects. In addition, there were 36 unrelated sentences for another experiment, with examples like those in (24). These sentences had two subjects, one in the matrix clause and one in the relative clause, that varied in number, though not all of the verbs were number-marked (e.g., past tense main verbs). All 76 of the fillers were grammatical, so in the experiment as a whole, the distribution of grammatical-ungrammatical sentences was 116-40. The 156 sentences were presented to each participant in an individually randomized order, following 12 practice trials.

(24) a. The investigator that the agency phoned for the job...

b. The mathematician that admired the chairman created...

Forty of the filler sentences (25.6% overall) were followed by a multiple-choice comprehension question. Across items, comprehension questions addressed various parts of the sentence and different thematic roles; this was done to prevent participants from adopting superficial reading strategies that extract information needed to answer the comprehension questions without fully comprehending the sentence. All participants scored above 75% (mean = 87.3%, $sd = 5.5\%$), and no one was excluded on the basis of low comprehension accuracy.

4.1.3. Procedure

The eyetracking experiment was carried out on a Windows XP computer running EyeTrack 7.10m (blogs.umass.edu/eyelab/software), in a normally illuminated room. Eye movements from the left eye were recorded at a sampling rate of 1000 Hz on an SR Research Eyelink 1000 tower-mount eyetracker. Prior to beginning the experiment, the eyetracker was calibrated with a 3-point linear display. The tower stands 55 cm from a 19-in Iiyama CRT monitor, giving the participant approximately 3.69 characters per degree of visual angle.

To initiate a trial, the participant first fixated on a black dot in the center of the computer screen for drift correction. Then, a black square appeared at the left-center edge of the screen where

the first letter of the upcoming sentence would appear. Once a fixation was successfully recognized by the eyetracker, the black square was replaced with a left-justified sentence presented in 11-point Monaco font. After reading the sentence, the participant was instructed to look at a pink square located at the right-center frame of the screen and press a button. A comprehension question and two response options may or may not replace the sentence, to which the participant would answer with a button press. If no question appeared, then the black dot reappeared to indicate the start of the next trial. The eyetracker was recalibrated as necessary between trials to ensure accurate measurement of eye movements.

Each participant was instructed to read for comprehension, but also informed that some of the sentences might be “a little weird” and that they should try to understand these as well as possible. Each session began with six practice sentences and three comprehension questions. The entire experiment lasted approximately 30 minutes.

4.2. Results

Initial stages of data analysis were carried out using RoboDoc and EyeDry (blogs.umass.edu/eyelab/software). Trials in which track loss occurred – a blink on first pass or a long saccade (>75ms) going into or out of the critical verb – were excluded. This resulted in the deletion of 7.8% of trials, leaving 4130 trials for inclusion in the analysis. Short fixations (<80 ms) within one character of an adjacent fixation (previous or subsequent) were added to the adjacent fixation.

The sentences were divided into five regions of interest, as illustrated with slashes in (25): (i) the first determiner and noun, (ii) the preposition or conjunction, (iii) the second determiner and noun, (iv) the inflected form of the verb *be* and the following word, and (v) the next two words. Henceforth, region (iv) will be referred to as critical verb. For the purposes of this thesis, only the critical verb was analyzed.

(25) a. The maid/ next to/ the butler/ is laboring/ away in/ the...

b. The maid/ and/ the butler/ are laboring/ away in/ the...

We computed four eye-movement measures that reflect early and late processing, thus allowing for finer-grained analyses of time-course. As measures of early processing effects, (i) *first pass time* is the sum of all fixations on a region of interest until the reader exits the region either to the left or right, and (ii) *regressions out* is the proportion of trials on which a reader exits a region to the left before exiting it to the right. For later processing effects associated with reanalysis, both of which involve regressive eye movements, (iii) *go-past time* is the sum of all fixations after entering a region (including those on previous portions of text, i.e., rereading), until the reader exits the region to the right, and (iv) *total time* is the sum of all fixations in a region.

Analyses of reading times were carried out using mixed-effects linear models. Analyses of raw times are presented for ease of interpretation, as the log transform did not produce different results. For the analysis of regressions out, a logistic model was used instead, as the dependent measure was categorical, i.e., whether a regression occurred or not. Participants and items were crossed random effects, and the three experimental factors (configuration type, second noun, grammaticality) were crossed fixed effects. The fixed factors were modeled using sum/deviation coding, with conjunction, plural second noun, and grammatical coded as +0.5. We started with a model that included all random slopes, but due to a failure to converge, the random effects structure was simplified until the largest converging model was achieved. For first pass and go-past time on the critical verb, the final model included random intercepts by participants and by items, and random slopes for all fixed effects except the interactions by participants and by items. For regressions out of the critical verb, the final model included only random intercepts by participants and by items. For total time on the critical verb, the final model included random intercepts by participants and by items, random slopes for configuration type and second noun by participants and by items, and a random slope for grammaticality by participants only.

4.2.1. First pass time

The mean first pass time on the verb in each condition is shown in Figure 7, and the model results are reported in Table 9. The only noticeable difference lies in the P&P and P&S conditions,

where first pass time on a grammatical plural verb was longer after a singular second conjunct than after a plural one.

