Exploring the abstractness of number retrieval cues in the computation of subject-verb agreement in comprehension

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ABSTRACT

Subject-verb agreement has provided critical insights into the cue-based memory retrieval system that supports language comprehension by showing that memory interference can cause erroneous agreement with non-subjects: 'agreement attraction'. Here we ask how faithful retrieval cues are in relation to the grammar. We examine the impact of conjoined singular attractors (*The advice from the doctor and the nurse…*), which are syntactically plural but whose plurality is introduced by a vehicle, the conjunction '*and*', that is not an unequivocal correlate of syntactic plurality. We find strong agreement attraction, which suggests that retrieval processes do not only target unequivocal morphological correlates of syntactic plurality. However, we also find some attraction with conjoined adjective attractors (*The advice from the diligent and compassionate doctor…*), which is compatible with a system in which an imperfect correlate of syntactic plurality, like the word '*and*,' can become associated with the plural retrieval cue due to frequent co-occurrence with the actual target feature.

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Introduction

In understanding sentences, comprehenders often form dependencies between linguistic items that are not directly adjacent. For example, in the sentence *The boy next to the beautiful trees probably does not hear the music,* the verb *does* has to agree in number with the subject phrase, despite being separated from it by an adverb and being separated by still more words from the head of that phrase (*boy*) which carries the relevant number information. Recent research has used a number of linguistic dependencies to investigate the architecture of the memory system underlying this process and has suggested that it relies on cue-based retrieval of content-addressable items in memory (Dillon, Mishler, Sloggett, & Phillips, 2013; Lago, Shalom, Sigman, Lau, & Phillips, 2015; Tanner, Nicol, & Brehm, 2014; Wagers, Lau, & Phillips, 2009). Here we ask how faithful retrieval is in relation to the grammar. Do retrieval models necessitate the inclusion of cues as abstract as the terms in which the grammatical dependencies are stated? Or is it sufficient for cues to target only certain instantiations of an abstract category, perhaps the most frequent ones? In this paper we pursue the issue through the comprehension of subject-verb agreement in English, aiming at the general question of how the grammar is respected in online comprehension processes (Lewis & Phillips, 2015).

Cue-based retrieval in sentence processing

Much recent work on sentence processing supports the view that the underlying memory system operates on the basis of cue-based retrieval (Lewis & Vasishth, 2005; Martin & McElree, 2009; McElree, 2000; McElree, Foraker, & Dyer, 2003; Van Dyke & McElree, 2006). Here, we will assume a cue-based retrieval system as outlined in detail by Lewis and Vasishth (2005). In this system, linguistic items are encoded in memory as bundles of features and are content-addressable based on the features they contain. Each item stored in memory is associated with a certain level of activation. When a comprehender encounters a retrieval cue in the input, this triggers a search for a target containing a matching feature. Due to the content-addressable nature of the system the search proceeds in a parallel rather than serial fashion (Martin & McElree, 2009). Items with a matching feature receive a boost of activation from the retrieval cue and the item with the highest activation level is retrieved from memory.

This model gives us an outline of the process underlying memory retrieval in language comprehension. But it does not specify whether the retrieval cues can be as abstract as the terms in which

a dependency is stated in the grammar. In the grammar, dependencies like subject-verb agreement typically respond to very general features, such as [plural], and not more specific categories, such as *suffixal plural* or *ablauting plural*, or even particular items, such as *duck'* or *geese* (Bock & Eberhard, 1993; Corbett, 2000). It is possible that retrieval cues are only associated with the morphological exponence of a feature, or its *vehicle*. However, the memory processes used to establish these dependencies might be equally abstract, targeting the relevant general feature, regardless of specifically how it is introduced or signaled. This would not preclude the possibility that cues might also be associated with particular morphological pieces, sometimes. But it would necessitate the inclusion of general or abstract cues in our retrieval models that are not linked to a specific morphological form. Here, we use the phenomenon of subject-verb agreement attraction in comprehension to explore this question.

Subject-verb agreement attraction in production

Agreement attraction was first systematically studied in production by Bock and Miller (1991). They found that in a sentence completion task participants were more likely to produce agreement errors if a preamble with a singular subject contained a plural noun inside a prepositional modifier (*The key to the cabinets*). Subsequent work has used agreement attraction with the aim of teasing apart the roles of notional, morphophonological and syntactic number in agreement production. Initially, Bock and Eberhard (1993) found no clear evidence for an impact of either morphophonological form or notional number in error elicitation tasks, as no significant increase in plural verb form errors was observed when the attractor was a syntactically singular pseudoplural ending in *-s* (e.g., *course*) or a syntactically singular collective (*fleet*), nor did attraction rates differ for regular and irregular plurals (*kids* vs. *children*) in attractor position. However, more recent crosslinguistic studies do find effects of morphophonology on agreement production (Franck, Vigliocco, Antón-Méndez, Collina, & Frauenfelder, 2008; Hartsuiker, Schriefers, Bock, & Kikstra, 2003; Lorimor, Jackson, Spalek, & van Hell, 2016; Mirković & MacDonald, 2013). Haskell and MacDonald (2003) also observed small effects of morphological regularity on agreement production in English when there was a conflict between the subject's notional and syntactic number information.

Similarly, there is accumulating evidence that notional number – that is, whether we view the referent of the noun as a single individual or a collection of many – impacts subject-verb agreement in production. Bock and Eberhard noted a non-significant numerical trend for the plural form of collectives (*fleets*) in attractor position to elicit more agreement errors than the plural form of individual nouns *(ships)*, despite their general conclusion that subject-verb agreement in production is controlled by syntactic number. There was also a correlation between how likely the singular form of a collective noun (*fleet*) was to be judged to refer to multiple entities and the frequency of agreement errors. A later study on the impact of notional number on agreement production by Humphreys and Bock (2005) used collectives as the subject's head noun followed by a prepositional modifier encouraging either a collected reading (*The gang near the motorcycles*) or a distributed reading (*The gang on the motorcycles*). They found that the rate at which preambles with (syntactically singular) collective head nouns elicited plural verb forms depended on whether their referents were construed as collected or distributed. Distributed readings more frequently led to the production of plural verbs, indicating that the notional number of the subject affects subject-verb agreement in production. Likewise, Brehm and Bock (2013) showed that the likelihood of producing plural agreement with a singular subject depends on how semantically integrated its referent is: more integrated preambles (*The drawing of the flowers*) were less likely to cause agreement errors than less integrated preambles (*The drawing with the flowers*). Brehm and Bock argue that this shows the effect of notional number: The less integrated a complex referent is, the more likely it is to be mentally construed as plural. Some of the crosslinguistic studies (Lorimor et al., 2016; Mirković & MacDonald, 2013) also report higher rates of plural agreement for notionally plural subjects. It should be noted that these studies manipulated the notional number of the entire subject, not the notional number of the attractor.

Accounts of agreement attraction in production have largely focused on representational explanations. The claim is that the number feature of a singular subject is affected by the presence of a plural attractor, either through feature percolation or spreading activation (e.g., Bock & Eberhard, 1993; Bock, Eberhard, & Cutting, 2004; Pearlmutter, Garnsey, & Bock, 1999). The most influential representational account is the marking and morphing model (Eberhard, Cutting, & Bock, 2005). According to this model, the number information on a noun phrase ranges continuously from unambiguously singular to unambiguously plural and the number marking on the verb is probabilistic. Although a subject with a singular head noun should be valued as unambiguously singular, the presence of a plural element inside it *(The key to the cabinets)* will raise the value and make the subject number more ambiguous. This sometimes results in agreement attraction errors. The marking and morphing model can account for the effects of number on agreement production: The impact of notional number can be seen as a message-level effect from the subject's intended referent.

Subject-verb agreement attraction in comprehension

Representational models have also been proposed for comprehension (Pearlmutter et al., 1999). But here they do not capture data as well as do cue-based retrieval models. Unlike cue-based retrieval models, they predict that grammatical sentences should sometimes be perceived as ungrammatical in the presence of a plural attractor (*The key to the cabinets is...*). But importantly, this does not seem to be the case (Lago et al., 2015; Tanner et al., 2014; Tucker, Idrissi, & Almeida, 2015; Wagers et al., 2009; but cf. Pearlmutter et al., 1999). Based on this grammatical asymmetry, we take the view that the mechanisms underlying agreement attraction are at least partially distinct processes in production and comprehension (Acuña-Fariña, 2012; Tanner et al., 2014), and therefore do not presume that the two domains must be governed by the same principles. We will assume that agreement attraction in comprehension has a retrieval-based account. At the end of this paper, in the General Discussion, we will broach the question of how the results from our experiments can be interpreted in an alternative, spreading activation account.

In comprehension, agreement attraction occurs when a subject-verb agreement violation is erroneously perceived to be grammatical in the presence of a non-subject that matches the verb in number. For example, comprehenders are much less likely to notice the agreement violation in a sentence like *The key to the cabinets are rusty*, which contains the structurally inaccessible plural noun *cabinets*, than in the same sentence without this plural non-subject. The facilitative impact of a number-matching non-subject can be accounted for very naturally by a cue-based retrieval model (Wagers et al., 2009). Subject-verb agreement is a dependency in which the syntactic number of the verb has to match the syntactic number of the subject. In order to check this, the subject has to be retrieved from memory. In the cue-based memory retrieval system assumed here, the verb provides a number cue (e.g. [plural]) as well as a structural cue (e.g. [subject]). When one of the items from memory has features that match both

the cues, it is highly likely to be retrieved. Note that when there is a number-matching non-subject present, this also receives an activation boost from the number retrieval cue. However, in a grammatical sentence the features of the subject are a perfect match for the retrieval cues on the verb: It fulfills both the structural cue of being the subject and its number feature matches the number cue. Thus it is retrieved as the appropriate target without any issues. In contrast, in ungrammatical sentences in which the subject does not match the verb in number, a number-matching non-subject (attractor) can be erroneously retrieved in a phenomenon called facilitative similarity-based interference. In this case, the subject does not receive a boost in activation from the number cue, and its activation level is only raised by the structural cue. The attractor noun in turn receives a boost in activation from the number cue. In some cases, this leads to the misretrieval of the attractor instead of the actual target, which results in an amelioration of the processing difficulty associated with agreement violations. Although agreement attraction is an example of cue-based retrieval "gone wrong", it has for this very reason served as a useful test case for investigating the architecture of the memory system.

Investigating subject-verb agreement attraction in comprehension provides an opportunity to address the question of whether the memory retrieval mechanisms employed in processing dependencies are ever as abstract as the very general features in terms of which these dependencies are specified in the grammar. Subject-verb agreement is a syntactic dependency: Subject and verb are syntactic categories, not phonological, morphological or semantic categories. However, the dependency involves a syntactic feature, [number], which correlates with morphological and semantic properties, if only imperfectly. For example, *the tree* is syntactically singular in triggering singular agreement, but also morphologically singular in lacking a plural affix, and semantically singular in representing its referent as a single tree. Crucially, however, these several properties are dissociable. Noun phrases headed by a collective noun, such as *fleet*, are both syntactically and morphologically singular, at least in American English, but semantically plural: They represent their referent as a plurality of like objects. Noun phrases like *the sheep* or *the deer* can function as syntactically and semantically plural, despite lacking any audible morpheme to mark this. And finally, several kinds of noun phrases are plural in syntax and morphology, but not plural in semantics. These include phrases headed by *pluralia tantum*, such as *the scissors*; those with the numeral *one-point-zero* (*one-point-zero children*); and those with the determiners *no* (*no children*) or *zero* (*zero grams*). For language production, the effects of morphological, syntactic and semantic plurality on errors of agreement attraction have been partially teased apart, as discussed in the previous section. And there the research suggests that agreement attraction is indeed affected by abstract association. But without further evidence we cannot assume that the same is true for comprehension, since the mechanisms underlying attraction in production and comprehension are plausibly distinct. Here we aim to use a parallel approach to determine whether the number retrieval cue in comprehension is as abstract as the features in terms of which the agreement dependency is specified in the grammar.

