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Misinterpretations in agreement and agreement attraction

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It has been well established that subject–verb number agreement can be disrupted by local noun phrases that differ in number from the subject head noun phrase. In sentence production, mismatches in the grammatical number of the head and local noun phrases lead to agreement errors on the verb as in: *the key to the cabinets are*. Similarly, although ungrammaticality typically causes disruption in measures of sentence comprehension, the disruption is reduced when the local noun phrase has a plural feature. Using a forced-choice comprehension question method, we report two experiments that provide evidence that comprehenders were likely to misinterpret the number information on the head noun phrase when morphosyntactic number markings on the local noun phrase and verb did not match the head. These results are consistent with a growing body of research that suggests that comprehenders often arrive at a final interpretation of a sentence that is not faithful to the linguistic input.

Keywords: Agreement; Agreement attraction; Misinterpretation; Comprehension; Good-enough processing

Sometimes the errors that people make during language processing are informative about how the normal language processing system works. The current paper focuses on errors in number agreement. In English, agreement is rather simple: Verbs must agree with their subjects in terms of number (e.g., if the subject is plural, then the verb must also be plural: *The cats were/ *was*). Despite this simplicity, numerous studies have demonstrated that agreement processing can be disrupted when the subject of the sentence is a complex noun phrase that contain two noun phrases with mismatched number information as in (1):

1. The key to the cabinets . . .

In (1), the number marking on an upcoming verb should agree with the head of the complex noun phrase (i.e., it should be singular). However, many sentence production studies have shown that sentence producers often erroneously produce verbs that agree in number with the local, or "attractor" noun phrase (e.g., *cabinets*; Bock & Miller, 1991; Brehm & Bock, 2013; Eberhard, 1997). This effect is known as an attraction error or simply agreement attraction. Agreement attraction is much more likely when the head is singular and the attractor is plural than when the head is plural and the attractor is singular. This is typically taken to indicate that *morphosyntactically* the plural is the marked condition while the singular is the unmarked, or default, condition (e.g., Eberhard, 1997). These attraction effects are also present in comprehension. In sentences where producers are likely to make agreement errors, sentence comprehenders tend not to be disrupted by the

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"ungrammatical" form of the verb (Clifton, Frazier, & Deevy, 1999; Pearlmutter, Garnsey, & Bock, 1999; Tanner, Nicol, & Brehm, 2014; Wagers, Lau, & Phillips, 2009). Interestingly, these effects seem to be "asymmetric". That is, the agreement attraction causes reduced disruption on the ungrammatical form of the verb but does not cause disruption on the grammatical form of the verb (Phillips, Wagers, & Lau, 2011; Tanner et al., 2014; Wagers et al., 2009, but cf. Nicol, Forster, & Veres, 1997; Pearlmutter et al., 1999; Thornton & MacDonald, 2003). Importantly, these attraction effects are not simply laboratory phenomenon; these types of errors are frequently found in corpus analyses (e.g., Bock et al., 2006), and in some dialects of English, mismatches in number agreement are considered acceptable (e.g., Tagliamonte & Baayen, 2012).

Although these attraction configurations are frequent and have been well studied, to our knowledge no one has investigated comprehenders' final representations of these types of constructions. In last decade or so, psycholinguists have begun probing sentence comprehenders' final interpretations of sentences and discovering that sentence comprehenders often build final representations that are not faithful to the linguistic input (e.g., Christianson, Hollingworth, Halliwell, & Ferreira, 2001; Christianson, Luke, & Ferreira, 2010; Christianson, Williams, Zacks, & Ferreria, 2006; Ferreira, 2003; Patson, Darowski, Moon, & Ferreira, 2009; Slattery, Sturt, Christianson, Yoshida, & Ferreira, 2013; van Gompel, Pickering, Pearson, & Jacob, 2006). For example, after reading a temporarily ambiguous sentence like *While Anna bathed the baby spit up in the crib*, comprehenders often incorrectly believe that the baby was being bathed by Anna (Christianson et al., 2001, 2010; Christianson et al., 2006; Patson et al., 2009; Slattery, Sturt, Christianson, Yoshida, & Ferreira, 2013; van Gompel et al., 2006). Similarly, Ferreira (2003) found that after reading sentences like *The cat was chased by the mouse,* comprehenders often incorrectly believe that it was the mouse that was being chased, an interpretation that is consistent with world knowledge, but inconsistent with the syntax. These studies, and others, highlight the importance of probing comprehenders' final representations. In the case of agreement, given the disruption in agreement processing, it is possible that these structures are often misinterpreted by comprehenders. Understanding how these sentences come to be understood by comprehenders may give us some insight into the processes that lead to attraction effects. As we describe below, two major proposals have been put forth to explain agreement effects: marking and morphing (Eberhard, Cutting, & Bock, 2005) and cue-based retrieval (Wagers et al., 2009). Neither of these proposals explicitly states how comprehenders will come to understand sentences with agreement errors. However, one critical difference between these two proposals is that marking and morphing assumes that the number value on the complex noun phrase is faulty while cue-based retrieval does not. This suggests that marking and morphing would most naturally predict that comprehenders would misinterpret the number information on the head noun phrase when number features are present to disrupt the number value. Cue-based retrieval does not seem to make this prediction. Thus, probing comprehenders' final representations of these sentences may be informative about the agreement processing mechanism.

Marking and morphing (Eberhard et al., 2005) is one example of a class of theories, derived from the production literature, which posits that agreement attraction arises when the number information on the head noun phrase is faulty or ambiguous (e.g., Eberhard, 1999; Eberhard, Cutting, & Bock, 2005; Franck, Vigliocco, & Nicol, 2002; Staub, 2009). According to this view, agreement attraction occurs when the number feature on the attractor noun phrase "percolates" through the syntactic structure of the complex noun phrase and is "visible" to the number agreement mechanism. An important feature of this model is that the number information on the head is continuously valued from 1 (unambiguously plural) to −1 (unambiguously singular). The number value on the complex noun phrase is based on the notional number of the intended referent (from the message level in a

sentence production model) and the morphological number information on the noun phrases contained within the complex noun phrase. Thus, the "more plural" a complex noun phrase is considered, the greater the probability that a plural verb is to be produced. As argued previously, this account seems to predict that during comprehension misinterpretations of the number information on the head noun phrase will arise based on the value of the number information assigned to the complex noun phrase (Staub, 2009; Tanner et al., 2014; Wagers et al., 2009). That is, if the value on the complex noun phrase is more plural than singular, regardless of the morphological information on the head noun phrase, comprehenders may be likely to misinterpret the head noun phrase as plural.

A second class of theories put forth to explain agreement attraction effects posits that attraction arises when the controller of agreement has been misidentified (Badecker & Kuminiak, 2007; Wagers, Lau, & Phillips, 2009). According to these accounts, the representation of number on the subject of the sentences is not ambiguous. Instead, agreement attraction arises due to similarity-based interference in working memory. The idea is that the verb triggers a search through working memory to retrieve the subject, or controller of agreement. If the verb shares a number feature with the attractor noun phrase, that may cause the attractor noun phrase to be misidentified as the agreement controller, thus causing the sentence processor not to notice the ungrammatical form of the verb. This theory predicts the agreement attraction "asymmetry" (i.e., that singular verbs are not disrupted by plural attractors) found in comprehension. When the singular verb is encountered, the search for the agreement controller is not disrupted by a plural attractor noun phrase because the verb and the attractor noun phrase do not share number features. Thus, the controller of agreement is correctly identified, so there is no disruption at the verb. Given that number information is not ambiguous or faulty under this account, it seems to be the case that this account would not predict misinterpretations of the number information on the head noun. The most natural prediction based on this account is that the overlapping number features may cause participants to misidentify the subject of the verb. Whether participants do misidentify the subject of the verb itself is a question we do not address in the following studies. However, even though number information is not faulty, it is still possible that this account may predict misinterpretation of number information on the head noun phrase caused by the retrieval process. This is not explicit in the model because this model was not designed to take into account comprehenders' final interpretations. We return to this in the General Discussion.