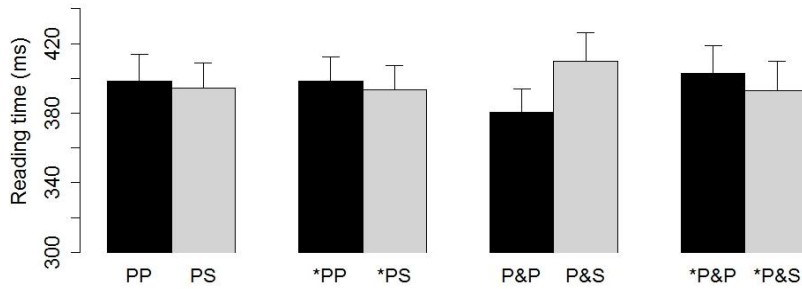


Figure 7. Mean first pass time on the critical verb, averaged over participants, in each of the eight conditions in Experiment 3. Error bars represent standard errors.

This pattern was supported statistically by a significant three-way interaction. Resolving this interaction revealed a second noun by configuration interaction only in the conjunction configuration ($\beta = -39.498$, $SE = 14.634$, $t = -2.699$); no effects were observed in the attraction configuration. Further resolving this interaction revealed a negative effect of a plural second noun in the grammatical ($\beta = -31.620$, $SE = 10.380$, $t = -3.045$), but not the ungrammatical ($\beta = 9.308$, $SE = 11.312$, $t = 0.823$), sentences. In other words, a singular second conjunct resulted in longer first pass time on a grammatical plural verb, but no significant effect on an ungrammatical singular verb. This reflects an early illusion of ungrammaticality.

Table 9

Coefficient Estimates in Milliseconds, and Associated Standard Errors and t-scores, for the Fixed Effects in the Mixed Linear Regression Model of First Pass Time on the Critical Verb in Experiment 3

	Estimate	Std. error	t
(Intercept)	395.548	14.434	27.403
Config: Conjunction	0.677	6.312	0.107
Second noun: Plural	-4.186	5.211	-0.803
Gram: Gram	-0.715	5.620	-0.127
Config: Conjunction \times Second noun: Plural	-13.526	10.073	-1.343
Config: Conjunction \times Gram: Gram	-3.928	10.074	-0.390
Second noun: Plural \times Gram: Gram	-18.510	10.068	-1.838
Config: Conjunction \times Second noun: Plural \times Gram: Gram	-40.351	20.144	-2.003

Note. Green rows are significant at $\alpha = .05$.

4.2.2. Regressions out

The probability of regressing out of the verb in each condition is shown in Figure 8, and the model results are reported in Table 10. There is a greater likelihood of regression in ungrammatical sentences, as well as after a singular second noun, which is unexpected and not consistent with any account of attraction.

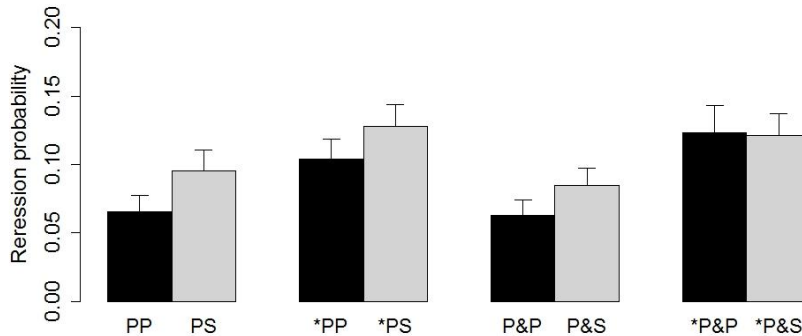


Figure 8. Mean proportion of trials in which a regression was initiated from the critical verb, averaged over participants, in each of the eight conditions in Experiment 3. Error bars represent standard errors.

Table 10

Coefficient Estimates in Log Odds, and Associated Standard Errors and p-values, for the Fixed Effects in the Mixed Logistic Regression Model of Regressions Out of the Critical Verb in Experiment 3

	Estimate	Std. error	p
(Intercept)	-2.471	0.115	<.001
Config: Conjunction	-0.027	0.110	.805
Gram: Gram	-0.489	0.100	<.001
Second noun: Plural	-0.266	0.110	.016
Config: Conjunction × Second noun: Plural	0.219	0.220	.318
Config: Conjunction × Gram: Gram	-0.196	0.200	.373
Second noun: Plural × Gram: Gram	-0.240	0.219	.274
Config: Conjunction × Second noun: Plural × Gram: Gram	-0.256	0.439	.559

Note. Green rows are significant at $\alpha = .05$.

These patterns were supported statistically. The estimate of the intercept is the log odds of regressing averaged across all conditions; the fact that this estimate is significant and negative indicates that regressions were very rare (~7.2%). The significant negative estimates associated with grammaticality and with the second noun indicate that the log odds of regressing out of the

verb was lower on a grammatical verb or if preceded by a plural second noun. An ungrammatical verb increased the probability of regression to ~12%, and a singular second noun increased the probability of regression to ~10%.

4.2.3. Go-past time

The mean go-past time on the verb in each condition is shown in Figure 9, and the model results are reported in Table 11. Go-past times were longer in the ungrammatical sentences compared to the grammatical ones. Consistent with first pass time, go-past time on a grammatical plural verb was slower after a singular second conjunct than after a plural one.