The present study

In the present study, we compare agreement attraction with plurals marked by suffixing (*the cats*) with attraction from those marked by coordination (*the cat and the dog*). Only the suffixal plural is an *unequivocal* sign of syntactic plurality, in this particular sense: Any occurrence of the plural suffix is within a plural noun phrase, while this is not the case with *and*. For example, we find *and* within singular noun phrases with a singular referent, such as *my wife and confidante* or *my cute and useful husband.*[1] Here we might say that *and* coincides semantically with the intersection of predicates, rather than the summing of individuals (for discussion see Champollion, 2013; Heycock & Zamparelli, 2005). Moreover, *and* also occurs between phrases of several other categories – adjective phrases, prepositional phrases, clauses – and in these cases it does not specifically mark plurality (McCloskey, 1991). Thus, while conjoined noun phrases are syntactically plural in general, the vehicle that signals this audibly, *and*, plays this role only when it sits between noun phrases (and even then, maybe not always). Therefore it is not, in our terms, an unequivocal signal of syntactic plurality. While this distinction makes no difference in the grammar, it allows us to investigate whether the retrieval cue employed in subject-verb agreement is responsive to features as abstract as [plural] or if it targets only certain exponents of the abstract category, for instance the ones that are unequivocal correlates of syntactic plurality.

Experiment 1

The goal of the set of experiments reported here was to determine whether in the computation of subject-verb agreement in comprehension the number retrieval cue on the verb targets an abstract category, [plural], in terms of which the agreement dependency is defined in the grammar. Alternatively, the cue could be more specific, targeting only morphological correlates that are unequivocal signals of syntactic plurality.

In Experiment 1 we used a speeded acceptability judgment task to examine whether agreement attraction in comprehension can occur even if the attractor does not contain the plural suffix -*s*, which is an unequivocal signal. If agreement attraction in comprehension is primarily form-driven and the number retrieval cue on the verb targets unequivocal morphological correlates of syntactic plurality in memory rather than the abstract category itself, conjoined singular noun phrases like *the husband and the wife* should not cause agreement attraction, since they lack an unequivocal morphological correlate of syntactic plurality.

We note that conjoined singular noun phrases are certainly syntactically plural in English, since they require plural agreement on the verb when they occupy subject position (*The husband and the wife were/∗was next in line.*) The fact that the comprehension of such simple sentences does not appear disrupted might already seem to be evidence that the number cue used for retrieval in agreement computation is not limited to probing for plural -*s*, an unequivocal morphological correlate of syntactic number. While there is no clear consensus in the literature about whether retrieval of the agreement controller is an error-driven process or occurs every time, at least in two-stage models of agreement attraction it is important to distinguish between the process of retrieving items from memory and the process of checking agreement. In two-stage models, verb number is predicted upon encountering the subject and cue-based retrieval occurs only in mismatch cases where the prediction is violated (Tanner, Grey, & van Hell, 2017; Tanner et al., 2014; Wagers et al., 2009). In these models, abstract syntactic number would certainly be used to generate the prediction, but might or might not be the target of the error-driven cue-based retrieval.

Several previous studies on sentence production have examined the production of agreement in sentences that contain conjoined

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[1] Perhaps this indicates a lexical ambiguity: maybe there are two words pronounced *and*, and only one of them occurs only within plural noun phrases (King & Dalrymple, 2004). Even so, we would then still like to say that conjunction is at least *superficially equivocal*, since its homophones have similar functions, syntactically and semantically. The affixal -*s* might be considered ambiguous too, as between the possessive clitic and the plural affix; but it is not even superficially equivocal, since these two homophones have very different functions.

Table 1
Example items for Experiment 1.

Condition	Example sentence
Singular-Grammatical	The slogan about *the husband* **was** designed to get attention
Suffixal-Grammatical	The slogan about *the husbands* **was** designed to get attention
Conjoined-Grammatical	The slogan about *the husband and the wife* **was** designed to get attention
Singular-Ungrammatical	The slogan about *the husband* **were** designed to get attention
Suffixal-Ungrammatical	The slogan about *the husbands* **were** designed to get attention
Conjoined-Ungrammatical	The slogan about *the husband and the wife* **were** designed to get attention

noun phrase, but largely focusing on the different question of what factors can drive singular agreement on the verb when the true syntactic subject is a conjoined noun phrase. Brehm and Bock (2017) and Lorimor et al. (2016) showed that the semantic properties of conjoined noun phrases have an effect on whether participants choose to use singular or plural agreement: In sentence completion, singular agreement is produced more frequently when the preamble contains two abstract rather than two concrete nouns (Brehm & Bock, 2017) or two mass/deverbal nouns rather than animate/count nouns (Lorimor et al., 2016). These findings are consistent with the effects of notional number on sentence production discussed in the previous section: It is easier to separately conceptualize the referents of conjoined concrete nouns than abstract nouns, and mass/deverbal nouns are more notionally singular than animate/count nouns. Keung and Staub (2016) show that agreement with conjoined subjects is also impacted by the number of the closest conjunct (more plural verbs when the second conjunct is plural). The focus of the current study is on agreement processing in comprehension, which may be supported by partially different mechanisms than production (Acuña-Fariña, 2012; Tanner et al., 2014). Here we critically ask about the extent to which conjoined noun phrase attractors *interfere* with singular subject-verb agreement, as a means of investigating memory retrieval mechanisms.

Participants

30 participants were recruited via the Amazon MechanicalTurk platform and received $3 for completing the experiment. All participants were native speakers of American English and had passed a native speaker proficiency test. Data from three additional participants were excluded because their acceptance rate for the ungrammatical filler items was above 40%. None of the subjects participated in more than one of the acceptability judgment experiments reported here.

Materials and design

The materials consisted of 36 experimental item sets in a 2 × 3 design, crossing grammaticality (grammatical/ungrammatical) and attractor number (singular/plural/conjoined), resulting in six conditions per item. The subject always consisted of a singular head noun followed by a prepositional modifier containing the attractor. Since the head noun was always singular, the verb (a form of copular or auxiliary *be*) was singular in the grammatical conditions and plural in the ungrammatical conditions. Attractor type was manipulated by using either a singular noun, a suffixal plural noun, or conjoined singular noun phrases, as illustrated in Table 1.

In addition to the experimental items we included 36 grammatical and 36 ungrammatical filler items to maintain a ratio of 1:1 of grammatical to ungrammatical items. There were also eight control items that specifically instructed participants to answer either 'yes' or 'no' in order to confirm that they were maintaining attention to the task. The experimental items were distributed across six lists in a Latin Square design, ensuring that each participant saw each item in only one condition. The fillers and control items were identical across lists.

Procedure

The items were displayed word by word in the center of the screen at a rate of 400 ms per word using IBEX software (Drummond, 2017). The last word of each sentence was followed by a response screen asking 'Was that a good sentence?' and participants had to judge whether the sentence they had just read was acceptable or not by pressing the 'f'-key for 'yes' and the 'j'-key for 'no'. A response had to be made within 2000 ms or the display would time out and a message would be displayed telling the participant that their response was too slow. Before the start of the experiment, participants completed five practice items to familiarize them with the procedure.

Analysis

Trials on which no response was made within the 2000 ms timeout were excluded from the analysis, leading to the exclusion of 1.8% of the data in the experimental conditions. We compared the grammaticality effect between the different attractor types, which is the difference in acceptance rates between the grammatical and ungrammatical conditions. Following Jaeger (2008), we analyzed the acceptance rate for each of the six experimental conditions using a mixed logit model with the lme4 package (Version 1.1-12, Bates, Maechler, Bolker, & Walker, 2015) in the R computing environment (R Development Core Team, 2017). The model had attractor type and grammaticality as fixed effects and by-subject and by-item random intercepts. This was the maximal random effects structure with which the model still converged for all acceptability judgment experiments reported here (Barr, Levy, Scheepers, & Tily, 2013). We used effects coding for the effect of grammaticality (grammatical: −0.5, ungrammatical: 0.5) and a reverse Helmert scheme for attractor type. This allowed us to use one contrast to compare the singular attractor to the average of the two types of plural attractor (singular: −0.5, conjoined: 0.25, suffixal: 0.25) and one contrast to directly compare the conjoined plural attractor to the suffixal plural attractor (singular: 0, conjoined: 0.5, suffixal: −0.5).[2]

Results

The proportion of 'yes' judgments for each of the experimental conditions in Experiment 1 is plotted in Fig. 1. See Table 2 for the output of the mixed logit analysis. The results show a significant effect of grammaticality (p < .001), with acceptance rates lower for ungrammatical than for grammatical sentences. There was also a significant effect of attractor type when comparing the singular attractor to the average of the two plural attractor types (p < .001). Sentences with singular attractors were accepted less frequently than sentences with a plural attractor. However, this effect was

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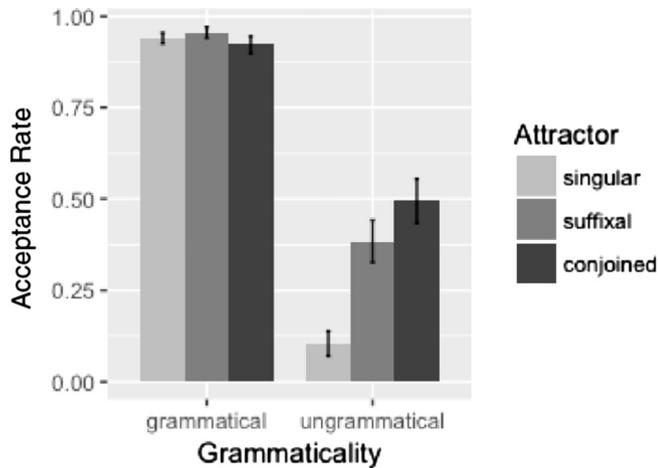[2] We thank an anonymous reviewer for suggesting this coding scheme.

Fig. 1. Acceptance rates across conditions in Experiment 1. Error bars indicate standard error of the mean.

primarily driven by the low acceptance rate for ungrammatical sentences with singular attractors. The significant interaction between grammaticality and attractor type for the comparison between singular and both types of plural attractors (p < .001) reflects the expected agreement attraction effect: The difference in acceptance rates for the grammatical and ungrammatical conditions (grammaticality effect) was much larger for singular attractors compared to the two types of plural attractors. Interestingly, the attraction effect for suffixal plurals was smaller than for conjoined NPs. This interaction between grammaticality and attractor type for the comparison between the conjoined and suffixal plural attractors was also significant (p = .01).