Finally, the question of whether or not agreement attraction can lead to comprehension errors is important for theories of parsing that assume that comprehenders sometimes build representations that are inconsistent with the input (e.g., Ferreira & Patson, 2007). In order to fully develop these theories, it is important to know the range of mistakes the comprehenders make during comprehension. The studies that have investigated the errors that comprehenders make show that syntactically (temporarily) ambiguous sentences and implausible, noncanonical sentences lead to misinterpretations (e.g., Christianson et al., 2001, 2010; Ferreira, 2003). To our knowledge, no one has shown that plausible, unambiguous sentences, such as *The key to the cabinets is on the table*, can also be systematically misinterpreted (but see Christianson & Luke, 2011, for evidence that unambiguous sentences can be misinterpreted when context and probe question bias comprehenders to misinterpret). In order to have a complete understanding of how misinterpretations arise, it is important to know the range of sentences that give rise to them.

EXPERIMENT 1

The purpose of Experiment 1 was to determine whether comprehenders misinterpret the number information on the heads of complex noun phrases in agreement and agreement attraction configurations. Because previous studies have shown that attraction errors are typically found on

singular heads, Experiment 1 focused on those cases. In our experiment, sentences had complex subjects with two noun phrases. All of the head noun phrases were singular, and the "attractor" noun phrase was either singular or plural. Additionally, the verb was either grammatical (i.e., singular) or ungrammatical (i.e., plural). Then we asked participants to answer a comprehension question about the number of objects denoted by the head noun phrase (e.g., *Was there more than one key?*). We were interested in whether comprehenders misinterpret the head noun phrase as plural based on the number feature on the attractor noun phrase and the verb.

To be clear, we define a misinterpretation to be an interpretation endorsed by participants that is not licensed by the final sentence structure. In a sentence like, *The key to the cabinets is . . .* , the grammar clearly indicates that a single key is present. If comprehenders indicate that they believe that more than one key is present, they have clearly misinterpreted the number information on the head noun phrase. Diagnosing a misinterpretation is less clear for ungrammatical cases such as *The key to the cabinet(s) are. . . .* In this case the comprehender is faced with two incompatible number features and may be confused about how to answer this question. For our purposes, we assume that the grammar states that the subject is the controller of agreement. Thus, in these cases, we assume that the grammar indicates that the plural verb is incorrect, thus, the "correct" interpretation of the sentence is that there was only one key. Responses that indicate that there was more than one key are considered misinterpretations under this assumption. Although we are asking questions about "ungrammatical" sentences, we do note that in the case of agreement attraction (e.g., *The key to the cabinets are . . .*) these types of agreement errors are produced often (e.g., Bock & Miller, 1991; Brehm & Bock, 2013; Eberhard, 1997) and reduce ungrammaticality disruption in comprehension (Tanner et al., 2014; Wagers et al., 2009). Given that comprehenders often encounter these types of agreement errors, it is important to understand how they come to interpret these kinds of sentences.

There are at least three hypotheses for how comprehenders come to interpret the number information on the heads of complex noun phrase subjects. First, at least in the ungrammatical cases, participants may be confused and not know how to answer the questions. This is because the head noun (e.g., *key*) and the verb (e.g., *are*) have inconsistent morphological number information. In these cases, comprehenders may be confused about whether they should answer the question based on the head or based on the verb. Under this hypothesis, we predict that about half of the time participants will answer the question based on the head, and half of the time they will answer the question based on the verb. Furthermore, their question response times should be disrupted when answering questions following ungrammatical sentences compared to grammatical cases due to their confusion about how to answer the question.

The second hypothesis is that participants are guided solely by the grammar in responding to comprehension questions. In English, the subject determines the number information, and the verb "agrees" with it. Thus, the grammar, in all of our sentences, specifies that the sentences contain only one object because the head was singular. This predicts that comprehenders will never, or rarely, misinterpret the number information on the head of the complex noun phrase.

Finally, the third hypothesis is that comprehenders do misinterpret the number information on the head of the complex noun phrases, and the pattern of misinterpretation depends on the mechanism that controls agreement processing. The marking and morphing account predicts that comprehenders will misinterpret the number information on the head in cases where the value of the complex noun phrase is more plural than singular. Thus, we expect misinterpretations in agreement attraction configurations. This is due to the fact that the presence of a plural verb should be a signal that the complex noun phrase was valued as more plural than singular. That plural verb should then strengthen the interpretation that the complex noun phrase is plural. Furthermore, this account predicts that misinterpretation of the

number information on the complex noun phrase leads comprehenders to accept the ungrammatical plural form of the verb. This predicts that misinterpretations should be related to reading times on the sentences. That is, when comprehenders misinterpret the head noun phrase as plural they should show an "illusion of grammaticality" when they encounter a plural verb and show disruption when they encounter a singular verb. Likewise, when they correctly interpret the complex noun phrase as singular, they should show disruption when the verb is plural but not when it is singular. In the cases when the attractor noun phrase is plural but the verb is singular, it is possible that misinterpretations could arise. Under this account, the plural feature on the attractor noun phrase should cause the complex noun phrase to be interpreted as slightly plural or not unambiguously singular. Although when the singular verb is used that is an indication that the complex noun phrase was not interpreted as more plural than singular, it could be that the slight plural valuation may cause some disruption when answering questions about number. This would predict a slight increase in misinterpretations compared to when no plural features are present. It is unclear what the marking and morphing account predicts in the case where both noun phrases are singular but the verb is plural (e.g., *the key to the cabinet is . . .*). One prediction would be that comprehenders should not misinterpret the number information on the complex noun phrase because nothing in the noun phrase itself should cause the number value to be considered plural. However, if the verb number information is allowed to influence the number value on the complex noun phrase, then this account would predict misinterpretations in these conditions.

Again, the predictions of the cue-based retrieval account are less straightforward. One prediction that most naturally arises is that comprehenders will not misinterpret the number information on the head noun phrase because number information is not ambiguous or faulty under this account. However, it is possible that this account would predict misinterpretations due to the retrieval process. Cue-based retrieval accounts posit that when comprehenders read a verb a search through memory may be triggered to look for the controller of agreement. It is well known that memories can be subject to distortion (e.g., Schacter & Slotnick, 2004). It is possible that during the retrieval process the memory representation of the head noun phrase becomes distorted. This prediction assumes that marked features (e.g., morphosyntactic plural features) would be more likely to cause disruption than unmarked features and that unmarked or default cases (e.g., singular noun phrases) would be more likely to be distorted in memory than marked cases. In cue-based retrieval accounts, it is unclear whether the memory search is automatic or triggered by ungrammaticality (Wagers et al., 2009). If the search is triggered by ungrammaticality, then we would predict that comprehenders would misinterpret singular heads as plural when they encounter a plural verb, suggesting that the attractor alone would not cause misinterpretation. If the search is automatic, we would predict that misinterpretations of singular heads could arise regardless of the verb type and whenever the attractor noun phrase is plural.

Method

Participants

Seventy-two native speakers of American English from Ohio State–Marion received partial course credit for their participation.

Design and stimuli

The experiment had a 2 × 2 repeated measures design. The first factor was the number marking on the attractor noun phrase: singular as in (1) versus plural as in (2). The second factor was the grammaticality of the sentence as marked by the verb: grammatical as in (a) versus ungrammatical as in (b).

1a. The key to the cabinet is on the table.
1b. The key to the cabinet are on the table.
2a. The key to the cabinets is on the table.
2b. The key to the cabinets are on the table.

Forty experimental items were divided into four lists such that each list contained one condition from each experimental item. Please see

Appendix for all items used in Experiment 1 and 2. Each participant viewed one list. Each list also contained the same set of 80 grammatical filler sentences, meaning that approximately 17% of the sentences that participants encountered were ungrammatical. This is consistent with the number of ungrammatical items that participants saw in each of the experiments reported by Wagers et al. (2009). We did not include ungrammatical fillers because we did not want to draw participants' attention to the agreement information. It is important to note that Tanner et al.'s (2014) experiments included 50% ungrammatical items, and their patterns of processing were consistent with the patterns reported by Wagers et al. The filler sentences in our study had a number of different constructions and included items from a subordinate–main garden-path study not reported here.

Every experimental and filler sentence was followed by a comprehension question. For the experimental items, comprehension questions probed participants' numerical representation of the head noun phrase—for example, *Was there more than one key?* Because the head noun was always singular, the correct answer to the comprehension question was always "no" for our experimental items. For the filler trials, comprehension questions probed various aspects of the sentences, such as identifying the event, the agent, or the patient in the sentence. Four fillers explicitly probed number interpretations, while additional four fillers implicitly probed number information (e.g., *Were there no cuts?* after the sentence *The administrator announced the cuts* . . .). We intentionally included few filler trials probing number so as not to draw attention to the agreement information in the sentences. An equal number of yes/no responses were required.