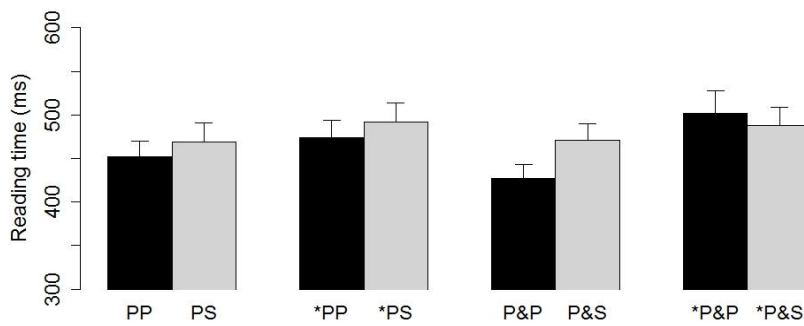


Figure 9. Mean go-past time on the critical verb, averaged over participants, in each of the eight conditions in Experiment 3. Error bars represent standard errors.

These patterns were mostly supported statistically. The significant negative estimate associated with grammaticality indicates that reading times were 33 ms faster on a grammatical plural verb, but this is qualified by a marginal three-way interaction. Resolving this interaction revealed a significant negative effect of a plural second noun ($\beta = -45.110$, $SE = 15.040$, $t = -3.000$) and a significant second noun by grammaticality interaction ($\beta = -60.60$, $SE = 23.88$, $t = -2.537$) only in the conjunction configuration; no effects were observed in the attraction configuration. Further resolving the interaction revealed a negative effect of a plural second conjunct in the grammatical ($\beta = -45.860$, $SE = 15.000$, $t = -3.057$), but not the ungrammatical ($\beta = 16.32$, $SE = 22.390$, $t = 0.729$), sentences. Consistent with first pass time, a singular second conjunct resulted in longer go-past time on a grammatical plural verb, but not on an ungrammatical singular verb.

Table 11

Coefficient Estimates in Milliseconds, and Associated Standard Errors and t-scores, for the Fixed Effects in the Mixed Linear Regression Model of Go-Past Time on the Critical Verb in Experiment 3

	Estimate	Std. error	t
(Intercept)	470.649	18.769	25.076
Config: Conjunction	-0.797	9.996	-0.080
Second noun: Plural	-17.353	10.865	-1.597
Gram: Gram	-32.916	11.668	-2.821
Config: Conjunction × Second noun: Plural	5.678	16.789	0.338
Config: Conjunction × Gram: Gram	-25.093	16.795	-1.494
Second noun: Plural × Gram: Gram	-28.640	16.782	-1.707
Config: Conjunction × Second noun: Plural × Gram: Gram	-63.921	33.548	-1.903

Note. Green rows are significant at $\alpha = .05$.

4.2.4. Total time

The mean total time spent on the verb in each condition is shown in Figure 10, and the model results are reported in Table 12. Total reading times were slower in the ungrammatical sentences compared to the grammatical ones. Consistent with first pass and go-past times, total time on a grammatical plural verb was longer after a singular second conjunct than after a plural one. Furthermore, total time on an ungrammatical singular verb was faster after a singular second conjunct than after a plural one.

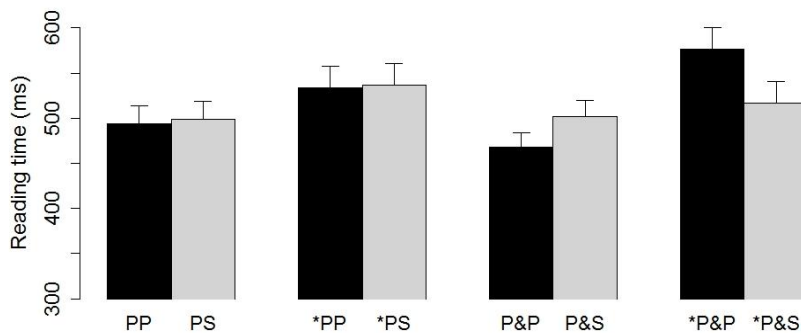


Figure 10. Mean total time on the critical verb, averaged over participants, in each of the eight conditions in Experiment 3. Error bars represent standard errors.

These patterns were supported statistically. The significant negative estimate associated with grammaticality indicates that reading times were 51 ms faster on a grammatical plural verb. This main effect is qualified by a significant three-way interaction. Resolving it revealed the full

asymmetry between the two configuration types. In the attraction configuration, only a main effect of grammaticality was observed ($\beta = -38.291$, $SE = 14.806$, $t = -2.586$). In the conjunction configuration, a main effect of grammaticality ($\beta = -63.250$, $SE = 14.300$, $t = -4.423$) as well as an interaction of grammaticality and second noun ($\beta = -91.740$, $SE = 20.870$, $t = -4.396$) were observed. Further resolving the interaction revealed a positive effect of a plural second conjunct in the ungrammatical sentences ($\beta = 58.500$, $SE = 18.13$, $t = 3.226$), but a negative effect in the grammatical sentences ($\beta = -35.330$, $SE = 13.140$, $t = -2.689$). This crossover interaction reflects both illusions of grammaticality and ungrammaticality. In other words, a singular second conjunct resulted in faster total times on an ungrammatical singular verb and slower on a grammatical plural verb, the latter of which is consistent with first pass and go-past times.