Discussion

The results of Experiment 1 show that conjoined singular noun phrases of the form *determiner-noun-and-determiner-noun* cause agreement attraction effects when they occur as part of the PP-modifier of a subject with a singular head noun. As expected, we found an agreement attraction effect with plural attractors compared to the singular attractor: Participants were more likely to accept ungrammatical sentences with a subject-verb agreement violation in the presence of a plural attractor, which were judged acceptable 43.8% of the time, compared to only 10% in the presence of a singular attractor. Critically, agreement attraction was observed for conjoined singular as well as suffixal plural phrases; in fact, the results show that conjoined singular noun phrases elicited even stronger attraction effects than suffixal plurals. While ungrammatical sentences were accepted 38.3% of the time in the presence of suffixal plural attractors, this rose to 49.3% for conjoined singular noun phrases. These findings indicate that it is not necessary for a potential attractor to contain an unequivocal

morphological correlate of syntactic plurality to cause facilitative similarity-based interference. The number retrieval cue in subject-verb agreement processing therefore does not specifically target the plural suffix -s in the online comprehension processes associated with agreement attraction. Instead, the number retrieval cue seems to either target a disjunctive list of items correlating with syntactic plurality (-s, *and*, etc.), or an abstract feature shared by all exponents of syntactic plurality. We return to this question in Experiments 4–6.

These results also lend support to the claim that agreement attraction is not based on linear order (Franck, Vigliocco, & Nicol, 2002; Wagers et al., 2009). In sentences with conjoined singular attractors, the linearly closest node to the verb is the second conjunct, which is singular. The syntactically plural node (the conjoined phrase) is therefore not adjacent to the verb and yet still creates attraction.

Speeded acceptability is a very powerful measure due to its binary outcome, but it is not possible to draw direct conclusions about the timecourse of the observed effect. Another method that has been used to measure agreement attraction in comprehension is self-paced reading. Self-paced reading data is relatively noisier but allows us to localize the effect of attraction to a particular position in the sentence. These two measures have shown congruent results in some previous work on agreement attraction (Wagers et al., 2009), suggesting that the speed of processing tightly relates to the extent to which participants notice the ungrammaticality. However, while it is possible that they provide different windows into the same process, we cannot take this equivalence for granted and the two measures remain complementary pieces of data. Therefore we investigate the timecourse of agreement attraction with conjoined singular attractors using self-paced reading in Experiment 2. If the increased acceptance rate of ungrammatical sentences with conjoined singular attractors in Experiment 1 reflects the same underlying process as attraction with suffixal plurals, we expect it to follow the same timecourse in self-paced reading.

We also note that while these results suggest that the number retrieval cue in agreement computation might be as abstract as the terms in which agreement is defined in the grammar, an unintended ambiguity in our experimental materials allows an alternative explanation. We intended strings like *the slogan about the husband and the wife* to be parsed as singular, with *and* embedded in the object of the preposition: [*the slogan about* [*the husband and the wife*]]. But participants could have parsed these strings differently, with *and* unembedded, in a way that makes them plural: [[*the slogan about the husband*] *and* [*the wife*]]. In that case the plural form of the verb would have been grammatical. Although this parse seems intuitively unlikely given the factors of syntactic and semantic parallelism in the current materials (e.g., [*The slogan about the husband*] and [*the wife*] feels quite awkward), it could account for the higher acceptance rate of ungrammatical sentences with conjoined singular NPs compared to suffixal plurals. We address this issue directly in Experiment 3, which uses conjoined singular nouns of the form *determiner-noun-and-noun*.

Table 2
Results of mixed logit model in Experiment 1.

Parameters	Estimate	Std. Error	z-value	p-value
Intercept	1.12	0.25	4.48	<.001
Grammaticality	−4.42	0.28	−15.55	<.001
Attractor: singular vs. plural	1.35	0.34	3.94	<.001
Attractor: suffixal vs. conjoined	−0.10	0.27	−0.38	.70
Gram. × Attractor: singular vs. plural	3.26	0.70	4.68	<.001
Gram. × Attractor: suffixal vs. conjoined	1.36	0.55	2.50	.01

Experiment 2

The results of Experiment 1 show that the presence of an attractor whose plurality is introduced by a vehicle that is not a perfect correlate of syntactic plurality leads to higher acceptance rates for subject-verb agreement violations. Previous research suggests that an increase in the acceptance rate for ungrammatical sentences with a plural attractor in speeded acceptability judgments correlates with a reduced slowdown in those conditions in the region immediately following the verb in self-paced reading (Wagers et al., 2009). The aim of Experiment 2 was to use self-paced reading to investigate whether the attraction effect with conjoined singular attractors in Experiment 1 follows the same timecourse during online processing that we expect with suffixal plurals.

Participants

42 members of the University of Maryland community participated in this experiment for course credit or monetary compensation. Data from two additional participants were excluded from all analyses due to low accuracy on the comprehension questions (below 80%). All participants were native speakers of American English and provided informed consent. None of the participants took part in more than one of the experiments presented here.

Materials and design

To ensure that the results from Experiment 2 were comparable to those from Experiment 1, the experimental items were identical across experiments. Although in some previous self-paced reading studies a preverbal adverb was inserted to avoid spillover effects from attractor noun number on the verb (Wagers et al., 2009), in the current study the attractor and verb were directly adjacent to each other. We decided not to include preverbal adjectives here because in English they are sometimes degraded in acceptability without a very specific intonation, which might have added undesirable noise to the speeded acceptability judgment results. While spillover effects are very common in self-paced reading, the data from Wagers et al. (2009) show that the plural complexity effect lasts no more than a single region. In our study, effects in the postverbal region (the critical verb's spillover region) should not be affected by plural spillover and can therefore be attributed to processing at the verb.

As in Experiment 1, the items were distributed across six lists in a Latin Square design, so that each participant only saw one condition per item and six items per condition. In addition to the experimental items, the materials also included 134 filler items, 102 of which belonged to four separate manipulations that are not reported here. None of these were related to agreement processing and all filler items were grammatical, meaning that 10.6% of the items were ungrammatical in total.

Procedure

The items were presented word-by-word in a self-paced moving window paradigm (Just, Carpenter, & Woolley, 1982) using Linger software (Doug Rhode, MIT) on a desktop computer. At the beginning of each trial a series of dashes appeared on the screen, masking the words of the sentence. Participants had to press the space bar to reveal each word, at which time the previous word was re-masked by a dash. Consequently, only one word at a time was visible and it was not possible for participants to re-read words that had already been re-masked. After the end of each sentence a yes/no comprehension question appeared on the screen in full. Participants had to press the 'f' key to answer 'yes' and the 'j' key to answer 'no'. The questions were simple comprehension questions and never focused on number information. Onscreen feedback was provided only when the response was incorrect. Participants were instructed to read as naturally as possible and to answer the comprehension questions as quickly and accurately as possible. Items were presented in three blocks and the order of presentation was randomized for each participant. Before the beginning of the experiment, participants completed five practice items to familiarize themselves with the procedure.

Analysis

All trials were included in the analysis of the self-paced reading data, regardless of whether the comprehension questions were answered correctly. The regions of analysis consisted of single words and included the verb region and the two words following the critical verb (spillover regions). Reading times exceeding a threshold of 2000 ms were excluded as outliers, resulting in the exclusion of less than 0.02% of all trials in the regions of analysis. RTs were log-transformed and analyzed with the *lme4* package for linear mixed effects models (Bates et al., 2015) in the R computing environment (R Development Core Team, 2017). The model included grammaticality and attractor type and their interaction as fixed effects. The effects of grammaticality and attractor type were coded the same way as in Experiment 1. Following Barr et al. (2013), we initially fitted a model with the maximal random effects structure. This model failed to converge and was then progressively simplified until convergence was reached. We report results from the model with the maximal random effects structure that converged for all three regions of analysis in both of the self-paced reading experiments reported here (Experiment 2 and Experiment 5). The final model included by-subject and by-item random intercepts and by-subject random slopes for grammaticality.

The current version of the lme4 package (version 1.1-12) no longer implements the calculation of p-values using Markov Chain Monte Carlo (MCMC) sampling, which has previously been recommended for deriving p-values from linear mixed effects models (Baayen, Davidson, & Bates, 2008). Instead, we treat the *t*-statistic as a z-statistic, where a *t*-statistic with an absolute value larger than 2 suggests significance at the .05 level (Gelman & Hill, 2006; Kush, Lidz, & Phillips, 2015).

Results

Comprehension accuracy

Mean comprehension accuracy for the experimental items was 94.1%. The mean accuracy for each of the conditions ranged from 92.4% to 96.4%, indicating that participants were paying attention during the experiment.

Self-paced reading

The region-by-region average log-transformed RTs in Experiment 2 are plotted in Fig. 2. Mean raw RTs for each condition in the verb and spillover regions are listed in Table 3. The results from the mixed effects models for the verb region and the two spillover regions are presented in Table 4.

In the verb region only the main effect of grammaticality was significant ($t = 2.03$), with agreement violations leading to slower average reading times (grammatical = 326 ms; ungrammatical = 341 ms). This slowdown remained significant in the first spillover region ($t = 4.34$; grammatical = 312 ms; ungrammatical = 352) and the second spillover region ($t = 4.52$; grammatical = 324 ms; ungrammatical = 355 ms). In the first spillover region there was also a significant effect of attractor type for the comparison between the singular and the two types of plural attractors
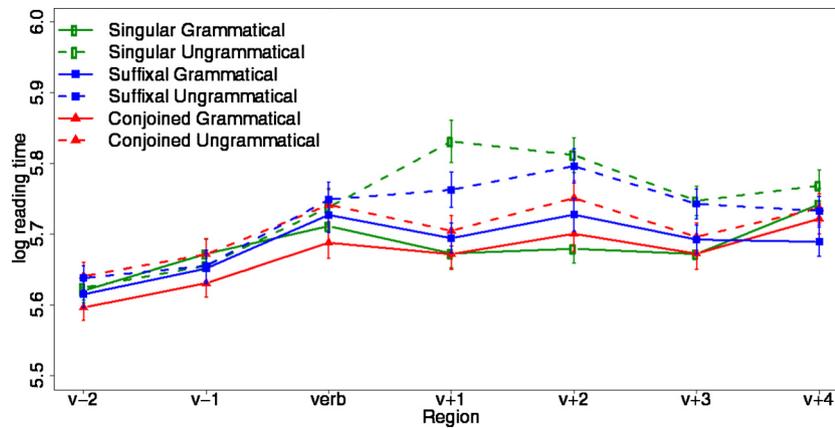
Fig. 2. Region-by-region mean log reading times in Experiment 2. Error bars indicate standard error of the mean.

Table 3
. Mean raw reading times per condition for regions of interest in Experiment 2.

Region	Singular	Conjoined	Suffixal
Verb			
Grammatical	324.5 (9.9)	316.4 (8.7)	337.0 (12.4)
Ungrammatical	341.8 (12.4)	339.3 (12.0)	342.0 (10.8)
First spillover			
Grammatical	308.0 (8.1)	310.3 (9.2)	316.2 (8.0)
Ungrammatical	385.8 (14.5)	321.3 (9.0)	349.0 (11.5)
Second spillover			
Grammatical	311.2 (8.8)	326.2 (10.5)	335.3 (12.6)
Ungrammatical	363.4 (10.6)	344.0 (12.0)	356.0 (10.0)

Note. Standard error of the mean in parentheses.

Table 4
Results of linear mixed effects model for regions of interest in Experiment 2.