Apparatus

The trials were presented using E-Prime v.2 experimental software (Schneider, Eschman, & Zuccolotto, 2002). A Dell P991 19″ monitor (800 × 600 pixels; 24 bit) displayed stimuli using a NIVIDIA GeForce3 video graphics card. The screen refresh rate was 100 Hz. Keyboard presses were used to log responses and record reaction time.

Procedure

Participants were tested in groups of no more than six. After providing informed consent, participants read the instructions and participated in one practice block of eight trials before moving on to the experiment. An experimental trial consisted of the following events. A fixation-cross appeared at the left side of the computer screen. When participants were ready to begin the trial, they pressed the space bar. Sentences were presented one word at a time using a moving-window procedure. Participants were instructed to read the word and then press a button to continue to the next word. After the sentence, a comprehension question appeared to which participants responded "yes" or "no" by pressing prespecified buttons. Participants were instructed to read the sentences as naturally as possible and to answer the question as quickly and accurately as possible. In an effort to avoid drawing attention to the cases with agreement errors, participants were not informed that some of the items might be ungrammatical. None of the participants reported noticing the agreement errors after participating in the experiment.

Results

Self-paced reading

The self-paced reading data for Experiment 1 are presented in Figure 1. Because word length was confounded with both factors in our study, we length-adjusted the reading times (Ferreira & Clifton, 1986; Trueswell, Tanenhaus, & Garnsey, 1994). We computed individual regression analyses for each participant. Word length was regressed from the raw reading times for all items including fillers. The residual values were used in all reading time analyses. We deleted residual reading times that were 3.5 standard deviations above the grand mean resulting in a loss of 1% of the total data. We analysed all experimental trials. We conducted a 2 × 2 repeated measures analysis of variance (ANOVA) crossing attractor noun phrase number (plural vs. singular) and sentence grammaticality [grammatical vs. ungrammatical using participants (F_1) and items (F_2) as random factors; see Table 1 for statistics] .

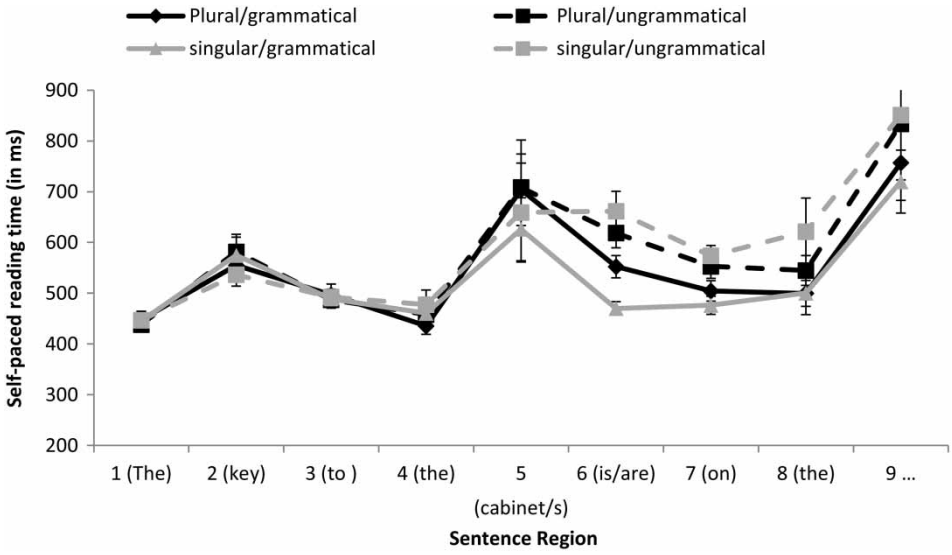

Figure 1. *Self-paced reading time for Experiment 1.*

There were no effects of either independent variable on Regions 1–3 of the sentences (ps > .05). In the region prior to the attractor region (Region 4) there was a main effect of grammaticality such that more time was spent in the region when the sentence was ungrammatical (M = −0.16 ms) than when it was grammatical (M = −0.21). Because this region occurs prior to the critical verb, it is likely that this effect is spurious. In the attractor region (Region 5) there was a main effect of number marking such that reading times were longer when the word was plural (M = −0.04 ms) than when it was singular (M = −0.10 ms); however, it was only significant by participants. In the critical verb region (Region 6), there was a significant main effect of attractor type such that comprehenders spent less time in the region when the attractor was singular (M = 0.097 ms) than when it was plural (M = 0.151 ms). There was also a significant main effect of grammaticality, such that reading times were longer when the word verb was ungrammatical (M = 0.18 ms) than when it was grammatical (M = 0.07 ms). These main effects were qualified by a significant interaction between attractor type and grammaticality. Planned comparisons indicate that the effect of grammaticality was fully reliable for sentences with singular attractors [$t_1(71)$ = 4.38, p < .001; $t_2(39)$ = 5.93, p < .001], but not for sentences with plural attractors [$t_1(71)$ = 0.68, p = .50; $t_2(39)$ = 0.66, p = .52], consistent with previous work showing that the plural attractor reduces the disruption due to the ungrammatical form of the verb (e.g., Tanner et al., 2014; Wagers et al., 2009). The effects continued into the next region (Region 7) of the sentence. There was a significant main effect of grammaticality, such that reading times were longer when the verb was ungrammatical (M = 0.09 ms) than when it was grammatical (M = −0.08 ms). This main effect was qualified by an interaction between attractor type and grammaticality. Planned comparisons indicate that the effect of grammaticality was fully reliable for sentences with singular attractors [$t_1(71)$ = 6.68, p < .001; $t_2(39)$ = 6.92, p < .001], and only reliable by participants for sentences with plural attractors [$t_1(71)$ = 2.45, p = .02; $t_2(39)$ = 1.84, p = .074]. The mean difference between the grammatical and ungrammatical conditions for sentences with plural attractors (M = 0.08 ms) was reduced compared to when the attractor was singular (M = 0.26 ms) although to a much smaller degree than in the critical verb region. The effects continued in the