Table 12

Coefficient Estimates in Milliseconds, and Associated Standard Errors and t-scores, for the Fixed Effects in the Mixed Linear Regression Model of Total Time on the Critical Verb in Experiment 3

	Estimate	Std. error	t
(Intercept)	515.757	19.501	26.448
Config: Conjunction	-2.603	9.056	-0.287
Second noun: Plural	2.926	8.922	0.328
Gram: Gram	-51.218	12.527	-4.089
Config: Conjunction \times Second noun: Plural	17.396	15.135	1.149
Config: Conjunction \times Gram: Gram	-24.579	15.135	-1.624
Second noun: Plural \times Gram: Gram	-46.870	15.131	-3.098
Config: Conjunction \times Second noun: Plural \times Gram: Gram	-86.055	30.267	-2.843

Note. Green rows are significant at $\alpha = .05$.

4.3. Discussion

Experiment 3 revealed different patterns of results in the attraction and conjunction configurations. As expected based on previous studies, a singular local noun induced neither an illusion of ungrammaticality on a grammatical singular verb nor an illusion of grammaticality on an ungrammatical plural verb. Only the grammaticality effect was observed in the attraction sentences, in regressions out, go-past time, and total time on the critical verb.

A singular second conjunct, in contrast, induced both types of illusions. The illusion of ungrammaticality, which is not generally seen in the attraction configuration, appeared in the first pass, go-past, and total time measures on the critical verb. This was characterized by longer reading times on a grammatical plural verb after a singular second conjunct (P&S) than after a plural one (P&P). The illusion of grammaticality, however, emerged later in total time on the critical verb, as total time was shorter on an ungrammatical singular verb after a singular second conjunct (*P&S) compared to after a plural one (*P&P).

In summary, Experiment 3 revealed clear dissociations in comprehension between classic agreement attraction and agreement with the nearer conjunct. Consistent with previous studies, a singular local noun had no effect in comprehension, while a singular second conjunct had clear effects. These effects took the form of both an illusion of grammaticality – which is often observed with plural local nouns – and an illusion of ungrammaticality, which is not usually observed. Indeed, the illusion of ungrammaticality that appeared when a singular second conjunct was followed by a plural verb was in evidence earlier than was the illusion of grammaticality, as the former illusion appeared in multiple reading time measures on the critical verb itself, while the latter only appeared in total time on the critical verb.

CHAPTER 5

GENERAL DISCUSSION

The present experiments were partly motivated by an atheoretical (and superficial) observation that a conjunction agreement error looks like an attraction error. In both, inconsistent number information within the subject phrase (i.e., a plural local noun following a singular controller, or a singular second conjunct) elicits the wrong verb form in production and makes illicit agreement less salient in comprehension. Throughout, however, we showed that the two phenomena, classic agreement attraction on the one hand, and variable agreement with coordinate subjects on the other, are qualitatively distinct from one another.

In production, an attraction error is driven by the *hierarchical* proximity of a *plural* local noun to the controller (Franck et al., 2002). Variable agreement with disjoined and conjoined subjects, in contrast, is sensitive to the *linear* proximity of a *singular* noun (cf. the mismatch asymmetry; e.g., Bock & Miller, 1991) to the target. This is characterized by effects of both linear order, in which the second disjunct or conjunct has a stronger influence on agreement computation than the first one (an extension of Haskell & MacDonald, 2005), as well as linear distance, in which the presence of material between the second noun and verb reduces the influence of that noun. In fact, neither linear order nor linear distance plays a role in agreement attraction, as evidenced by the replicated finding that the first local noun is a stronger attractor than the second one, and the novel finding that the presence of material between the first local noun and verb does not modulate its strength as an attractor.

Moreover, in comprehension, a singular second conjunct induces both an early illusion of ungrammaticality (cf. the grammaticality asymmetry; e.g., Wagers et al., 2009) as well as a late illusion of grammaticality, whereas a plural local noun only induces the latter, and a singular local noun induces neither.

Taken together, these results suggest that variable agreement with the nearer noun in a coordinate subject should not be considered an attraction phenomenon, as it has none of the

defining characteristics of attraction: there is no mismatch asymmetry, there is no grammaticality asymmetry, and there is sensitivity to linear, not hierarchical, relations. This conclusion has one major implication: The presence of linear order and linear distance effects with coordinate subjects is *not* evidence that linear order and linear distance play a role in agreement computation more generally (cf. Haskell & MacDonald, 2005). Instead, distinct theoretical treatments are required for the two distinct phenomena. In the following section, we summarize the two types of accounts that have been offered for classic attraction: feature mis-valuation and controller mis-retrieval. These accounts, however, depend on the markedness of plurals to explain the mismatch asymmetry and an error-driven mechanism to explain the grammaticality asymmetry, and so they are inadequate to account for variable agreement with coordinate subjects. In the end, we discuss assumptions that would enable a controller mis-retrieval account to be compatible with the coordination results. We speculate that the critical linear effects in production and the symmetrical illusions in comprehension arise from the structure of coordinate phrases and how number is represented in these phrases.

5.1. Feature mis-valuation

One type of explanation of agreement attraction emphasizes the possibility that the number of the subject phrase is incorrectly represented, which can be explained with *feature percolation* (Franck et al., 2002) or *marking and morphing* (Bock et al., 2001; Eberhard, Cutting, & Bock, 2005 for a computational implementation). In feature percolation, the representation of the subject phrase's number is susceptible to change if information is spuriously passed through the links between constituents. A plural feature on a local noun may percolate node-by-node up the syntactic tree, and if it travels high enough, then it may mis-value a singular subject phrase and make it look plural. (In some versions, the feature may percolate downward, primarily to account for non-intervening attraction errors.) In production, this would elicit an attraction error, and in comprehension, this would make an ungrammatical verb less salient (i.e., an illusion of grammaticality).