Parameter	Estimate	Std. error	t-value
Verb region			
Intercept	5.73	0.03	185.89
Grammaticality	0.03	0.02	2.03
Attractor: singular vs. plural	0.003	0.02	0.15
Attractor: suffixal vs. conjoined	−0.02	0.02	−1.11
Gram. × Attractor: singular vs. plural	0.02	0.05	0.36
Gram. × Attractor: suffixal vs. conjoined	0.03	0.04	0.58
First spillover region			
Intercept	5.72	0.03	201.88
Grammaticality	0.09	0.02	4.34
Attractor: singular vs. plural	−0.06	0.02	−2.48
Attractor: suffixal vs. conjoined	−0.04	0.02	−1.98
Gram. × Attractor: singular vs. plural	−0.14	0.05	−3.06
Gram. × Attractor: suffixal vs. conjoined	−0.04	0.04	−0.87
Second spillover region			
Intercept	5.75	0.03	206.87
Grammaticality	0.08	0.02	4.52
Attractor: singular vs. plural	−0.002	0.02	−0.10
Attractor: suffixal vs. conjoined	−0.04	0.02	−1.77
Gram. × Attractor: singular vs. plural	−0.10	0.05	−2.04
Gram. × Attractor: suffixal vs. conjoined	−0.02	0.04	−0.50

($t = -2.48$). Mean reading times were slower for singular attractors than for plural attractors (singular = 347 ms; plurals = 322 ms). The significant interaction between grammaticality and attractor type for singular compared to plural attractors in the first spillover region ($t = -3.06$; grammaticality effect singular = 78 ms; grammaticality effect plurals = 22 ms) and the second spillover region ($t = -2.04$; grammaticality effect singular = 52 ms; grammaticality effect plurals = 19 ms) indicates that the slowdown associated with ungrammaticality was significantly reduced in the presence

of a plural attractor. Although none of the other effects reached an absolute t-value larger than 2, the effect of attractor type for suffixal compared to conjoined plurals in the first spillover region was marginally significant ($t = -1.98$). This region was read faster for conjoined attractors. Although the grammaticality effect for suffixal plurals was numerically larger than for conjoined attractors in the first spillover region, this interaction was not significant ($t = -0.87$; grammaticality effect suffixal = 33 ms; grammaticality effect conjoined = 11 ms).

Discussion

The results of Experiment 2 are mostly consistent with the speeded acceptability judgment data from Experiment 1. As expected, subject-verb agreement violations led to slower reading times. In the critical verb's spillover regions this slowdown was reduced in the presence of plural compared to singular attractors indicating that comprehenders experienced agreement attraction from a structurally irrelevant number-matching noun. Unlike in Experiment 1, there was no evidence that conjoined singular NPs caused stronger agreement attraction than suffixal plurals. While numerically suffixal plurals showed a smaller attraction effect, this contrast was not significant.

Together, the findings from the self-paced reading task in Experiment 2 and the end-of-sentence judgment task in Experiment 1 suggest that the retrieval process that supports agreement computation in comprehension targets something more general than the plural suffix -s. Experiment 3 was designed to rule out an alternative explanation for these results based on the coordination ambiguity.

Experiment 2 used the same experimental materials as Experiment 1, which means that there was still an unintended ambiguity in the sentences with the conjoined singular noun phrases: it is possible, if unlikely, that participants parsed them as *[subject head noun [preposition [determiner noun]]]* and *[determiner noun]* (*[The slogan about the husband] and [the wife]*), rather than *[subject head-noun [preposition [determiner noun and determiner noun]]]* (*The slogan about [the husband and the wife]*). In that case, the plural form of the verb would have been grammatical. We address this issue in Experiment 3, which avoids this ambiguity by using conjoined singular noun phrases of the form *determiner-noun-and-noun*.

Experiment 3

The aim of Experiment 3 was to ensure that the results we saw with conjoined singular attractors in Experiment 1 and 2 were not

due to an unintended parse of this attractor type. Although conjoined attractors showed a profile very similar to suffixal plural attractors, it is possible that this profile derived from a completely different source in the conjoined case. This is because the conjoined conditions had an alternative parse which is not available in the suffixal plural attractor conditions: They could be parsed as *[subject head-noun [preposition [determiner noun]]] and [determiner noun]* (*[The slogan about the husband] and [the wife]*), rather than as the intended *[subject head-noun [preposition [determiner noun and determiner noun]]]* (*The slogan about [the husband and the wife]*). Under this alternative parse, the plural form of the verb, which was intended to be a subject-verb agreement violation, would have been grammatical. This could drive increased acceptability and reduced reading times in the *mismatch* condition.

Fortunately, in English it is possible to coordinate noun phrases without a second determiner, and this forces a parse in which the two local noun phrases are coordinated (*The slogan about the husband and wife*). If participants are still more likely to accept sentences with a singular subject and a plural verb when the conjoined singular attractor does not have a second determiner, this could not be explained by parsing ambiguity and would support our original interpretation of Experiment 1 and 2.

Participants

30 native speakers of American English were recruited via the Amazon MechanicalTurk platform and received $3 for completing the experiment. One additional participant who had an acceptance rate of 40% or above for the ungrammatical filler items was excluded from all analyses. None of the participants took part in any other experiments.

Materials and design

The experimental items were adapted from those used in Experiment 1 and 2 by removing the determiner in front of the second noun phrase in the conjoined singular attractor (*The slogan about the husband and wife*). Consequently, the only possible parse for the sentences with the conjoined singular attractor was *[preposition [determiner noun and noun]]*, avoiding the unintended ambiguity in these items in Experiment 1 and 2. The items were not changed for any of the other conditions. The same 36 grammatical and 36 ungrammatical filler items plus eight control items were included as in Experiment 1, and the experimental items were distributed across six lists in a Latin Square design.

Procedure and analysis

The procedure and analysis were identical to Experiment 1. Trials on which no response was made within 2000 ms were excluded, resulting in the exclusion of 0.2% of all experimental trials.

Results

Fig. 3 shows the proportions of 'yes' judgments for each of the experimental conditions in Experiment 3. The results of the mixed logit model are presented in Table 5. There was a significant effect of grammaticality ($p < .001$): Grammatical sentences were much more likely to be judged acceptable than ungrammatical ones. The effect of attractor type was significant for the comparison between singular and the two types of plural attractors ($p < .001$). Sentences with singular attractors were less likely to be judged acceptable than those with plural attractors. This was due to the low acceptance rate for ungrammatical sentences with a singular attractor. The interaction between grammaticality and
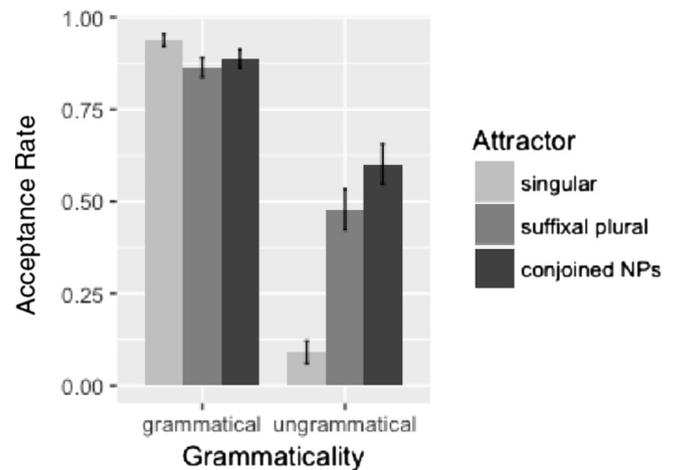
Fig. 3. Acceptance rates across conditions in Experiment 3. Error bars indicate standard error of the mean.

attractor type for the comparison between singular and both types of plural attractors was significant ($p < .01$) and the decrease in acceptance for ungrammatical compared to grammatical sentences was much larger for singular attractors. There was also a marginal effect of attractor type for conjoined singulars compared to suffixal plurals ($p = .06$). Numerically sentences with conjoined singulars had a higher acceptance rate than those with suffixal plurals, but the interaction between grammaticality and attractor type was not significant ($p = .4$) between these two attractor types.

Discussion

The pattern in Experiment 3 is clearly consistent with the results from Experiment 1 and 2. Although no alternative parse was available for the conjoined conditions in Experiment 3, conjoined attractors still caused agreement attraction. This rules out the alternative explanation based on an unintuitive parse of the complex subject in Experiment 1 and 2. These results further support the idea that an attractor that is syntactically plural can cause agreement attraction effects in comprehension even when its plurality is not marked by the plural *-s*, an unequivocal signal. The retrieval cue must be more general than just a single morpheme. While the attraction effect was numerically larger for conjoined plurals than suffixal plurals in Experiment 3, the interaction was not statistically significant (unlike in Experiment 1). It is possible that this is a very small effect that is difficult to detect. We return to this point in the General Discussion.

There are at least two options for exactly how the number retrieval cue could be general. It might be an abstract feature, [plural], shared by all exponents of syntactic plurality. Alternatively, the plural retrieval cue might target not one abstract feature, but instead a list of items that correlate with the [plural] feature (such as *-s* or *and*). Under this model, the plural retrieval cue would be directly associated with the morphological exponents of syntactic plurality rather than syntactic plurality itself. In that case, the attraction seen with conjoined singular noun phrases would not be because they possess an abstract [plural] feature, but rather because the verb's retrieval cue targets *and*. So far, we have assumed that if conjoined singular noun phrases cause agreement attraction, it must be because of the abstract [plural] feature. In Experiments 4–6, we examine the alternative possibility by considering noun phrases such as *the loyal and caring husband* in attractor position. These include *and* but are syntactically singular, since here the conjunction coordinates adjectives modifying a singular noun. We ask whether these too can cause errors of agreement

Table 5
Results of mixed logit model for Experiment 3.

Parameter	Estimate	Std. Error	z-value	p-value
Intercept	0.85	0.17	4.99	<.001
Grammaticality	−3.19	0.21	−15.03	<.001
Attractor: singular vs. plural	1.30	0.31	4.15	<.001
Attractor: suffixal vs. conjoined	0.38	0.20	1.88	.06
Gram. × Attractor: singular vs. plural	4.75	0.63	7.49	<.001
Gram. × Attractor: suffixal vs. conjoined	0.34	0.40	0.85	.40

attraction. If they do, it suggests the word *and* has become statistically associated with syntactic plurality, to the extent that it can itself respond to the number retrieval cue triggered by the plural verb.

Experiment 4

In Experiment 4, we use singular attractors with conjoined adjectives to investigate the possibility that the number retrieval cue on the verb targets correlates of syntactic plurality rather than the abstract category itself, even in cases where the correlates do not actually introduce this category. While the results of Experiments 1–3 show that retrieval is not limited to probing for an unequivocal morphological correlate of syntactic plurality (plural -*s*), they are also compatible with a model in which the plural retrieval cue targets a disjunctive list of items correlating with syntactic plurality (e.g., -*s*, *and*, etc.), rather than an abstract [plural] feature shared by all exponents of syntactic plurality. Consequently, they do not rule out that the attraction effects we find with conjoined noun phrases is the result of retrieval targeting the word *and*, which is a correlate of syntactic plurality, although an imperfect one. Here we examine the possibility that the conjunction *and* might be targeted in agreement computations, even though the correlation is not perfect and is not directly represented in the grammar. We can dissociate the role of abstract number and surface cues to syntactic plurality by examining the impact of singular attractors with conjoined adjectives (*the loyal and caring husband*), which contain *and* but are not syntactically plural. If the memory processes used to establish the subject-verb agreement dependency do not just target correlates of the abstract category [plural], but are as abstract as the terms in which the dependency is stated in the grammar, this type of attractor should not cause agreement attraction effects. However, if it is morphological correlates of syntactic plurality that are targeted by the verb's number cue in retrieval, singular attractors with conjoined adjectives should cause attraction just like suffixal plural attractors.