Table 1. *ANOVA self-paced reading with residual reading times*

			F1				F2			
Experiment	*Region*	*Source of Variance*	F	df	MSE	p	F	df	MSE	p
Experiment 1	Head NP (Region 2)	Attractor NP	0.38	1, 71	0.05	.540	0.01	1, 39	0.05	.940
		Grammaticality	0.32	1, 71	0.05	.575	0.08	1, 39	0.03	.779
		Attractor NP × Grammaticality	0.44	1, 71	0.04	.509	0.004	1, 39	0.02	.952
	"to" (Region 3)	Attractor NP	2.81	1, 71	0.04	.098	2.93	1, 39	0.02	.095
		Grammaticality	0.19	1, 71	0.04	.666	0.51	1, 39	0.03	.478
		Attractor NP × Grammaticality	0.38	1, 71	0.03	.538	0.61	1, 39	0.02	.440
	"the" (Region4)	Attractor NP	0.52	1, 71	0.04	.472	1.48	1, 39	0.02	.231
		Grammaticality	**6.47**	**1, 71**	**0.03**	**.013**	**4.81**	**1, 39**	**0.02**	**.034**
		Attractor NP × Grammaticality	0.16	1, 71	0.04	.687	0.07	1, 39	0.02	.801
	Attractor (Region 5)	Attractor NP	**4.22**	**1, 71**	**0.06**	**.044**	1.17	1, 39	0.05	.286
		Grammaticality	0.16	1, 71	0.05	.691	0.02	1, 39	0.05	.896
		Attractor NP × Grammaticality	1.54	1, 71	0.05	.218	0.15	1, 39	0.05	.703
	Verb (Region 6)	Attractor NP	**4.98**	**1, 71**	**0.04**	**.029**	2.01	1, 39	0.05	.164
		Grammaticality	**10.42**	**1, 71**	**0.09**	**.002**	**18.63**	**1, 39**	**0.03**	**<.001**
		Attractor NP × Grammaticality	**10.00**	**1, 71**	**0.06**	**.002**	**5.41**	**1, 39**	**0.04**	**.025**
	Postverb (Region 7)	Attractor NP	0.004	1, 71	0.05	.948	0.00	1, 39	0.03	.990
		Grammaticality	**35.45**	**1, 71**	**0.06**	**<.001**	**28.57**	**1, 39**	**0.03**	**<.001**
		Attractor NP × Grammaticality	**15.98**	**1, 71**	**0.04**	**<.001**	**6.87**	**1, 39**	**0.03**	**.001**
	Verb + 2 (Region 8)	Attractor NP	0.48	1, 71	0.05	.49	0.05	1, 39	0.03	.818
		Grammaticality	**28.51**	**1, 71**	**0.04**	**<.001**	**8.44**	**1, 39**	**0.06**	**.006**
		Attractor NP × Grammaticality	**11.49**	**1, 71**	**0.05**	**.001**	**6.69**	**1, 39**	**0.03**	**.014**
Experiment 2	Head (Region 2)	Head NP	1.41	1, 47	0.04	.241	0.86	1, 39	0.04	.358
		Grammaticality	1.40	1, 47	0.04	.242	1.04	1, 39	0.06	.314
		Head NP × Grammaticality	0.11	1, 47	0.06	.739	0.01	1, 39	0.04	.942
		"to" (Region 3)								
		Head NP	0.004	1, 47	0.03	.947	0.03	1, 39	0.04	.863
		Grammaticality	0.10	1, 47	0.05	.753	0.19	1, 39	0.03	.668
		Head NP × Grammaticality	1.41	1, 47	0.03	.241	0.67	1, 39	0.04	.418
	"the" (Region 4)	Head NP	0.75	1, 47	0.03	.391	0.48	1, 39	0.04	.493
		Grammaticality	1.18	1, 47	0.02	.281	1.15	1, 39	0.03	.291
		Head NP × Grammaticality	0.26	1, 47	0.06	.613	0.18	1, 39	0.04	.676
	Attractor (Region 5)	Head NP	0.19	1, 47	0.08	.663	0.14	1, 39	0.08	.706
		Grammaticality	2.71	1, 47	0.08	.107	**4.49**	**1, 39**	**0.05**	**.041**
		Head NP × Grammaticality	0.003	1, 47	0.06	.814	0.14	1, 39	0.07	.711
	Verb (Region 6)	Head NP	2.16	1, 47	0.05	.148	1.74	1, 39	0.04	.195
		Grammaticality	1.21	1, 47	0.06	.277	0.83	1, 39	0.05	.369
		Head NP × Grammaticality	3.78	1, 47	0.04	.058	3.95	1, 39	0.03	.054
	Post-Verb (Region 7)	Head NP	0.93	1, 47	0.04	.339	0.82	1, 39	0.06	.369
		Grammaticality	**5.53**	**1, 47**	**0.05**	**.023**	**4.80**	**1, 39**	**0.05**	**.034**
		Head NP × Grammaticality	0.77	1, 47	0.04	.384	0.59	1, 39	0.05	.447
	Verb + 2 (Region 8)	Head NP	0.40	1, 47	0.04	.529	0.28	1, 39	0.04	.599
		Grammaticality	0.11	1, 47	0.05	.739	0.10	1, 39	0.03	.754
		Head NP × Grammaticality	0.22	1, 47	0.05	.638	0.12	1, 39	0.04	.734

Note: Reading times in ms. ANOVA = analysis of variance; NP = noun phrase. Bold values are significant at the $p < .05$ level.

next region of the sentence (Region 8). Participants spent more time on the region when the sentence was ungrammatical ($M = 0.01$ ms) than when it was grammatical ($M = -0.12$ ms). The interaction between attractor and sentence grammaticality showed that the effect of grammaticality was present for sentences with singular attractors [$t_1(71) = 5.48$, $p < .001$; $t_2(39) = 4.24$, $p < .001$], but not for sentences with plural attractors [$t_1(71) = 1.26$, $p = 0.21$; $t_2(39) = 0.86$, $p = .397$]. Because of variability in the number of words in the sentence, we did not analyse the final regions of the sentence.

Comprehension accuracy

Responses to comprehension questions were coded to reflect misinterpretation. In Experiment 1, responses of "yes" indicate misinterpretation of the number information on the head noun phrase. Misinterpretation scores were modelled using logistic mixed effects modelling using the maximum random effect structure justified by the data (Barr, Levy, Scheepers, & Tily, 2013). Model criticism was used to remove outliers by first fitting an initial model to all data and then refitting the model to data within 2.5 standard deviations of the absolute standardized residuals of the initial model (Baayen, 2008). This resulted in the loss of 3.02% of the data. The final model included as fixed factors: the attractor, the verb, and the interaction between attractor and verb. The models also included random intercepts for participants and items (see Table 2).

The effect of attractor was significant ($p = .002$), indicating that participants were more likely to misinterpret the number of the head noun phrase when the attractor was plural than when it was singular. The effect of verb was also significant ($p < .001$), indicating that participants were more likely to misinterpret the number of the head noun phrase when the verb was plural than when it was singular. The significant interaction between these two factors indicates that the misinterpretation effect was largest in the agreement attraction cases ($p = .047$). Figure 2 illustrates this interaction.

An inspection of our items indicated that seven of them appear to have a distributed reading. Distributivity has not been shown to affect agreement production in English (Bock & Miller, 1991) but it has been shown to be important in other languages (e.g., Spanish, Italian, Dutch, Vigliocco, Butterworth, & Garrett, 1996a; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996b). Although distributivity is not known to disrupt English processing of agreement, it could influence how comprehenders understand the meaning of the sentence. In fact, a plural response for a distributed complex noun phrase in our study would be a reasonable interpretation and perhaps should not be labelled a misinterpretation. To determine whether these items influenced our effects, we conducted a separate analysis dropping those seven items. We found the same pattern of data and found that participants were no more likely to respond to the distributed items as plural than the nondistributed items. A separate logistic mixed effects model using the same random and fixed effects was computed and showed the same pattern of effects (see Table 2); however, the interaction between attractor noun phrase and sentence grammaticality failed to reach significance, probably due to decreased power. Given the consistency in the two analyses, we do not believe that the distributed items influenced our results.

Comprehension response times

Given that participants were being asked to answer comprehension questions following ungrammatical sentences, there might be some concern that participants were confused during the experiment and were unsure how to answer the questions. We think there are at least three reasons why this is not a concern for the data reported here. First, we analysed the question response times by condition. Response times were trimmed at 3.5 standard deviations above the grand mean to eliminate outliers (see Table 3 for means). A 2×2 repeated measures ANOVA (see Table 4 for statistics) crossing attractor type and sentence grammaticality indicated that participants were significantly faster to respond to questions when the attractor was singular ($M = 2527$ ms) than when

Table 2. *Effects of attractor NP and grammaticality on proportions of misinterpretations in Experiments 1 and 2*

Experiment	*Analysis*	*Fixed effects*	*Estimate*	SE	z	p
Experiment 1	All items included	(Intercept)	−4.78	0.81	−5.91	<.001
		Attractor	**2.04**	**0.67**	**3.05**	**.002**
		Grammaticality	**2.49**	**0.68**	**3.67**	**<.001**
		Attractor × Grammaticality	**1.31**	**0.66**	**−1.99**	**.047**
	Items with distributed readings excluded	(Intercept)	−5.69	1.14	−5.00	<.001
		Attractor	**2.20**	**0.97**	**2.27**	**.023**
		Grammaticality	**2.89**	**1.00**	**2.90**	**.004**
		Attractor × Grammaticality	−1.39	0.95	−1.46	.14
Experiment 2	All items included	Fixed effects				
		(Intercept)	−3.43	0.60	−5.76	<.001
		Head NP	**−2.45**	**0.65**	**−3.77**	**<.001**
		Grammaticality	**1.47**	**0.56**	**2.60**	**.009**
		Head NP × Grammaticality	0.71	0.57	1.25	.212
	Items with distributed readings excluded	Fixed effects				
		(Intercept)	−1.75	0.14	−12.50	<.001
		Head NP	**−0.79**	**0.20**	**−3.91**	**<.001**
		Grammaticality	**0.44**	**0.13**	**3.46**	**<.001**
		Head NP × Grammaticality	−0.17	0.12	−1.41	.159

Note: NP = noun phrase. Number in bold correspond to statistically significant ($p < .05$) values.