The marking and morphing model, on the other hand, is less constrained with respect to where and how a plural feature can spread. A subject phrase's reconciled number is computed as a weighted average of its "marked" notional number (generated at the message level) and its "morphing" elements, i.e., the grammatical number (retrieved from morphology) of each noun in the subject phrase. For example, the subject phrase *The helicopter for the flights over the canyons* is notionally singular; the controller (*helicopter*) is grammatically singular; and the local nouns (*flights* and *canyons*) are grammatically plural. The two nouns are weighted according to their level of embedding such that the controller (the head of the subject phrase) is weighted the most, and subsequent local nouns are weighted less and less. But in the event that the latter incorrectly overpowers the valuation, then the reconciled number is computed to be more plural-like. A probabilistic decision process then takes the reconciled number as its input and outputs the final verb number, which may result in an attraction error or an illusion of grammaticality.

Feature mis-valuation can account for the two main characteristics of agreement attraction. First, the influence of syntactic hierarchy, that attraction is driven by the hierarchical distance between the local noun and controller and not by the linear distance between the local noun and target, follows quite naturally. In feature percolation, the closer the local noun is to the controller, the fewer nodes there are for the number feature to percolate up. In marking and morphing, the level of embedding determines how strongly each noun affects number valuation. Second, the weak influence of singulars (i.e., the mismatch asymmetry) also follows quite naturally, as long as the markedness asymmetry is assumed: In English, a singular noun is characterized by the absence of a plural feature and not by the presence of a singular one. So in feature percolation, there exists no singular feature that can percolate up to a plural subject phrase and mis-value it as singular. In marking and morphing, the singular number on a noun is weighted less so that it does not affect number valuation as strongly.

Feature mis-valuation, on the other hand, cannot account for the grammaticality asymmetry observed in Wagers et al.'s (2009) self-paced reading experiments. If *The helicopter for the flights*

is mis-valued as plural on some proportion of the sentences, which should not depend on grammaticality, then a grammatical singular verb should be erroneously considered ungrammatical (i.e., an illusion of ungrammaticality is induced) as often as an ungrammatical plural verb is considered grammatical (i.e., an illusion of grammaticality). Existing evidence, however, shows that attraction effects are restricted to ungrammatical sentences, as illusions of ungrammaticality have not been reported (e.g., Dillon et al., 2013; Wagers et al., 2009).

Moreover, feature mis-valuation cannot account for the observed linear and singular effects associated with coordination agreement. First, the hierarchical structure of a coordinate phrase appears to be a non-factor. The second constituent, which is more deeply embedded, has a stronger influence on agreement than the first constituent, which is in a supposedly privileged specifier position. Second, increasing linear distance between the second constituent and verb (by adding a non-number-marked adverb or reduced relative clause) reduces the influence of the second constituent. This is not predicted by feature mis-valuation because the syntactic distance between the second constituent and head node remains unaffected by intervening material, and the second constituent's level of embedding remains constant. And third, most notably, singular nouns elicit singular verbs. In an error like **The maid and the butler is*, there is no singular feature on *maid* or *butler* that can percolate up to make the entire coordinate subject phrase look singular. Although the grammatical number of each constituent is singular, it is unlikely that they can overpower (or “morph”) the marked notional plurality, given that singulars are weak in number valuation. Because neither feature percolation nor marking and morphing can account for these qualitative differences, variable agreement with coordination should not be attributed to feature mis-valuation.

5.2. Controller mis-retrieval

We instead propose that variable agreement with conjunction is the result of a *controller mis-retrieval* process. We first summarize how mis-retrieval applies to attraction, and then describe how it can also explain the effects observed in coordination agreement, both in production and in comprehension. Lewis and Vasishth (2005) incorporated principles of working memory – limited

focal attention, cue-based retrieval, (re)activation, decay, and similarity-based interference – into a computational framework for sentence processing, which has since been applied to agreement attraction in production (Badecker & Kuminiak, 2007, though in Slovak with gender instead of number; Badecker & Lewis, 2007) and in comprehension (Wagers et al., 2009).

Prior to producing a verb form, the speaker (or button presser in the case of Staub’s (2009) paradigm) must retrieve the subject/controller from working memory and inspect it for its number information. This is the number that will be marked onto the verb. In *The helicopter for the flights*, the targeted properties (e.g., [ROLE: SUBJECT]⁴, [CATEGORY: DP], [NUMBER: VAR]) fully converge on the subject phrase, which is the true controller of the verb form. This must be isolated from other elements that share some of the relevant properties (e.g., *flights* is a DP with number). An agreement error occurs when the number feature is retrieved from a non-subject noun. Because the variable number cue is included, the retrieval system is biased to return number-marked nouns, so plural local nouns lead to greater attraction than singular ones, which is consistent with the mismatch asymmetry.