Participants

We recruited 30 participants via Amazon's Mechanical Turk platform. All participants were native speakers of American English and received $3 for participating in the experiment. Two additional participants were excluded from all analyses because they accepted the ungrammatical filler sentences more than 40% of the time.

Materials and design

The materials consisted of modified versions of the 36 experimental item sets from Experiment 1. The materials also included the same 36 grammatical and 36 ungrammatical fillers, as well as the eight control items, as used in the other acceptability judgment experiments reported here. The experimental items were distributed across six lists in a Latin Square design, with fillers and control items identical across lists. The 2 × 3 design crossed

Table 6
Example items for Experiment 4.

Condition	Example sentence
Singular-Grammatical	The slogan about the caring husband was designed to get attention
Plural-Grammatical	The slogan about the caring husbands was designed to get attention
Conjoined adjectives-Grammatical	The slogan about the loyal and caring husband was designed to get attention
Singular-Ungrammatical	The slogan about the caring husband were designed to get attention
Plural-Ungrammatical	The slogan about the caring husbands were designed to get attention
Conjoined adjectives-Ungram.	The slogan about the loyal and caring husband were designed to get attention

attractor type (singular with adjective/plural with adjective/singular with conjoined adjectives) with grammaticality (grammatical/ungrammatical), resulting in six conditions per item, see Table 6. As in the previous experiments, the head noun of the subject was always singular and followed by a prepositional modifier containing the attractor. The attractor took the form of the definite article *the* followed by an adjective and a singular noun (singular attractor), an adjective and a plural noun (plural attractor), or a singular noun preceded by two adjectives conjoined by *and* (conjoined adjective attractor). Participants saw each experimental item in only one condition.

Procedure and analysis

The procedure used in Experiment 4 was identical to that in Experiment 1 and 3. Trials on which no response was made within 2000 ms accounted for 0.1% of all experimental trials and were excluded. Like in Experiment 1 and 3, we used effects coding for the effect of grammaticality (grammatical: −0.5, ungrammatical: 0.5). However, attractor types were coded differently, as the central question in the current experiment was whether the two singular attractors differed as a function of whether they were preceded by a single adjective or conjoined adjectives. Therefore we used one contrast to directly compare the singular attractor with a single adjective to the singular attractor with conjoined adjectives (adjective and singular noun: −0.5; adjective and plural noun: 0; conjoined adjectives and singular noun: 0.5). To keep the contrasts orthogonal, the other contrast was set to compare the attractor with a plural noun to the average of the two other attractor types (adjective and singular noun: 0.25; adjective and plural noun: −0.5; conjoined adjectives and singular noun: 0.25).

Results

The proportion of 'yes' judgments for all experimental conditions is illustrated in Fig. 4 and Table 7 contains the output of the mixed logit model. As in the other speeded acceptability judgment experiments, grammatical sentences were more likely to be accepted than ungrammatical ones (*p* < .001). As expected, ungrammaticality had a smaller effect on acceptance rates for sen-
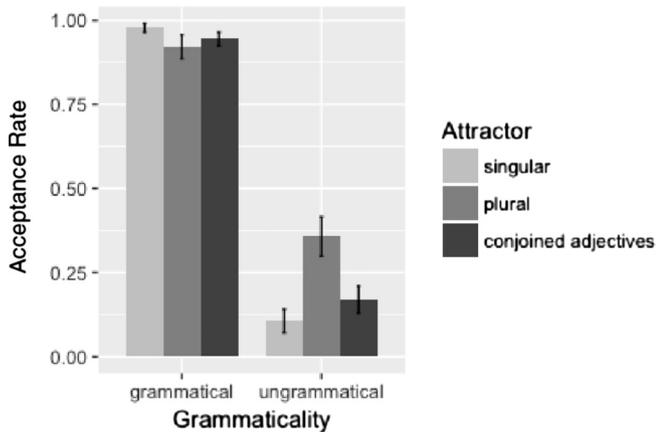
Fig. 4. Acceptance rates across conditions in Experiment 4. Error bars indicate standard error of the mean.

tences with attractors containing a plural noun than for sentences with attractors that contained a singular noun ($p < .001$). Crucially, the interaction between grammaticality and attractor type was also significant for the comparison between attractors with one adjective and a singular noun and attractors with conjoined adjectives and a singular noun ($p = 0.02$).

Plural attractors had a numerically much larger attraction effect than conjoined adjective singular attractors. We performed a post hoc test for which the model was refit with the effect of attractor type treatment coded and releveled (Linck & Cunnings, 2015). The glht function in the multcomp package (Hothorn, Bretz, & Westfall, 2008) was then used to directly compare the difference between differences: effect of grammaticality for singular attractors with conjoined adjectives and for plural attractors with a single adjective. Note that this comparison is not orthogonal to the comparison between the two types of singular attractors in the main model. The post hoc test showed that plural attractors caused a significantly larger attraction effect than singular attractors with conjoined adjectives (Estimate = -1.61; Std. Error = 0.52; z-value = -3.08; $p = .002$).

Discussion

These results provide intriguing if tentative support for the hypothesis that the word *and* is a target for retrieval upon encountering the verb's number cue. Singular attractors that contained the word *and* appeared to induce a small attraction effect, leading to an increased acceptance rate for ungrammatical sentences compared to those with singular attractors with only a single adjective (grammaticality effect single adjective with singular noun = 87.2%; conjoined adjective with singular noun = 77.5%). However, the drop in acceptance associated with subject-verb agreement violations was reduced much more by the attractor containing a single adjective and a plural noun than by the attractor with a singular noun and two conjoined adjectives (grammaticality effect single adjective with plural noun = 56.4%).

In contrast to the true syntactically plural conjoined attractors examined in Experiment 1–3, the grammaticality effect was reduced less with conjoined adjective attractors than with attractors containing a (suffixal) plural. Nevertheless, the data do suggest that an attractor that does not actually signal syntactic plurality can nonetheless cause some degree of interference in agreement computation simply because it contains an imperfect correlate of syntactic plurality. In order to further investigate this possibility, Experiment 5 uses the materials from Experiment 4 in a self-paced reading experiment.

Experiment 5

The results from Experiment 4 suggest that the presence of the conjunction *and* in an attractor that is not syntactically plural might cause agreement attraction. Here, we follow this up by using the same materials as in Experiment 4 in a self-paced reading task. If the presence of *and* in the attractor is sufficient to cause agreement attraction, singular attractors with conjoined adjectives should reduce the slow-down associated with encountering an agreement violation.

Participants

41 members of the University of Maryland community participated in this experiment for course credit or monetary compensation. The data from two additional participants were excluded from all analyses due to a low accuracy rate (below 80%) on the comprehension questions. None of the participants took part in any of the other experiments reported here.

Materials and design

The experimental items in Experiment 5 were identical to those used in Experiment 4 to ensure that results were easily comparable. The same set of fillers was used as in Experiment 2.

Procedure and analysis

The same self-paced reading procedure was used as in Experiment 2. Grammaticality and attractor type were coded the same way as in Experiment 4. Reading times exceeding a threshold of 2000 ms were excluded as outliers, resulting in the exclusion of less than 0.03% of all trials in the regions of analysis.

Results

Comprehension accuracy
Mean comprehension accuracy for the experimental items was 94.5%. The mean accuracy for each of the conditions ranged between 92.6% and 96.7%.

Self-paced reading
Region-by-region average log-transformed RTs in Experiment 5 are plotted in Fig. 5 and mean raw RTs for each experimental con-
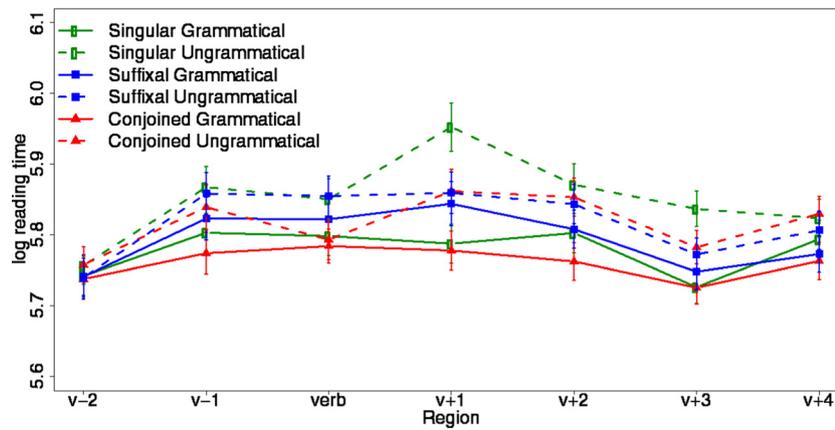
Table 7
Results of mixed logit model in Experiment 4.

Parameter	Estimate	Std. error	z-value	p-value
Intercept	0.85	0.22	3.79	<.001
Grammaticality	−5.11	0.30	−17.05	<.001
Attractor: plural. vs. sg. & conj. adjectives	−0.41	0.33	−1.27	.20
Attractor: sg. vs. conj. adjectives	−0.17	0.35	−0.50	.62
Gram. × Attractor: pl. vs. sg. & conj. adj.	−3.21	0.65	−4.94	<.001
Gram. × Attractor: sg. vs. conj. adjectives	1.61	0.70	2.30	.02

Fig. 5. Region-by-region mean log reading times in Experiment 5, error bars indicate standard error of the mean.

Table 8
Mean raw reading times per condition for regions of interest in Experiment 5.

Region	Singular	Conjoined Adj.	Plural
Verb			
Grammatical	363.6 (11.9)	349.8 (9.2)	376.0 (11.9)
Ungrammatical	388.9 (14.2)	362.7 (11.8)	389.9 (13.8)
First spillover			
Grammatical	361.1 (11.8)	357.7 (12.2)	394.7 (16.3)
Ungrammatical	448.4 (18.3)	399.0 (15.0)	391.8 (13.3)
Second spillover			
Grammatical	367.4 (12.7)	350.6 (12.2)	365.5 (11.6)
Ungrammatical	397.7 (13.9)	383.7 (12.9)	383.3 (13.3)

Note. Standard error of the mean in parentheses.

Table 9
Results of linear mixed effects model for the regions of interest in Experiment 5.

Parameter	Estimate	Std. Error	t-value
Verb region			
Intercept	5.82	0.05	127.53
Grammaticality	0.03	0.02	1.59
Attractor: plural vs. singular & conj. adjectives	−0.04	0.02	−1.76
Attractor: singular vs. conjoined adjectives	−0.04	0.02	−1.68
Gram. × Attractor: plural vs. sg & conj. adjectives	−0.004	0.05	−0.08
Gram. × Attractor: sg vs. conjoined adjectives	−0.04	0.04	−0.99
First spillover region			
Intercept	5.85	0.05	120.90
Grammaticality	0.09	0.02	4.06
Attractor: plural vs. singular & conj. adjectives	−0.01	0.03	−0.42
Attractor: singular vs. conjoined adjectives	−0.05	0.02	−2.17
Gram. × Attractor: plural vs. sg & conj. adjectives	0.14	0.05	2.70
Gram. × Attractor: sg vs. conjoined adjectives	−0.08	0.05	−1.75
Second spillover region			
Intercept	5.82	0.05	129.77
Grammaticality	0.06	0.02	3.66
Attractor: plural vs. singular & conj. adjectives	−0.01	0.02	−0.26
Attractor: singular vs. conjoined adjectives	−0.03	0.02	−1.37
Gram. × Attractor: plural vs. sg & conj. adjectives	0.06	0.05	1.21
Gram. × Attractor: singular vs. conj. adjectives	0.02	0.04	0.44

dition in the regions of interest are provided in Table 8. Table 9 presents the results from the linear mixed effects models for the verb region and the two spillover regions.