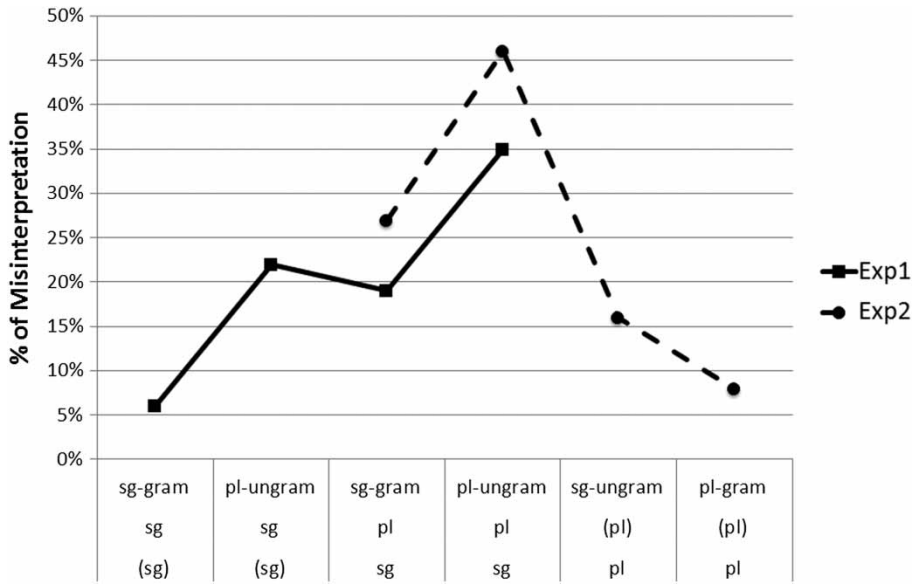

Figure 2. *Percentage of misinterpretation in Experiments 1 and 2. NP = noun phrase; sg = singular; pl = plural; gram = grammatical; ungram = ungrammatical. To view this figure in colour, please visit the online version of this Journal.*

it was plural ($M = 2827$ ms). Participants were also faster to respond to grammatical sentences ($M = 2551$ ms) than ungrammatical sentences ($M = 2803$ ms). However, these main effects were qualified by a significant interaction. Pairwise comparisons indicated that the effect of grammaticality

Table 3. *Question response times (overall responses times and response times by question accuracy) in Experiments 1 and 2*

	Overall response times by condition (in ms)					
	Experiment 1			*Experiment 2*		
Condition	*Overall RT*	*Correct*	*Misinterpretation*	*Overall RT*	*Correct*	*Misinterpretation*
The key to the cabinet is . . .	2319	2365	2438			
The key to the cabinet are . . .	2734	3340	2903			
The key to the cabinets is . . .	2783	2871	2995	2538	2579	2535
The key to the cabinets are . . .	2871	3205	2984	2355	2509	2327
The keys to the cabinets is . . .				2071	1980	2861
The keys to the cabinets are . . .				1994	1890	3064
	Overall response times by experiment half (in ms)					
First half of experiment	3011			2374		
Second half of experiment	2518			1991		

Note: RT = response time.

Table 4. *Response times for comprehension questions in Experiments 1 and 2*

		F*1*				F*2*			
Experiment	*Analysis*	F	df	MSE	p	F	df	MSE	p-*value*
Experiment 1	Attractor NP	2409	1, 71	268,953.98	<.001	21.69	1, 39	176,424.60	<.001
	Grammaticality	10.35	1, 71	441,655.73	.002	8.42	1, 39	303,505.74	.006
	Attractor NP × Grammaticality	9.20	1, 71	209,060.30	.003	5.22	1, 39	173,350.16	.028
	First half vs. second half	14.99	1, 143		<.001	64.27	1, 79		<.001
Experiment 2	Head NP	28.22	1, 47	270,410.73	<.001	25.96	1, 39	233,904.24	<.001
	Grammaticality	0.62	1, 47	170,935.71	.43	0.57	1, 39	131,285.97	.453
	Head NP × Grammaticality	5.14	1, 47	159,354.80	.028	3.41	1, 39	190,922.02	.073
	First half vs. second half	14.08	1, 95		<.001	57.03	1, 79		<.001

Note: NP = noun phrase.

was only present for the singular attraction noun phrase condition [$t_1(71) = 4.74$, $p < .001$; $t_2(39) = 3.78$, $p = .001$], but not for the plural attractor condition [$t_1(71) = 0.87$, $p = .388$; $t_2(39) = 0.92$, $p = .364$]. This interaction suggests that overall grammaticality did not cause participants to slow down in a way that suggests that they were weighing two equally likely responses. Additionally, Fine, Jaeger, Farmer, and Qian (2013) recently provided evidence that during the course of an experiment participants speed up as they become accustomed to the types of sentences in the experiment. This suggests that if participants are confused during a study, their response times may slow down throughout the experiment as confusion increases. However, this was not the case in our experiment. A one-way ANOVA revealed that participants' response times were significantly faster in the second half of the experiment than in the first half (ps $< .05$; see Table 3 for means). Finally, after the experiment session, participants were allowed to provide feedback on the experiment. None indicated being confused by any of the questions in the experiment.

Reading times given misinterpretation

One prediction that arises from the marking and morphing account is that comprehenders' final

Table 5. *Reading times by experiment condition and misinterpretation in Experiments 1 and 2*

Experiment	*Fixed effects* Critical verb region	*Estimate*	SE	t
Experiment 1	(Intercept)	0.14	0.03	4.17
	Attractor	0.02	0.02	0.94
	Grammaticality	**0.08**	**0.02**	**3.63**
	Misinterpretation	−0.08	0.05	−1.70
	Attractor × Grammaticality	**−0.06**	**0.02**	**−3.44**
	Attractor × Misinterpretation	0.07	0.04	1.82
	Grammaticality× Misinterpretation	**−0.10**	**0.04**	**−2.41**
	Attractor × Grammaticality× Misinterpretation	0.05	0.04	1.40
Experiment 2	(Intercept)	0.03	0.03	0.96
	Head NP	−0.04	0.02	−1.92
	Grammaticality	0.03	0.02	1.38
	Misinterpretation	**0.10**	**0.04**	**2.30**
	Head NP × Grammaticality	0.01	0.02	0.75
	Head NP × Misinterpretation	**0.10**	**0.04**	**2.54**
	Grammaticality × Misinterpretation	−0.03	0.04	−0.79
	Head NP × Grammaticality × Misinterpretation	0.04	0.04	1.20

Note: Number in bold correspond to statistically significant ($p < .05$) values.

representations may be linked to their online processing of the sentence. That is, the decreased disruption in reading times on the plural verb following a plural attractor should follow from comprehenders misinterpreting the number information on the head noun phrase. Similarly, this account predicts that a correct interpretation of the number information on the head noun phrase should be related to increased processing on the ungrammatical form of the verb. It is important to note that marking and morphing predicts disruption at the verb during reading when the attractor is plural due to the ambiguity of the number information on the complex noun phrase. Consistent with previous work (e.g., Tanner et al., 2014; Wagers et al., 2009), we did not find evidence for this. However, to determine whether reading times were predicted by comprehenders' final interpretations of the number information, we conducted an analysis using linear mixed effect modelling. Residual response times (RTs) on the verb region were modelled with attractor, grammaticality, misinterpretation, and their interactions as fixed effects. The maximum random effect structure justified by the data was also included. Model criticism was used to remove outliers by first fitting an initial model to all data and then refitting the model to data within 2.5 standard deviations of the absolute standardized residuals of the initial model. This resulted in the loss of 2.99% of the data (see Table 5). Models were also fit to the attractor region and spillover (verb + 1) region, but no interesting significant interactions with misinterpretation were discovered. The resulting *p*-values of linear mixed effects models were calculated based on the *t*-values of the model by treating *t*-values as *z*-values (R. Levy and D. Barr, personal communication, September 12, 2012).

Focusing on interactions with misinterpretation scores, the interaction of verb and misinterpretation was significant ($p = .016$). Participants read the verb slowest when the verb was ungrammatical, and they did not misinterpret the sentence. This effect was not predicted, and any interpretation of it would be speculation. Importantly, there was no significant three-way interaction between attractor, grammaticality, and final interpretation.

Discussion

The data from Experiment 1 indicate that comprehenders sometimes represent number information

that is inconsistent with what the grammar licenses. This is consistent with previous findings that show that often comprehenders assign an interpretation to a sentence that is not licensed by the grammar (e.g., Christianson et al., 2001, 2010; Christianson et al., 2006; Ferreira, 2003; Patson et al. 2009; Slattery, Sturt, Christianson, Yoshida, & Ferreira, 2013; van Gompel et al., 2006). The results reported show that unambiguous, plausible structures can also be subject to misinterpretation. We return to this in the General Discussion.