Extending controller mis-retrieval to coordination agreement is straightforward. The speaker must retrieve the subject coordinate phrase (CoordP), such as *The maid and the butler*, and inspect it for number. Unlike in attraction, though, the targeted properties do not fully converge on the coordinate phrase. Only [ROLE: SUBJECT] provides a match, as the subject here is neither a DP (i.e., it is a CoordP) nor specified for number. The agreement mechanism will have to appeal to the semantics for number information (Farkas & Zec, 1995; Wechsler, 2011; see Section 5.3). Errors, then, arise because the individual constituents match the other properties (i.e., they are DPs that may or may not have number) and interfere with retrieval. If either *maid* or *butler* is mis-retrieved in (26a), then an erroneous singular verb is produced. Moreover, *maid* is weaker in activation (i.e., it is more decayed in working memory because more time passed) than *butler*, suggesting that

⁴ This could also be [CASE=NOMINATIVE] or [POSITION=SPEC OF IP].

butler will be mis-retrieved more often. There would be more errors like (26b) than like (26c), which is consistent with the linear order effect observed in Experiment 1b.

- (26) a. The maid and the butler are...
- b. *The maids and the butler is...
- c. *The maid and the butlers is...

In comprehension, the mechanism is slightly different. Readers are thought to initiate cue-based retrieval as a repair strategy only when they detect a mismatch in subject and verb number (Lago, Shalom, Sigman, Lau, & Phillips, 2015). When a subject phrase is encountered, the number of the upcoming verb can immediately be predicted. When the verb is encountered, and its number matches the predicted number, nothing needs to be retrieved. This explains the grammaticality asymmetry observed in Wagers et al.'s (2009) self-paced reading experiments. An illusion of ungrammaticality is not induced because retrieval is not needed in grammatical sentences. However, when the verb's number mismatches the predicted number, then retrieval is initiated to check whether the subject's number feature was somehow missed. It is during this repair stage that a number-matching attractor is sometimes mis-retrieved. Following the markedness asymmetry, an ungrammatical singular verb has no number feature to use as a cue during retrieval, so a singular attractor is seldom mis-retrieved, which is consistent with the mismatch asymmetry.

Extending this mechanism to coordination agreement is less straightforward. Two inconsistencies arise if cue-based retrieval is used as a repair strategy and if the markedness asymmetry is preserved. First, Experiment 3 revealed an illusion of ungrammaticality (i.e., slower reading times) on the grammatical plural verb in a sentence like (27a) compared to (27b), which is not consistent with the grammaticality asymmetry reported by Wagers et al. (2009). A grammatical verb does not initiate retrieval, so the singular feature of the second constituent is not predicted to interfere with processing the verb. Second, Experiment 3 also revealed an illusion of grammaticality (i.e., faster reading times) on the ungrammatical singular verb in a sentence like (27c) compared to (27d). This finding is not consistent with the mismatch asymmetry. A singular

verb supposedly has no number feature to use as a cue during retrieval, so a singular constituent is not predicted to be mis-retrieved.

- (27) a. The maids and the butler are laboring away.
b. The maids and the butlers are laboring away.
c. *The maids and the butler is laboring away.
d. *The maids and the butlers is laboring away.

In order to resolve these inconsistencies, we propose that retrieval occurs on all sentences (perhaps as a repair strategy) during coordination agreement. When a conjunction is encountered, the number prediction made on the first constituent is suspended because a coordinate phrase is syntactically undefined for number (Farkas & Zec, 1995; Wechsler, 2011; see Section 5.3). The number of the upcoming verb cannot be predicted, so there is never a match between the predicted and actual verb numbers. At the verb, then, retrieval has to occur regardless of its grammaticality. As in the production mechanism, the entire coordinate subject phrase must be retrieved, and its semantics has to be inspected for number information. The targeted properties do not fully converge on the coordinate phrase (which only matches [ROLE: SUBJECT]), so a singular constituent (which partially matches [CATEGORY: DP]) may be mis-retrieved. Unlike in attraction, the number cue provided by the verb plays a smaller role in coordination agreement, where interference mainly arises from the conflict between [ROLE: SUBJECT] and [CATEGORY: DP].

5.3. Differences in number computation

In fact, the controller mis-retrieval account of agreement attraction is no different from that of variable agreement with coordination. What differs is how the number of the respective subject phrases is computed and the role that each noun plays in that computation. More generally, the empirical differences between the two phenomena arise from the differences in the structure of a subject DP and the structure of a subject CoordP (Nevins, 2015). When a head noun is followed by a local noun in object position, that head noun is the controller, so it transmits its number value to the maximal projection DP. The number of that noun (and therefore the DP) is the number that will

be involved in agreement. The local noun is embedded inside a PP and does not need to be considered to compute subject number. Thus, attraction effects are sensitive to this hierarchical relationship. In contrast, when two nouns are coordinated, neither noun is the head of the subject CoordP (assuming Munn's (1993) syntax), so neither noun provides a number for agreement. This obviates any reason for the agreement computation to respect the nouns' hierarchical relationship. The number feature cannot come from the individual nouns alone, as two conjoined singulars require a plural verb, nor can it come from the Coord head, as there is evidence that *and* is not inherently plural, as illustrated by sentences like those in (28) (adapted from Heycock & Zamparelli, 2005).

- (28) a. No linguist and no philosopher thinks/*think that this is easy.
b. Every parent and every teacher wants/³want to speak.
c. This/*These boy and girl are dancing together.
d. That Andy is here and that Billy has left seems/³seem strange.