There were no significant effects in the verb region. The effect of grammaticality became significant in the first spillover region ($t = 4.06$) and remained significant in the second spillover region ($t = 3.66$): Reading times were slower for sentences with a subject-verb agreement violation. The effect of attractor type for the two singular attractors was also significant in the first spillover region ($t = −2.17$). Sentences with singular attractors with conjoined adjectives were read faster than those with singular attractors with only a single adjective. The interaction between grammaticality and attractor type was significant for the plural attractor compared to the average of the two types of singular attractors ($t = 2.70$) in the first spillover region. The slowdown in response to an agreement violation was much reduced in the presence of a plural attractor. Ungrammaticality led to a numerically smaller slowdown in the presence of a singular attractor with conjoined adjectives compared to a singular attractor with a single adjective. However, unlike in Experiment 4, the interaction between grammaticality and attractor type was only marginally significant for the comparison between the attractors with a single adjective and with conjoined adjectives ($t = −1.75$).

Numerically, the slowdown in response to an agreement violation in the first spillover region was also reduced for a plural attractor in comparison to a singular attractor with conjoined adjectives. However, a post hoc test following the same procedure as in Experiment 4 to compare the difference between differences showed that this was not significant (Estimate = −0.068; Std. Error = 0.046; z-value = −1.47; $p = .14$).

Discussion

In the speeded acceptability judgment results of Experiment 4, we found a small but reliable plural agreement attraction effect from singular attractors that contained conjoined adjectives, suggesting that the word *and* itself may act as a weak cue to plural agreement in comprehension even when all noun phrases in the context are syntactically singular. The results from self-paced reading in Experiment 5 showed a similar pattern numerically, although the effect was less robust. Singular subject – plural verb agreement violations elicited less reading time disruption in the presence of singular attractors with conjoined adjectives, which surfaced in the statistical analysis as a marginally significant interaction between grammaticality and attractor type. Both speeded acceptability judgment and self-paced reading are well-known indices of agreement attraction in comprehension, and therefore

we take the consistent pattern of results across these the two experiments together to provide tentative support for the hypothesis that the agreement attraction effect observed for conjoined NPs in comprehension (Experiments 1–3) reflects not only interference from the abstract plural number on the attractor, but also, to a smaller degree, interference from the word *and* itself. We note that as it is unknown whether these measures are sensitive to exactly the same components of agreement computation. The fact that the self-paced reading effect of conjoined adjectives was only marginally significant might suggest that the underlying sources of this effect only partially overlap with the sources of the standard agreement attraction effect.

It is notable that in both experiments the attraction effect was numerically smaller for singular conjoined adjective attractors than for the plural attractors, which was not the case for the conjoined noun phrase attractors examined in Experiments 1–3. This suggests that the attraction observed with conjoined noun phrases is not simply due to retrieval of the word *and* as a correlate of syntactic plurality. Nevertheless, the fact that singular attractors with conjoined adjectives increase the acceptance rate of ungrammatical sentences and lead to a reduced slowdown in self-paced reading suggests that the presence of *and* in the attractor causes some interference in agreement computation, even if the attractor is neither syntactically plural nor contains an unequivocal signal of syntactic plurality.

One potential explanation for the observed attraction effect with *and* is that comprehenders are more likely to expect a plural noun following conjoined adjectives. If that were the case, their prediction of a plural noun even in the absence of one in the actual input might have caused interference in computing agreement. To rule this out, we conducted an untimed cloze task with the materials from Experiment 5. The items were cut off after the adjective/-conjoined adjectives and 32 participants completed the sentences. The cloze probability of a plural noun following conjoined adjectives was only 5.6% (32 completions out of 576), This was in fact lower than after a single adjective, where it was 6.6% (38 completions out of 576). This shows that comprehenders were not more likely to expect a plural noun after conjoined adjectives. Consequently, predicting a plural cannot be the source of the attraction effect observed with conjoined adjective attractors.

However, there is a potential confound in the materials used in Experiment 4 and 5. In the conditions with singular attractors with conjoined adjectives, the head noun of the subject is separated from the verb by two additional words in comparison to the other conditions with only one adjective. In Experiment 6 we address this issue by testing singular attractors with stacked adjectives (*the loyal caring husband*), which increase the distance between the head noun and the verb. They have a similar semantic representation to explicitly conjoined adjectives but do not include the word *and* as a potential target for retrieval.

Experiment 6

The aim of Experiment 6 was to investigate whether the apparent attraction effect observed in Experiments 4 and 5 for singular attractors with conjoined adjectives was simply due to the additional length/complexity of the attractor region rather than specifically the presence of the word *and,* which is an imperfect correlate of syntactic plurality. In Experiment 6, we adapted the materials used in Experiments 4 and 5 to include a singular attractor with stacked adjectives (*The slogan about the loyal caring husband*), thereby increasing the distance between the head noun and the verb. If the higher acceptance rate for the ungrammatical sentences with conjoined adjective attractors was a result of the increased distance between the head noun and the verb, then a singular attractor with stacked adjectives should also lead to an increase

in the acceptance rate. If the effect is due to the word *and*, attraction should be observed in with conjoined adjectives but not stacked adjectives.

Participants

As with the other acceptability judgment experiments reported here, participants were recruited via Amazon's Mechanical Turk platform. They were all native speakers of American English and received $3 for completing the experiment. There were 30 participants, plus 4 additional participants who were excluded from all analyses because they accepted the ungrammatical filler items at a rate of 40% or above.

Materials and design

The materials were adapted from those used in Experiment 4 and 5. Instead of using a suffixal plural attractor as one of the attractor types, we included a singular attractor preceded by two stacked adjectives (*the loyal caring husband*). Consequently, the three attractor types were singular attractor with single adjective (*the caring husband*), singular attractor with stacked adjectives (*the loyal caring husband*), and singular attractor with conjoined adjectives (*the loyal and caring husband*). For some of the items, the order of the adjectives was reversed from Experiment 4 and 5 to make the stacked adjectives sound more natural, but this was kept constant across experimental conditions. The experimental items were distributed across six lists in a Latin Square design, so that each participant saw each item in only one condition. Filler items (72, ratio of 1:1 grammatical vs. ungrammatical) and control items were the same as in the other acceptability judgment experiments and were identical across lists.

Procedure and analysis

The same acceptability judgment procedure and analysis was used as in Experiment 1, 3, and 4. Trials on which no response was made within 2000 ms were excluded from the analysis, resulting in the exclusion of 0.65% of experimental trials. Grammaticality was coded the same as in all other experiments reported here (grammatical: -0.5, ungrammatical: 0.5). For attractor type, one contrast was used to directly compare the attractor with stacked adjectives to the attractor with conjoined adjectives (single adjective: 0; stacked adjectives: -0.5; conjoined adjectives: 0.5). To keep the contrasts orthogonal, the other contrast compared the attractor with a single adjective to the average of the two other attractor types (single adjective: -0.5; stacked adjectives: 0.25; conjoined adjectives: 0.25).

Results

Fig. 6 plots the proportion of '*yes*' judgments for each experimental condition and the results from the logit model are presented in Table 10. As expected, there was a main effect of grammaticality ($p < .001$), with ungrammatical sentences accepted less frequently than grammatical ones. There was no significant interaction between grammaticality and attractor type for the comparison between the attractor with one adjective compared to the average of the other two attractors ($p = .25$; grammaticality effect single adjective = 81.2%; average grammaticality effect other attractors = 76.4%). The interaction between grammaticality and attractor type was significant for the comparison between the attractor with stacked adjectives and the attractor with conjoined adjectives ($p = .04$). The impact of ungrammaticality was smaller for attractors with conjoined adjectives compared to attractors
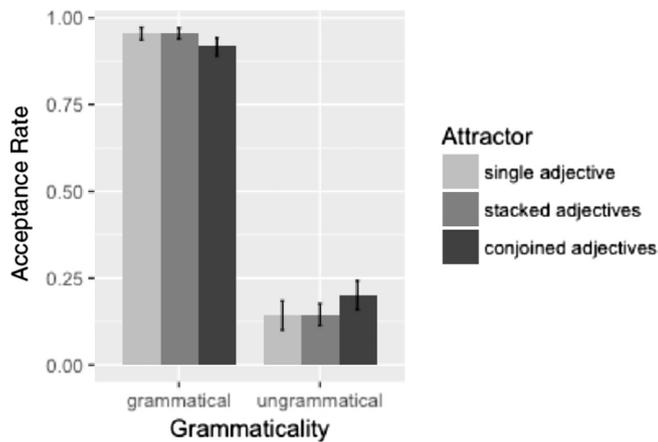
Fig. 6. Acceptance rates across conditions in Experiment 6. Error bars indicate standard error of the mean.

with stacked adjectives (grammaticality effect conjoined adjectives = 71.6%; grammaticality effect stacked adjectives = 81.2%).

To test whether the attractor with conjoined adjectives caused attraction in comparison to the attractor with a single adjective, we conducted a post hoc test following the same procedure as in Experiment 4 and 5. The interaction between grammaticality and attractor type for attractors with a single adjective and conjoined adjectives was significant (Estimate = 1.18; Std. Error = 0.56; z-value = 2.12; *p* = .03), which is consistent with the results from Experiment 4 and 5.

Discussion

The results of Experiment 6 provide further data suggesting that syntactically singular attractors containing two conjoined adjectives can cause agreement attraction in comprehension. In contrast, the grammaticality effect for singular attractors with stacked adjectives was not at all reduced compared to the grammaticality effect for singular attractors with a single adjective. This suggests that the increase in the acceptance rate we see with the conjoined adjectives in Experiment 5 is not simply due to the increased linear distance between the subject's head noun and the verb. Instead, it seems that the presence of the conjunction *and* results in some degree of agreement attraction when the verb is plural, even when the noun phrase it appears in is syntactically singular as in the conjoined adjective case. We return to the question of what this means for the relationship between cues and features in the memory system in the General Discussion.

General discussion

The experiments reported here investigated the processing of subject-verb agreement in comprehension. We asked whether the pattern of attraction errors in comprehension is sensitive to how the relevant agreement feature, namely syntactic plurality,

is signaled morphologically. Is the number retrieval cue on the verb specific to a particular morphological correlate of number, such as the plural -*s*, an unequivocal signal? Or is it more general, ranging over both -*s* and *and* at least, and perhaps even as abstract as the number feature itself? The experiments that used conjoined singular noun phrases as attractors (Exp. 1–3) show that conjoined attractors that are syntactically plural, but contain only an *equivocal* signal of syntactic plurality, namely *and*, cause agreement attraction effects in both self-paced reading and speeded acceptability measures. In Experiment 1, attraction from conjoined singular noun phrases was significantly greater than for attractors containing plural -*s*, which correlates perfectly with syntactic plurality; but this asymmetry was not statistically significant in either Experiment 2 or 3. The findings suggest that syntactically plural attractors cause similarity-based interference in agreement computation in comprehension regardless of whether they are marked by suffixing or conjunction. In Experiments 4–6, we observed evidence that, beyond syntactic plurality, an additional (small) contributor to agreement attraction from conjoined NPs is the coordinator itself, as we found an attraction effect even with syntactically singular attractors when they contained conjoined adjectives. This effect was significant in both speeded acceptability judgment tasks (Exp. 4 and 6) and marginal in self-paced reading (Exp. 5). It did not appear to result from increased expectations for a plural noun after conjoined adjectives, or from increased linear distance between the subject's head noun and the verb (Exp. 6).