It is important to note that the self-paced reading times reported here are consistent with previous results showing that comprehenders often do not notice agreement errors when they occur in agreement attraction configurations (e.g., Pearlmutter, Garnsey, & Bock, 1999; Tanner et al., 2014; Wagers, Lau, & Phillips, 2009). This suggests that the comprehension questions that we asked did not draw attention to the agreement information and did not cause participants to process these sentences differently than other studies have shown. This is similar to findings in other studies that show that misinterpretations are not due to probe questions (Christianson et al., 2010; Patson et al., 2009; van Gompel et al., 2006).

Furthermore, our data also suggest that comprehenders were not simply confused when asked questions about the number information. As we suggested, we believe this hypothesis would predict that sentences would be misinterpreted about half of the time. Instead, the highest rate of misinterpretation was around 40% (in the agreement attraction case). Importantly, in the ungrammatical, nonattraction case (e.g., *the key to the cabinet are . . .*), rates of misinterpretation were around 25%. This percentage of misinterpretations does not suggest that comprehenders were confused about whether they should interpret the sentences based on the number information on the head or the number information on the verb. Instead, these data indicate that most often comprehenders used the number information on the head noun phrase, as licensed by the grammar, to answer the comprehension questions. The response times for the comprehension questions do not indicate that comprehenders were confused. In the ungrammatical conditions, participants were not necessarily slower to respond than in the grammatical conditions. Additionally, response times decreased as the experiments progressed, indicating that comprehenders were not getting more confused during the duration of the experiment.

Our data seem to indicate that whenever a plural feature is present on an attractor noun phrase or on the verb, it is available to interfere with comprehenders' number representations of singular noun phrases. These effects are particularly strong when both the attractor and the verb have plural features. This finding seems most consistent with the marking and morphing account of agreement attraction. That is, plural features are able to "percolate" up the syntactic representation of the complex noun phrase, which may cause comprehenders to conceptually represent the head as plural.

However, the marking and morphing account predicts disruption on the verb following a plural attractor regardless of whether the verb is grammatical or not. It also seems to predict that misinterpretation of the number information should be related to comprehenders' online reading times. However, consistent with previous findings, we did not find evidence that processing on the verb was disrupted following a plural attractor. Instead, we found evidence for the asymmetry agreement effects in comprehension—that is, a decreased ungrammaticality effect on the verb following a plural attractor without a corresponding disruption for the grammatical form of the verb following a plural attractor. Furthermore, we did not find evidence for a relationship between comprehenders' online processing time and their final interpretations of the sentences. Thus, while the misinterpretation data support the marking and morphing hypothesis, the combination of the online processing data and offline question answering data do not. We return to this in the General Discussion.

EXPERIMENT 2

Experiment 2 was designed to replicate and extend the findings in Experiment 1. In Experiment 1,

participants never read experimental sentences with plural heads, and none of the "correct" responses for the comprehension questions on experimental trials were "yes". It is possible that this inflated the rates of misinterpretation. Thus, it is important to replicate those effects in environments where participants are presented with plural heads, and the comprehension questions should correctly be responded to with "yes".

Method

Participants

Forty-eight participants were recruited from the same population as that in Experiment 1. None had participated in Experiment 1.

Design and stimuli

The experiment had a 2 (head noun: singular vs. plural) × 2 (grammaticality: grammatical vs. ungrammatical) repeated measures design. The first factor was the number marking on the head noun phrase: singular as in (3) versus plural as in (4). The second factor was the grammaticality of the sentence as marked by the verb: grammatical as in (a) versus ungrammatical as in (b).

3a. The key to the cabinets is on the table.
3b. The key to the cabinets are on the table.
4a. The keys to the cabinets are on the table.
4b. The keys to the cabinets is on the table.

Forty experimental items were divided into four lists such that each list contained one condition from each experimental item. Each participant viewed one list. Each list also contained the same set of 60 grammatical filler sentences. This means that 20% of the sentences that comprehenders read were ungrammatical. Filler sentences had a number of different structures.

The same comprehension questions as those used in Experiment 1 were used in Experiment 2 —for example, *Was there more than one key?* However, in Experiment 2, the correct answer for items like (3) was "no", while the correct answer for items like (4) was "yes". All of the filler sentences were followed by a comprehension question, which probed various aspects of the sentence. As in Experiment 1, four items explicitly probed for number, and four items implicitly probed number information. An equal number of yes/no responses were required.

Apparatus and procedure

The same apparatus and procedure were used in Experiment 2 as in Experiment 1.

Results

Self-paced reading

The self-paced reading data for Experiment 2 are presented in Figure 3. We used the same procedure for computing residual reading times as that in Experiment 1. The residual values were used in all reading time analyses. Residual reading times greater than 3.5 standard deviations from the grand mean were deleted, resulting in a loss of 1% of the data. We conducted a 2 × 2 repeated measures ANOVA crossing head noun phrase number (plural vs. singular) and sentence grammaticality [grammatical vs. ungrammatical using participants (F_1) and items (F_2) as random factors; see Table 1 for statistics].

There were no effects of either independent variable on Regions 1–4, 7, and 8 of the sentences ($ps > .05$). In the attractor region (Region 5), there was a main effect of grammaticality that was not significant by participants ($p = .107$) but significant by items ($p = .041$). This effect is probably spurious given that the verb region had not been read yet. In the critical verb region (Region 6), there was a main effect of grammaticality such that participants spent less time on the verb when it was grammatical ($M = 0.10$ ms) than when it was ungrammatical ($M = 0.19$ ms). In the postverb region (Region 7), there was a main effect of grammaticality such that participants spent less time on the verb when it was grammatical ($M = -0.08$ ms) than when it was ungrammatical ($M = -0.004$ ms).

Comprehension accuracy

Responses to comprehension questions were coded to reflect misinterpretation. In Experiment 2, responses of "yes" indicate misinterpretation for items in which the head was singular (as in 3

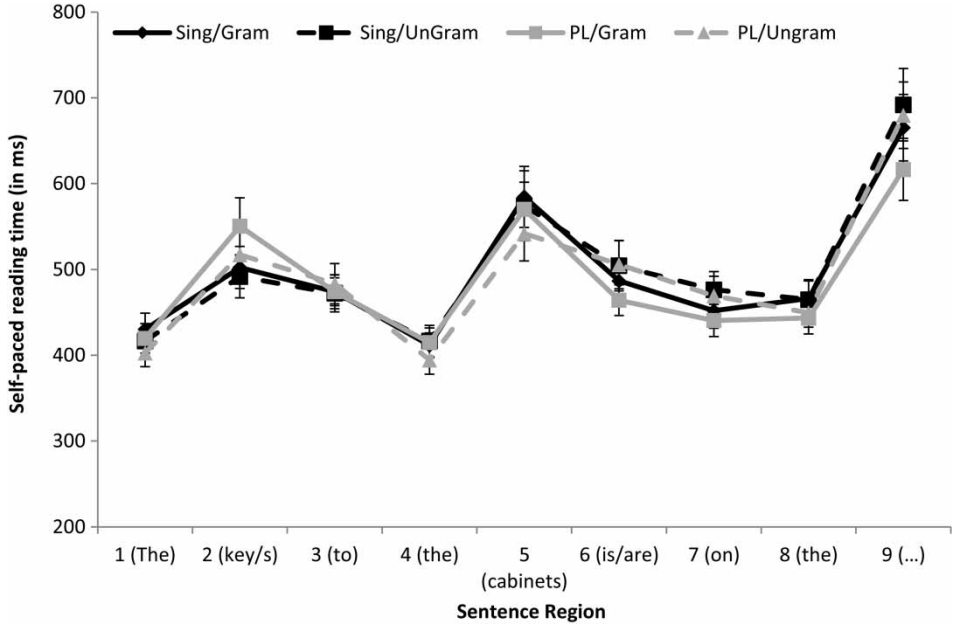

Figure 3. *Self-paced reading times for Experiment 2. Sing = singular; pl = plural; gram = grammatical; ungram = ungrammatical.*

above), whereas a response "no" indicates misinterpretation for items in which the head was plural (as in 4 above). Misinterpretation scores were modelled using logistic mixed effects modelling using the maximum random effect structure justified by the data (Barr et al., 2013). Model criticism was used to remove outliers by first fitting an initial model to all data and then refitting the model to data within 2.5 standard deviations of the absolute standardized residuals of the initial model (Baayen, 2008). This resulted in the loss of 2.04% of the data. The final model is reported.