If the Coord head is inherently featureless, there is no number value to transmit to the maximal projection CoordP, so the number of the subject remains syntactically undefined. We follow Farkas and Zec (1995) who claim that “the agreement features of coordinate noun phrases will have to be determined by the properties of the corresponding discourse referents, rather than by the morphosyntactic features of their conjuncts” (p. 89). This *semantic* agreement contrasts with the *syntactic* agreement involved in the typical attraction configuration, where only the number of the head noun needs to be considered to determine the subject DP's number. This also contrasts with languages like Hungarian and Slovenian, in which the Coord head deterministically computes its own number by inspecting the number features of both of its constituents (e.g., Kiss, 2012; Marušič, Nevins, & Badecker, 2015).

More recently, Wechsler (2011) proposed the Agreement Marking Principle, as defined in (29), to enforce agreement when the controller lacks a syntactic feature. For example, a noun like

sheep is not specified for number, so semantic agreement is necessary: *this sheep is* and *these sheep are* are allowed if their interpretations are semantically singular and plural, respectively.

(29) Agreement Marking Principle:

Agreement is driven by a syntactic feature of the controller, if the controller has such a feature. If the controller lacks such a feature, then the target agreement inflection is semantically interpreted as characterizing the controller denotation (p. 22).

A CoordP essentially behaves like a number-ambiguous noun like *sheep*. Because the agreement features of a subject CoordP depend on the properties of its discourse referent, the alternation in (30) is straightforwardly accounted for (see also Note 1). The singular agreement is allowed in the case where the two singular conjuncts identify the same discourse referent. The plural agreement is also allowed even though there are no morphosyntactically plural elements anywhere.

(30) The psychologist and the linguist is/are sitting at my table.

Given these theoretical and representational claims, we now return to a discussion of the experimental results in a retrieval-based and featureless framework.

5.4. Summary

Although classic agreement attraction and variable agreement with coordination are sensitive to different factors (i.e., weak vs. strong singulars, hierarchical structure vs. linear order/distance), a singular conjunct exhibited the same effects as a plural attractor⁵ (Staub, 2009, 2010). They not only increase the likelihood of error responses, but also increase the latency of correct responses, and the sizes of these two effects are related, with more errors corresponding to more slowing (illustrated in Figure 5). In other words, both of them generally affect the difficulty of agreement computation, across all trials and not only on a subset of them. This warrants unifying the two phenomena, despite the qualitative empirical differences, under a single controller mis-

⁵ Well, only if you compare my coordination results with Staub's (2009, 2010) attraction results.

retrieval mechanism that involves general interference in agreement computation. Under such an account, there might be competition between retrieving the true controller (i.e., the subject DP or the subject CoordP) and retrieving a non-subject noun (i.e., the local noun or an individual conjunct) that partially matches the targeted properties (e.g., [ROLE: SUBJECT], [CATEGORY: DP], [NUMBER: VAR]). The effect of mis-retrieving a plural conjunct is not separable from the effect of retrieving the subject CoordP, as both would elicit a plural verb. But if a singular conjunct is mis-retrieved, a speaker will erroneously produce a singular verb, and a reader will show processing ease at an ungrammatical singular verb (i.e., an illusion of grammaticality) and difficulty at a grammatical plural verb (i.e., an illusion of ungrammaticality, which is not observed in attraction).

The distinction between weak singular effects in attraction and strong singular effects in coordination, as observed in Experiments 1 and 2, follows quite naturally from our controller mis-retrieval account. During controller retrieval, the agreement mechanism targets an element that is a number-marked DP in the subject role. Note that this retrieval process only identifies the controller of number agreement and has no bearing on thematic role assignment. In attraction, the subject DP and the local noun are both DPs, so CATEGORY is the least influential property in identifying the controller. Mis-retrieving the local noun, then, arises from a partial match with respect to NUMBER. The markedness asymmetry explains why a singular local noun is a weak attractor: It carries no number feature, so it cannot provide a partial match. A plural local noun, on the other hand, does have a number feature, which creates a partial match and allows it to be mis-retrieved as the controller. In contrast, a singular conjunct has no number feature like a singular local noun, but neither does the subject CoordP (it is inherently featureless), so NUMBER is in fact the least influential property in identifying the controller. Mis-retrieving the singular conjunct, then, arises from a partial match with respect to CATEGORY and not NUMBER (as is the case with a plural local noun). The subject CoordP is not a DP, while an individual conjunct is, thereby allowing it to be mis-retrieved as the controller (assuming DP is a typical targeted property for a controller).

The distinction between hierarchical structure and linear order/distance does not necessarily follow from our controller mis-retrieval account⁶, but can be explained by a theoretical account of how a subject DP and a subject CoordP compute their respective number features. A head noun followed by a PP modifier is the agreement controller, so the number of that noun is transmitted to the subject DP and eventually the verb. The local noun plays no role during number computation because it is embedded inside of a PP. Consequently, attraction effects are sensitive to the nouns' hierarchical relationship. In contrast, neither noun in a coordinate subject is the agreement controller. The Coord head is a featureless *and* (or *or*), so nothing is transmitted to the subject CoordP. It remains syntactically undefined for number and instead acquires its number from the discourse referents (Farkas & Zec, 1995; Wechsler, 2011). This implies that the subject CoordP's number comes from considering both conjuncts, unlike a subject DP which gets its number only from the head noun. Even though the second conjunct is more deeply embedded as the complement to the Coord head (compared to the first conjunct in specifier position), it is more recently processed (i.e., less decayed in working memory), so coordination agreement is sensitive to the conjuncts' linear relationship. These claims are consistent with Experiments 1 and 2, which revealed independent effects of the first and second conjuncts (i.e., both nouns are being considered), with the second conjunct having stronger effects⁷.