The role of morphological form in memory retrieval

The results of Experiments 1–3 suggest that the agreement computation process in comprehension is not limited to targeting the unequivocal exponent of syntactic plurality (plural -*s*) during cue-based memory retrieval. It can also target an abstract feature related to number, or at least a set of exponents of this feature, not all of which are unequivocal correlates. Specifically, we found that comprehenders showed facilitation in ungrammatical singular-subject/plural-verb sentences when a non-subject consisting of conjoined singular noun phrases served as an attractor, even though the syntactic plurality of this attractor was not introduced by an unequivocal signal (plural -*s*). In the self-paced reading experiment, this facilitation took the form of a reduced slow-down in the verb's spillover region, and in the speeded acceptability judgment tasks this was reflected in higher acceptance rates. These results suggest that the online cue-based retrieval process used in the comprehension of agreement might make use of retrieval cues that are just as abstract as the agreement dependency is in the grammar, rather than being specific to the form of exponence per se.

In contrast, one recent study in Arabic (Tucker et al., 2015) suggests that agreement attraction effects in comprehension might depend at least partially on how the syntactic plural feature is introduced, i.e. on its vehicle. Arabic has two different plural formation strategies. *Suffixing* plurals append a plural suffix to the singular stem, similar to the formation of the English plural by adding the suffix '-*s*'; but *ablauting* plurals are formed by internal vowel

Table 10
Results of mixed logit model in Experiment 6.

Parameter	Estimate	Std. Error	z-value	p-value
Intercept	0.64	0.22	2.90	<.01
Grammaticality	−5.23	0.31	−17.14	<.001
Attractor: sg adj. vs. stacked & conj. adj.	−0.05	0.35	−0.14	.89
Attractor: stacked adj. vs. conjoined adj.	−0.14	0.28	−0.49	.63
Gram. × Att.: sg adj. vs. stacked & conj. adj.	0.80	0.69	1.16	.25
Gram. × Attractor: stacked adj. vs. conj. adj.	1.16	0.56	2.10	.04

change, similar to the English change from 'goose' to 'geese'. Tucker et al. (2015) found that, when a suffixing plural was in attractor position, there were significant agreement attraction effects in the reading times. But this was not so when the attractor was an ablauting plural: then there was only a trend towards attraction, not reaching statistical significance.

The data from Tucker et al. (2015) suggest that there is a difference in retrieval interference as a function of whether the plural is suffixal or ablauting. This might indicate that memory retrieval mechanisms in comprehension target only some particular exponents or correlates of the abstract category, perhaps only the unequivocal ones. But in seeming contrast to their findings, our results suggest that retrieval mechanisms for agreement computation in comprehension do not respond just to the vehicle of syntactic plurality. Retrieval models must also include more general cues, not simply a specific morphological form.

These apparently divergent findings can be reconciled if the Arabic data reflect only a quantitative contrast, not a qualitative one. In our experiments, agreement attraction effects for conjoined singulars were indeed larger than for suffixal plurals, at least numerically. But these differences were relatively small and were only statistically significant in Experiment 1. Whether they are qualitatively meaningful will require more work, with larger samples. Meanwhile, we suggest that the quantitative differences might relate to differences between suffixal and conjoined plurals in properties such as notional plurality or the relative strength of plural -s or and as associative cues to plurality. We discuss broader evidence about the role of these factors in agreement comprehension in the next two sections.

Furthermore, some of our results in fact provide some positive evidence that surface form can have effects on the memory retrieval processes in the computation of agreement in comprehension. Specifically, the agreement attraction effect we observed with singular attractors containing conjoined adjectives (the diligent and compassionate doctor) might be interpreted as an indication that the morpheme and, which is only an imperfect correlate of syntactic plurality, may nonetheless be targeted by the verb's number retrieval cue, even if the noun phrase in which it occurs is not syntactically plural. Thus actual indicators of syntactic plurality are not the only possible matches for the number retrieval cue on the verb. Items that merely correlate with plurality may also match. But importantly, the effect is very weak quantitatively: Conjoined adjectives led to a markedly smaller and less reliable attraction effect than suffixal plural attractors.

Notional plurality in agreement computation in comprehension

Our findings indicate that in the processing of subject-verb agreement in comprehension a structurally inaccessible noun phrase may function as an attractor, even if it is not an unequivocal morphological correlate of syntactic plurality (as plural -s is). But our experiments cannot clearly distinguish between the roles of syntactic versus notional plurality. The conjoined singular noun phrases we used as attractors in Experiments 1–3 are not only syntactically but also notionally plural. In fact, conjoined noun phrases (the man and the woman) have been argued to have a 'higher degree' of notional plurality than other plurals, such as plural definite descriptions (the neighbors), because they provide two separate antecedents for subsequent pronouns (him and her; Patson, 2014). And notional number does seem to have effects on production: in production, both collective noun phrases (the fleet) and conjoined noun phrases (the man and the woman) raise the likelihood of agreement errors (Brehm & Bock, 2013, 2017; Humphreys & Bock, 2005; Lorimor et al., 2016; Mirković & MacDonald, 2013).

But our concern is comprehension. And whether comprehension is affected by notional number requires more research; very few studies have pursued the question. We do have some preliminary reasons, however, to think it does not have the same effects as it does in production. In one recent self-paced reading experiment (unpublished), we tested a notional number manipulation using collective nouns, such as fleet. Arguably these represent their referent as comprising multiple objects, and so are notionally plural. But in American English they are syntactically singular and take only singular agreement. In our experiment, we manipulated the notional plurality of the collective attractor by varying the preceding sentence such that it either simply mentioned the collective as a whole or drew attention to the fact that it referred to a group consisting of multiple entities, thus emphasizing its distributive meaning (The fleet was powerful and looked very impressive. / The fleet consisted of forty ships and looked very impressive. – The captain of the fleet was/were known for his battle skills.). Collective attractors never led to a reduction in processing difficulty in ungrammatical sentences, regardless of the preceding sentence. This one initial study, therefore, fails to support the possibility that notional number, rather than syntactic number, explains the observed pattern of errors and non-errors in comprehension of agreement dependencies. But much more work will be needed to settle the question.

Associative cues

Experiments 4–6 provided some evidence that the presence of the conjunction and within the attractor caused a small interference effect even when the phrase was syntactically singular. Any conclusions should be taken as somewhat preliminary since the effect was only marginally significant in self-paced reading (Exp. 5) and the linear distance between the verb and the subject's head noun in Experiment 6 was still greater for the conjoined adjective construction than for the stacked adjective construction. Nevertheless, the observed agreement attraction effect with conjoined adjectives is compatible with the hypothesis that the relationship between retrieval cues and features in sentence processing is associative rather than categorical, and may not strictly follow the cue-feature relationships licensed by the grammar (Engelmann, Jäger, & Vasishth, 2016). Under this view, the relationship between cues and features is not a categorical match or mismatch; instead cues can be associated with multiple features to different extents. The association between cues and features is learned based on exposure, and while they usually reflect grammatical knowledge, over time co-occurrence patterns can lead to the association of cues with features they are not linked to in the grammar.

Engelmann et al. (2016) suggest that if two features frequently co-occur on the target item in a linguistic dependency, over time they might both become associated with the retrieval cue even if only one of them is conceptually linked with it. For example, in the case of reciprocals in English, the features +c-command and +plural always co-occur on the antecedent of the reciprocal. Consequently, in this dependency the plural retrieval cue becomes associated not only with the plural feature but also the c-command feature, and vice versa for the c-command retrieval cue. In the case of subject-verb agreement, while the actual target of the number retrieval cue is syntactic plurality, which controls agreement in the grammar, the presence of and might have served as a kind of surface cue to plurality, even in the absence of a syntactically plural attractor.

To determine whether and could potentially become associated with the plural retrieval cue through frequent co-occurrence with syntactic plurality, we conducted a small corpus-based analysis to determine its distribution. The corpus was a subset of the Corpus of Contemporary American English (Davies, 2008) consisting of 250 sentences. We limited the analysis to occurrences of and for which

the syntactic context could be unambiguously identified, resulting in a total of 308 tokens. The distribution was as follows: 3.2% occurred between two prepositional phrases (10 tokens), 4.2% between verb phrases (13 tokens), 15.3% between adjectives (47 tokens), 23.7% between clauses (73 tokens) and 53.6% between two noun phrases (165 tokens). A native speaker of English judged whether each instance of conjoined noun phrases would take plural agreement if it occurred in subject position. Only two of the tokens of *and* occurred in a conjoined noun phrase that the native speaker considered likely to take singular agreement. This indicates that over half of all tokens of *and* co-occur with syntactic plurality. In summary, although singular attractors with conjoined adjectives are not actually plural, a small corpus search confirmed that there is a strong correlation between *and* and syntactic plurality. It is possible that its frequent co-occurrence with syntactic plurality has led *and* to become associated with the plural retrieval cue. This association would not be as strong as the association between the cue and its actual target feature. While a singular attractor with conjoined adjectives might receive some activation from the verb's plural retrieval cue, this would lead to the attractor being misretrieved much less frequently than a syntactically plural attractor.

As an anonymous reviewer points out, an associative cue account might also provide an explanation for the effects of morphological form on attraction observed by Tucker et al. (2015) in Arabic. Interestingly, in Arabic the majority of inanimate ablauting plurals require obligatory singular agreement even in the plural (Ryding, 2005). Although the ablauting plurals used in the study by Tucker et al. referred to animates and did not trigger obligatory singular agreement, the frequent use of ablauting plurals with singular agreement might impact to what extent this vehicle of plurality is associated with the plural retrieval cue on the verb. Thus the associative cue account provides an appealing explanation for the Arabic data and our observation of agreement attraction with conjoined adjectives. However, such an account would become too powerful, if left unconstrained: Far too many items would engender agreement attraction. Its plausibility, or its limits, will therefore need to be tested further in future research.

Spreading activation and agreement attraction with conjunctions

In the discussion so far we have assumed a cue-based retrieval account of agreement processing in comprehension and have discussed how the current results would constrain this kind of model. However, it should be noted that a spreading activation account of the kind originally developed to model agreement production (Eberhard et al., 2005; Staub, 2009, 2010) could also be straightforwardly extended to account for the data presented here. While cue-based retrieval models assume that the subject either possesses a plural feature or not, in a model like marking and morphing (Eberhard et al., 2005) the number information of the subject is not binary but ranges on a continuum between unambiguously singular (0) to unambiguously plural (1). Attraction occurs because a subject with a singular head noun and a plural embedded noun has an intermediate number value and is therefore no longer unambiguously singular. In agreement attraction studies in production this has typically been a suffixal plural noun. Conjoined singular noun phrases are syntactically and notionally plural and could therefore have a similar impact on the number value of a singular subject (unpublished data by Lap Keung and Adrian Staub suggests that conjoined noun phrases also induce agreement attraction in production). The spreading activation model could similarly incorporate the small agreement attraction effect we see with conjoined adjectives if a conjunction inside a subject with a singular head noun raises its number value slightly, but not as much as a syntactically and notionally plural element such as a

suffixal plural or conjoined singular noun phrases. Since in this framework agreement is probabilistic based on the continuous value of the number feature, this means that attraction would be stronger with suffixal plurals and conjoined singular noun phrases than with conjoined adjectives. However, as discussed in the introduction, the major challenge for applying spreading activation models of agreement to comprehension is that they seem to very straightforwardly predict symmetrical *decreases* in acceptability and increases in reading times on some proportion of grammatical trials in which a singular subject with a plural attractor combines with a singular verb, as such subjects are not unambiguously singular. Such symmetrical effects have not generally been reported in comprehension experiments (e.g., Dillon et al., 2013; Lago et al., 2015; Tucker et al., 2015; Wagers et al., 2009), nor do we observe them in the experiments here.