The effect of head noun phrase marking was significant ($p < .001$) indicating that participants were more likely to misinterpret the number of the head noun phrase when it was singular than when it was plural. The effect of grammaticality was also significant ($p = .009$) indicating that participants were more likely to misinterpret the number of the head noun phrase when the verb was ungrammatical than when it was grammatical. The interaction between these two factors was not significant ($p = .212$). These results are illustrated in Figure 2.

As in Experiment 1, we conducted a separate analysis dropping the same seven items that had a distributed reading. Again, the pattern of results was the same (see Table 2).

Comprehension response times

As in Experiment 1, we analysed the time it took for participants to respond to comprehension questions. A 2 × 2 repeated measures ANOVA crossing head type and sentence grammaticality indicated that participants were slower to respond to questions after a singular head than a plural head (mean difference 399 ms, see Table 4 for statistics). There was no difference in response times based on grammaticality. The interaction between head type and sentence grammaticality was only significant by participants. As in Experiment 1, a one-way ANOVA revealed that participants' response times were significantly faster in the second half of the experiment than in the first half (see Table 3 for means). Again, as in Experiment 1, participants did not report noticing the experimental manipulation or finding any of the comprehension questions confusing.

Reading times given misinterpretation

As in Experiment 1, we investigated the self-paced reading data on the critical verb region given participants' final interpretation of the head noun phrase using linear mixed effect modelling. Residual RTs were modelled with head noun phrase, grammaticality, misinterpretation, and their interactions as fixed effects. The maximum random effect structure justified by the data was also included. Model criticism was used to remove outliers by first fitting an initial model to all data and then refitting the model to data within 2.5 standard deviations of the absolute standardized residuals of the initial model. This resulted in the loss of 2.50% of the data (see Table 5). The resulting p-values of linear mixed effects models were calculated based on the t-values of the model by treating t-values as z-values (R. Levy and D. Barr, personal communication, September 12, 2012).

Focusing on interactions with misinterpretation scores, the interaction of head noun phrase (NP) and misinterpretation was significant ($p = .011$). Participants read the verb region slowest when the head noun phrase was plural, and they misinterpreted the sentence. This effect was not predicted, and any interpretation of it would be speculation. Importantly, we found no three-way interaction among head noun phrase, grammaticality, and final interpretation.

Discussion

The comprehension data replicated and extended the findings from Experiment 1. First, the data indicate that plural information on an attractor noun phrase can cause comprehenders to misinterpret a singular head noun phrase as conceptually plural. Furthermore, this occurs even in an environment where comprehenders are presented with plural heads. The data from Experiment 2 also showed that plural heads can be influenced by singular marking on an attractor noun phrase, albeit to a much smaller degree. The small proportion of misinterpretations for plural heads with singular attractors (e.g., *the keys to the cabinet*) is consistent with findings that show that rates of agreement attraction errors for preambles like these are typically low (e.g., Eberhard et al., 2005; Staub, 2009). This is consistent with the notion that in morphosyntax the plural is the marked condition while the singular is the unmarked, or default, condition.

For the reading time data, although the interaction between verb and head noun phrase was not reliable on the critical verb region of the sentence, comparisons of the means indicated that the effect of grammaticality was present for plural heads but less so for singular heads. This is consistent with previous data showing an illusion of grammaticality for erroneous plural verbs following singular heads and plural attractors (e.g., Wagers et al., 2009). Finally, our analysis predicting reading time based on comprehenders' final interpretations does not suggest that any reading time effects on the verb when the head is singular is based on comprehenders' final interpretations of the noun phrase.

GENERAL DISCUSSION

The findings reported here suggest that plural features on attractor noun phrases and verbs can cause comprehenders to misinterpret singular heads in complex noun phrases as plural. Both experiments showed that participants were more likely to misinterpret the head noun phrase as conceptually plural when the complex noun phrase contained a plural attractor (e.g., *the key to the cabinets*). Additionally, both experiments showed that this effect was stronger when both the attractor and the verb were plural (e.g., *the key to the cabinets are*). These findings are consistent with evidence showing that comprehenders often form interpretations of sentences that are not faithful to the grammatical input (e.g., Christianson et al., 2001; Ferreira, 2003; Patson et al., 2009). Furthermore, these data extend these effects to unambiguous, plausible sentences (Christianson & Luke, 2011). These data highlight the importance of probing the final interpretations derived by comprehenders.

Importantly, our data indicate that participants in our studies were reading the sentences naturally

and were not confused by the comprehension questions that we asked them to answer. First, the self-paced reading data from both experiments appear consistent with previous results (Wagers et al., 2009). That is, we found evidence that comprehenders are not disrupted by an ungrammatical plural verb when the attractor noun phrase is plural. Furthermore, we found that comprehenders were less disrupted by a singular verb following a singular head and plural attractor than a singular head and singular attractor. This pattern is the same pattern as that reported by Wagers et al. (2009) using self-paced reading and Tanner et al. (2014) using event-related potentials (ERPs). This consistency suggests that the comprehension questions in our study did not draw participants' attention to the agreement information or cause them to read the sentences differently than in other experiments. This is consistent with findings that misinterpretations occur even when the misinterpretation is not explicitly probed via comprehension questions (Christianson et al., 2010; Patson et al., 2009; van Gompel et al., 2006). Furthermore, the response times for comprehension questions indicate that participants were not confused by the questions they were asked to answer. If participants were confused, we might expect their reaction times to get slower during the course of the experiment. Instead, participants' question response times were faster in the second half of each experiment than in the first half.

It is also important to note that most of the time comprehenders did not misinterpret the head noun phrase. The highest percentage of misinterpretations came from the agreement attraction condition—those conditions were misinterpreted about 45% of the time. That means that the majority of the time comprehenders were using the morphosyntactic number information on the head to determine to answer the comprehension questions as licensed by the grammar. This is similar to previous findings using implausible, non-canonical structures—that is, in those experiments, most of the time comprehenders' final representations were consistent with the syntactic structure of the sentence (Christianson et al., 2010; Ferreira, 2003). Taken together, these findings suggest that although misinterpretations occur frequently and systematically, most often comprehenders' final interpretations are consistent with the linguistic input.

Given that comprehenders do misinterpret these kinds of sentences, and do so systematically, it is important to understand the mechanism that gives rise to these misinterpretations. The first account we considered was marking and morphing (Eberhard et al., 2005), which naturally predicts misinterpretation of the number information on the head due to the fact that number information is faulty, or ambiguous. Under this account, the number information on the complex noun phrase is consistently being valued from unambiguously singular (1) to unambiguously plural (–1). This account predicts that number information on a plural attractor (and possibly the plural verb) may "percolate" through the structure of the complex noun phrase. This may cause the complex noun phrase to be valued as "more plural than singular", which may cause the head of the noun phrase to be similarly valued as "more plural than singular", leading comprehenders to conceptually represent the head as plural. Our patterns of misinterpretation seem consistent with this account. In cases whether the number information on the complex noun phrase would be ranked as "more plural than singular" (e.g., when plural features exist that can "percolate" through the structure) we found evidence that comprehenders indeed misinterpreted the number information on the head. This effect was particularly strong in agreement attraction cases as predicted by this account because the verb should be a signal that the complex noun phrase was more plural. However, as previously noted, marking and morphing suggests that agreement processing should be disrupted whenever a plural attractor is present in the complex noun phrase (e.g., Staub, 2009; Tanner et al., 2014; Wagers et al., 2009). Consistent with previous findings, our self-paced reading data only showed a lack of disruption for the plural verb, but no disruption for the singular verb, following a plural attractor (Tanner et al., 2014; Wagers et al., 2009; but cf. Nicol et al., 1997; Pearlmutter et al., 1999; Thornton & MacDonald, 2003).

Furthermore, marking and morphing seems to predict that the lack of disruption for a plural verb following a plural attractor is due to the fact that the head noun has been misinterpreted as plural. However, we did not find a relationship between the self-paced reading effects and the ultimate interpretation that comprehenders derived. This suggests that while the final representations may be consistent with marking and morphing, the online processing data do not seem consistent with this account.