These claims are also consistent with Experiment 3. A singular attractor induced neither illusions of ungrammaticality nor grammaticality, while a singular second conjunct induced both. When the subject CoordP and the second conjunct matched in number (P&P), readers readily

⁶ In particular, we wanted a unified mechanism that explains the hierarchical effects seen in agreement attraction as well as the linear effects seen in coordination agreement. As a result, our mis-retrieval account is independent of any form of structure.

⁷ Although the ex-Gaussian analyses were very equivocal (due to low power), an interesting pattern was observed. A singular first conjunct and a singular second conjunct resulted in equally-sized μ shifts. The sizes of the τ effect, however, were graded depending on which conjunct was singular, with the second one having a larger τ effect. This might reflect two sources of interference: a general effect of "singular-ness" (μ shift) and a less general effect of "second-ness" (τ effect). This claim will need to be tested.

accepted the plural verb (fastest total time) and strongly dispreferred the singular (slowest). And when the subject CoordP and the second conjunct mismatched in number (P&S), the grammatical plural verb was processed slower (illusion of ungrammaticality), while the ungrammatical singular verb was processed faster (illusion of grammaticality). Critically, total reading times on the singular or plural verb were similar after a singular second conjunct. This might reflect that readers mis-retrieved the singular conjunct equally often, regardless of the sentence's grammaticality. Nevertheless, the singular verb elicited slightly more regressions, indicating that readers did indeed disprefer the singular verb, perhaps as a result of having a clear agreement rule.

Our controller mis-retrieval account explains the illusion of ungrammaticality in the following way. Retrieval is always necessary at the verb because a number prediction for the upcoming verb is never made when a coordinate subject phrase is encountered (it is syntactically undefined for number). So on some proportion of the P&S sentences, the reader may have mis-retrieved the singular second conjunct, whose lack of a number feature mismatches the plural feature on the verb, and so we see an illusion of ungrammaticality when the verb is in fact grammatical. A similar explanation can account for the late illusion of grammaticality. The singular second conjunct facilitated the processing of the ungrammatical verb as a result of a partial match between conjunct and verb. Again, on some proportion of the *P&S sentences, the reader might have mis-retrieved the singular second conjunct, whose lack of a number feature "matches" the absence of a number feature on the verb. Because the illusion of grammaticality emerged only on total time, this suggests that readers were faster to detect the perceived ungrammaticality between a singular second conjunct and a plural verb, than to detect the perceived grammaticality between a singular second conjunct and a singular verb. This could be explained by the markedness asymmetry, in that a plural verb is marked with a number feature, so the mismatch with an unmarked singular conjunct was more readily detected, compared to detecting the match between two unmarked elements.

Our account of these illusions rests on three assumptions, all of which need to be tested. (i) Upon encountering the subject CoordP, a number prediction for the upcoming verb is never made, so controller retrieval has to occur all the time. This follows from the theoretical account that a CoordP is syntactically undefined for number. (ii) Detecting the perceived ungrammaticality between a singular second conjunct and a plural verb is faster than detecting the perceived grammaticality between a singular second conjunct and a singular verb. This follows from the markedness asymmetry, in that a plural verb is marked with a number feature, so the mismatch with an unmarked conjunct is more readily detected, compared to the “match” between an unmarked verb and an unmarked conjunct. And (iii) A singular conjunct is able to be mis-retrieved in the first place because it matches the [CATEGORY: DP] property, while the true controller does not (it is a CoordP). This assumes that, across all controller types, the DP controller is the most common and the one that the retrieval mechanism expects to find.

CHAPTER 6

CONCLUSION

In summary, we had four goals throughout this study, all of which were accomplished: (i) To show that the effect of linear order is present in coordinate structures more broadly, and not just in disjunctions, (ii) To distinguish the effect of linear order from the effect of linear distance, (iii) To assess whether linear effects are limited to agreement with coordinate structures, or whether they play a role in number computation more generally, and (iv) Lastly, to investigate whether variable agreement with coordinate subjects have similar or different underlying mechanisms as classic agreement attraction.

We presented evidence suggesting that the two phenomena show qualitatively different profiles. Experiments 1 and 2, both production experiments, revealed that (i) Neither linear order nor linear distance played a role in classic attraction, but both affected variable agreement with coordinate subjects, and (ii) While a singular attractor did not elicit a singular verb, a singular conjunct (whether in first position, second, or both) did. A singular conjunct in second position elicited more singular responses compared to one in first position (a linear order effect), and the presence of intervening material after a singular second conjunct decreased its influence (a linear distance effect). Experiment 3, a comprehension experiment, confirmed the null effect of a singular attractor and the robust effect of a singular second conjunct. A singular attractor induced neither illusions of grammaticality nor ungrammaticality, while a singular second conjunct induced both.

Despite these qualitative empirical differences, we claimed that both types of variable agreement behavior can be explained by a single controller mis-retrieval mechanism that involves interference in agreement computation. The differences, then, arise from a representational claim that a coordinate subject phrase is not headed by the individual conjuncts and is syntactically unspecified for number. This enables mistaken agreement with a nearby noun as well as with a singular.

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