Conclusion

We used self-paced reading and speeded acceptability judgments to show that the vehicle by which the relevant feature that licenses the subject-verb agreement dependency in the grammar, syntactic number, is introduced, does not have an impact on whether a structurally inaccessible syntactically plural noun phrase interferes in agreement computation in comprehension. Conjoined singular NPs, which are plural in their syntax but contain only an *equivocal* morphological signal of this, namely *and*, caused strong attraction effects. Thus the verb's number retrieval cue does not target just plural -*s*, an unequivocal exponent of syntactic plurality, but is instead specified in more general terms. However, we also found a numerically much smaller attraction effect with attractors with conjoined adjectives, which are not syntactically plural and do not license plural agreement in the grammar. We hypothesize that this is because *and* frequently co-occurs with syntactic plurality and has therefore become weakly associated with the plural retrieval cue. Taken together, these findings suggest that the feature primarily targeted in memory retrieval operations linked to agreement processing is not a specific exponent of syntactic number, but something more general or abstract; and yet that at the same time, imperfect surface correlates of syntactic plurality, such as *and*, can also interfere to a smaller extent, due to the associative nature of features and cues.

References

Acuña-Fariña, J. C. (2012). Agreement, attraction and architectural opportunism. *Journal of Linguistics, 48*, 257–295. https://doi.org/10.1017/S0022226712000084.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*, 390–412. https://doi.org/10.1016/j.jml.2007.12.005.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68*, 255–278. https://doi.org/10.1016/j.jml.2012.11.001.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*, 1–48. https://doi.org/10.18637/jss.v067.i01.

Bock, K., & Eberhard, K. M. (1993). Meaning, sound and syntax in English number agreement. *Language and Cognitive Processes, 8*, 57–99. https://doi.org/10.1080/01690969308406949.

Bock, K., Eberhard, K. M., & Cutting, J. C. (2004). Producing number agreement: How pronouns equal verbs. *Journal of Memory and Language, 51*, 251–278. https://doi.org/10.1016/j.jml.2004.04.005.

Bock, K., & Miller, C. A. (1991). Broken agreement. *Cognitive Psychology, 23*, 45–93. https://doi.org/10.1016/0010-0285(91)90003-7.

Brehm, L., & Bock, K. (2013). What counts in grammatical number agreement? *Cognition, 128*, 149–169. https://doi.org/10.1016/j.cognition.2013.03.009.

Brehm, L., & Bock, K. (2017). Referential and lexical forces in number agreement. *Language, Cognition and Neuroscience, 32*, 129–146. https://doi.org/10.1080/23273798.2016.1234060.

Champollion, L. (2013). Man and woman: The last obstacle for Boolean coordination. In M. Aloni, M. Franke, & F. Roelofsen (Eds.), *Proceedings of the 19th Amsterdam colloquium* (pp. 83–90). https://doi.org/10.13140/2.1.4779.1045.

Corbett, G. G. (2000). *Number.* Cambridge: Cambridge University Press.

Davies, M. (2008). *The Corpus of Contemporary American English: 520 million words, 1990-present.* Retrieved from <http://corpus.byu.edu/coca/>.

Dillon, B., Mishler, A., Sloggett, S., & Phillips, C. (2013). Contrasting intrusion profiles for agreement and anaphora: Experimental and modeling evidence. *Journal of Memory and Language, 69*, 85–103. https://doi.org/10.1016/j.jml.2013.04.003.

Drummond, A. (2017). Ibex farm Retrieved from <http://spellout.net/ibexfarm>.

Eberhard, K. M., Cutting, J. C., & Bock, K. (2005). Making syntax of sense: Number agreement in sentence production. *Psychological Review, 112*(3), 531–559. https://doi.org/10.1037/0033-295X.112.3.531.

Engelmann, F., Jäger, L. A., & Vasishth, S. (2016). The determinants of retrieval interference in dependency resolution: Review and computational modeling (submitted for publication). Retrieved from <http://www.ling.uni-potsdam.de/~engelmann/publications/EngelmannJaegerVasishth2016_R1_160429.doc.pdf>.

Franck, J., Vigliocco, G., Antón-Méndez, I., Collina, S., & Frauenfelder, U. H. (2008). The interplay of syntax and form in sentence production: A cross-linguistic study of form effects on agreement. *Language and Cognitive Processes, 23*, 329–374. https://doi.org/10.1080/01690960701467993.

Franck, J., Vigliocco, G., & Nicol, J. (2002). Subject-verb agreement errors in French and English: The role of syntactic hierarchy. *Language and Cognitive Processes, 17*, 371–404. https://doi.org/10.1080/01690960143000254.

Gelman, A., & Hill, J. (2006). *Data analysis using regression and multilevel/hierarchical models.* Cambridge: Cambridge University Press.

Hartsuiker, R. J., Schriefers, H. J., Bock, K., & Kikstra, G. M. (2003). Morphophonological influences on the construction of subject-verb agreement. *Memory & Cognition, 31*, 1316–1326. https://doi.org/10.3758/BF03195814.

Haskell, T. R., & MacDonald, M. C. (2003). Conflicting cues and competition in subject–verb agreement. *Journal of Memory and Language, 48*, 760–778. https://doi.org/10.1016/S0749-596X(03)00010-X.

Heycock, C., & Zamparelli, R. (2005). Friends and colleagues: Plurality, coordination, and the structure of DP. *Natural Language Semantics, 13*, 201–270. https://doi.org/10.1007/s11050-004-2442-z.

Hothorn, T., Bretz, F., & Westfall, P. (2008). Simultaneous inference in general parametric models. *Biometrical Journal, 50*, 346–363. https://doi.org/10.1002/bimj.200810425.

Humphreys, K. R., & Bock, J. K. (2005). Notional number agreement in English. *Psychonomic Bulletin & Review, 12*, 689–695. https://doi.org/10.3758/BF03196759.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language, 59*, 434–446. https://doi.org/10.1016/j.jml.2007.11.007.

Just, M. A., Carpenter, P. A., & Woolley, J. D. (1982). Paradigms and processes in reading comprehension. *Journal of Experimental Psychology: General, 111*, 228–238. https://doi.org/10.1037/0096-3445.111.2.228.

Keung, L., & Staub, A. (2016). Closest conjunct agreement in English: A comparison with number attraction. *Paper presented at 29th annual CUNY conference on human sentence processing, University of Florida, Gainesville, FL.*

King, T. H., & Dalrymple, M. (2004). Determiner agreement and noun conjunction. *Journal of Linguistics, 40*, 69–104. https://doi.org/10.1017/S0022226703002330.

Kush, D., Lidz, J., & Phillips, C. (2015). Relation-sensitive retrieval: Evidence from bound variable pronouns. *Journal of Memory and Language, 82*, 18–40. https://doi.org/10.1016/j.jml.2015.02.003.

Lago, S., Shalom, D. E., Sigman, M., Lau, E. F., & Phillips, C. (2015). Agreement attraction in Spanish comprehension. *Journal of Memory and Language, 82*, 133–149. https://doi.org/10.1016/j.jml.2015.02.002.

Lewis, S., & Phillips, C. (2015). Aligning grammatical theories and language processing models. *Journal of Psycholinguistic Research, 44*, 27–46. https://doi.org/10.1007/s10936-014-9329-z.

Lewis, R. L., & Vasishth, S. (2005). An activation-based model of sentence processing as skilled memory retrieval. *Cognitive Science, 29*, 375–419. https://doi.org/10.1207/s15516709cog0000_25.

Linck, J. A., & Cunnings, I. (2015). The utility and application of mixed-effects models in second language research. *Language Learning, 65*, 185–207. https://doi.org/10.1111/lang.12117.

Lorimor, H., Jackson, C. N., Spalek, K., & van Hell, J. G. (2016). The impact of notional number and grammatical gender on number agreement with conjoined noun phrases. *Language, Cognition and Neuroscience, 31*, 646–661. https://doi.org/10.1080/23273798.2015.1136426.

Martin, A. E., & McElree, B. (2009). Memory operations that support language comprehension: Evidence from verb-phrase ellipsis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*, 1231–1239. https://doi.org/10.1037/a0016271.

McCloskey, J. (1991). There, it, and agreement. *Linguistic Inquiry, 22*, 563–567.

McElree, B. (2000). Sentence comprehension is mediated by content-addressable memory structures. *Journal of Psycholinguistic Research, 29*(2), 111–123. https://doi.org/10.1023/A:1005184709695.

McElree, B., Foraker, S., & Dyer, L. (2003). Memory structures that subserve sentence comprehension. *Journal of Memory and Language, 48*, 67–91. https://doi.org/10.1016/S0749-596X(02)00515-6.

Mirković, J., & MacDonald, M. C. (2013). When singular and plural are both grammatical: Semantic and morphophonological effects in agreement. *Journal of Memory and Language, 69*, 277–298. https://doi.org/10.1016/j.jml.2013.05.001.

Patson, N. D. (2014). The processing of plural expressions. *Language and Linguistics Compass, 8*, 319–329. https://doi.org/10.1111/lnc3.12085.

Pearlmutter, N. J., Garnsey, S. M., & Bock, K. (1999). Agreement processes in sentence comprehension. *Journal of Memory and Language, 41*, 427–456. https://doi.org/10.1006/jmla.1999.2653.

R Core Team (2017). *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing. Retrieved from <http://www.R-project.org/>.

Ryding, K. C. (2005). *A reference grammar of modern standard Arabic.* Cambridge: Cambridge University Press.

Staub, A. (2009). On the interpretation of the number attraction effect: Response time evidence. *Journal of Memory and Language, 60*, 308–327. https://doi.org/10.1016/j.jml.2008.11.002.

Staub, A. (2010). Response time distributional evidence for distinct varieties of number attraction. *Cognition, 114*, 447–454. https://doi.org/10.1016/j.cognition.2009.11.003.

Tanner, D., Grey, S., & van Hell, J. G. (2017). Dissociating retrieval interference and reanalysis in the P600 during sentence comprehension. *Psychophysiology, 54*, 248–259. https://doi.org/10.1111/psyp.12788.

Tanner, D., Nicol, J., & Brehm, L. (2014). The time-course of feature interference in agreement comprehension: Multiple mechanisms and asymmetrical attraction. *Journal of Memory and Language, 76*, 195–215. https://doi.org/10.1016/j.jml.2014.07.003.

Tucker, M. A., Idrissi, A., & Almeida, D. (2015). Representing number in the real-time processing of agreement: Self-paced reading evidence from Arabic. *Frontiers in Psychology, 6*, 347. https://doi.org/10.3389/fpsyg.2015.00347.

Van Dyke, J. A., & McElree, B. (2006). Retrieval interference in sentence comprehension. *Journal of Memory and Language, 55*, 157–166. https://doi.org/10.1016/j.jml.2006.03.007.

Wagers, M. W., Lau, E. F., & Phillips, C. (2009). Agreement attraction in comprehension: Representations and processes. *Journal of Memory and Language, 61*, 206–237. https://doi.org/10.1016/j.jml.2009.04.002.