Previous researchers have argued that cue-based retrieval accounts better explain the effects of agreement attraction during comprehension (Tanner et al., 2014; Wagers et al., 2009). Again, cue-based retrieval argues that agreement attraction occurs when the controller of agreement is misidentified due to partially overlapping (number) features. Because this account does not posit that number information is faulty, it does not naturally predict that misinterpretations of number information should occur. However, it is possible that this account could be revised to take into account the findings reported here. For example, it may be the case that misinterpretations of the kind we report here are a natural consequence of interference during the retrieval process. Much evidence from the memory literature suggests that memory representations can be distorted (e.g., Schacter & Slotnick, 2004). If retrieval is an automatic process that occurs whenever a verb is identified, it is possible that the retrieval process could cause the representation of the noun phrases to become distorted. It is plausible that marked features would be more likely to cause distorting than unmarked/default features, and that noun phrases with unmarked or default features would be more likely to be distorted than those with marked features. This would predict that singular heads are more likely to be misinterpreted than plural heads due to mismatching number information.

An alternative possibility is that although cue-based retrieval captures the online syntactic processing effects, it may not predict effects that exist when conceptual meaning is probed (i.e., responses to comprehension questions). Recently, Tanner et al. (2014) attempted to provide evidence that agreement effects in sentence production and comprehension are due to the same mechanisms (Staub, 2009; Wagers et al., 2009). However, they concluded that accounts like marking and morphing do a better job capturing production effects (cf. Wagers et al., 2009), while cue-based retrieval captures comprehension effects. Instead of arguing that production and comprehension are separate processes, Tanner et al. argue that only a subset of the mechanisms active during production are active during comprehension. Tanner et al. argue that this is plausible because during production the intended message is known by the speaker. Thus, conceptual information may be more active and available to cause interference during production than during comprehension. During comprehension, comprehenders do not initially have conceptual number information activated; instead they build up the conceptual representation incrementally. As Tanner et al. argue, this predicts that conceptual number effects will be limited during comprehension (e.g., they may appear later). If our comprehension questions probed comprehenders' conceptual representation of the head noun, then this prediction is consistent with our data. Our data indicate that misinterpretations of the conceptual number of noun phrases occur after the sentence has been processed. We found no evidence that misinterpretations of the number information on the head noun lead to online comprehension disruption. However, it is unclear whether our comprehension questions probed conceptual number or morphological number. Future work is needed to tease these two alternatives apart.

It is possible that the misinterpretations reported here are not due to agreement processing, but rather occur when comprehenders must monitor their final meaning representation of the sentence (e.g., when they are asked a comprehension question). This is consistent with an account put forth by Christianson et al. (2010) who proposed that "good-enough" representations arise when comprehenders fail to correctly integrate information from syntactic and semantic processing streams. Increasing evidence suggests that language processing occurs via two independent but interacting steams—namely, a syntactic stream and a semantic

stream (Bornkessel & Schlesewsky, 2006; Clahsen & Felser, 2006; Jackendoff, 2007). These proposals predict that language processing will be difficult when the information from the two streams conflict. A number of studies have shown that misinterpretations arise due to conflicts in the morphosyntactic and semantic streams (e.g., Christianson, Luke, Ferreira, 2010; Ferreira, 2003; Kuperberg, Caplan, Sitnikova, Eddy, & Holcomb, 2006; Kuperberg, Kreher, Sitnikova, Caplan, & Holcomb, 2007). This work has focused on thematic role assignment and found that conflicts between semantic and syntactic information can be resolved by reassigning thematic roles, which leads to an interpretation that may be plausible but is not a faithful representation of the linguistic content. For example, Ferreira (2003) investigated sentences like: *The cat was chased by the mouse*. A strict syntactic analysis of this sentence would correctly identify the subject, and therefore the agent, of this sentence as the mouse. However, this interpretation is implausible. It is possible that a separate semantic strategy may identify the agent as the cat, which is more consistent with world-knowledge. The conflict in these two interpretations would predict the misinterpretation effects shown by Ferreira (2003) and Christianson et al. (2010).

How could this account be used to explain the results reported here? There is evidence that plural morphemes immediately activate conceptual/semantic plural information that can disrupt nonlinguistic number processing (Berent, Pinker, Tzelgov, Bibi, & Goldfarb, 2005; Patson & Warren, 2010; Patson & Warren, 2014). For example, Berent et al. (2005) showed that in a number of word judgement tasks, when a single, plural word (e.g., *cats*) appears on the screen, participants are slower to judge that one word is on the screen than when the word is singular (e.g., *cat*). Similar to the effects in agreement, this effect occurs most consistently with the plural morpheme—that is, participants are not slower to judge two singular words than two plural words, suggesting that the plural morpheme is marked while the singular is unmarked or default. Importantly, Patson and Warren (2014), who extended this effect to sentence processing, showed that this effect is not due to general semantic complexity inherent in processing a plural, but rather is the result of activating conceptual plural information. Thus, it is possible that during sentence processing, plural morphemes on the attractor noun phrase or verb activate general conceptual plural information. It is possible that the plural information that is active in the semantic stream could interfere with singular information active in the syntactic stream. Thus, when the two streams are integrated, misinterpretations arise.

Finally, all of the accounts of agreement attraction errors described above posit that mismatches in number features lead to some kind of interference. An alternative account is that the mismatch in number information leads to agreement errors due to a "rational misidentification of the sentence preamble" (Bergen & Gibson, 2012, p. 41). This proposal stems from sentence comprehension theories that posit that errors occur when the probability of noise in the input is rationally combined with prior grammatical knowledge (e.g., Levy, 2008). The idea is that in sentence production paradigms, participants must first read and comprehend sentence preambles like: *The key to the cabinets*. Given this, Bergen and Gibson (2012) proposed that agreement errors in production are due to comprehension processes during the reading of the preamble. This account explicitly predicts that during the comprehension of preambles (at least some of the time) comprehenders will misinterpret singular head noun phrases followed by plural attractor noun phrases as plural. Under this proposal, the *–s* feature on the attractor noun acts as a cue that the head noun phrase may have been misidentified. This proposal predicts that the more cues to plurality, the more likely it is that the head noun will be misidentified. Furthermore, singular head noun phrases are more likely to be misidentified than plural head noun phrases because according to the Bayesian size principle it is more likely that a feature has been deleted than added. This account has been supported empirically (Bergen & Gibson, 2012) and does seem to predict the pattern of misinterpretations reported here.

The data we report here cannot tease apart these possibilities. One piece of information that may be relevant is the time course of misinterpretation. For example, marking and morphing predicts that misinterpretations may arise when the plural feature on the attractor is encountered. Cue-based retrieval predicts that misinterpretations may arise at the verb. It is less clear when misinterpretations would arise under a proposal that misinterpretations are due to conflicts in the syntactic and semantic streams, as it is unclear that the two streams become integrated (Christianson et al., 2010). Finally, it is unclear when misinterpretations arise under the "rational misinterpretation" account. Future work aimed at investigating the time course of misinterpretation may prove useful at teasing these accounts apart.

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APPENDIX

Stimuli used in all sentences

Plural verb conditions used the form "are".

1	The key to the cabinet is on the table.
2	The cookie for the boy is on the plate.
3	The pill for the ailment is in the bottle.
4	The bridge over the river is old and rusty.
5	The marker for the whiteboard is in the tray.
6	The switch to the light is on the wall.
7	The candle for the cake is on the table.
8	The tent for the hiker is over there.
9	The pizza for the teenager is steaming hot.
10	The frame for the photo is on the shelf.
11	The microphone for the singer is on the stand.
12	The easel for the artist is in the art room.
13	The computer for the student is in the lab.
14	The envelope for the paper is in the drawer.
15	The box for the gift is in the closet.
16	The blanket for the crib is at the department store.
17	The pot for the plant is on the porch.
18	The lunchbox for the kid is in the cabinet.
19	The ring for the bride is in a velvet box.
20	The hook for the jacket is on the wall.
21	The pillow for the couch is overpriced.
22	The hanger for the dress is in the closet.
23	The mug for the drink is in the cabinet.
24	The tray for the meal is over there.
25	The plate for the pie is on the counter.
26	The collar for the dog is shipping on Wednesday.
27	The cake for the wedding is made from chocolate.
28	The medal for the winner is on the podium.
29	The book by the author is in the library.
30	The trophy for the competitor is on the stage.
31	The pencil for the student is on the desk.
32	The lipstick for the model is on the vanity.
33	The skirt for the cheerleader is way too short.
34	The helmet for the football players is the wrong colour.
35	The button on the coat is made from plastic.
36	The mat for the yogi is brightly coloured.
37	The whistle for the lifeguard is very high pitched.
38	The knife for the chef is in need of sharpening.
39	The banana for the monkey is fully ripened.
40	The apple for the teacher is very juicy.