Discourse Processes
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hdsp20

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Accepted author version posted online: 11 Sep 2013.

To cite this article: Judith Schweppe (2013) Distance Effects in Number Agreement, Discourse Processes, 50:8, 531-556, DOI: 10.1080/0163853X.2013.841074
To link to this article: http://dx.doi.org/10.1080/0163853X.2013.841074

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Distance Effects in Number Agreement

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One pronoun production experiment and one pronoun comprehension experiment were performed to investigate the role of grammatical number information in long-distance anaphora, with referent and pronoun either in adjacent sentences or separated by an intervening sentence. The experiments tested the assumption that the influence of grammatical number relative to conceptual number on number agreement in pronouns is a function of the accessibility of grammatical number and thus decreases with increasing distance between referent and anaphoric pronoun. For the production and comprehension of pronouns referring to collective nouns in German, grammatical number agreement was preferred when the pronoun was in an adjacent sentence compared with the condition in which a sentence intervened between collective noun and anaphoric pronoun. The results are interpreted as reflecting the availability of grammatical and conceptual information in short-term memory.

INTRODUCTION

Agreement processes are present in most of the world’s languages. According to Steele (1978, p. 610), agreement is “some systematic covariance between a semantic or formal property of one element and a formal property of another.” The present study aims to investigate how the distance between an agreement controller and an agreement target affects the way number agreement is realized. In German, the language under investigation, verbs agree with a noun in number and person and pronouns agree with nouns in number and gender. It follows that by
the time a verb or pronoun is to be produced or is encountered, the noun’s number and its gender or person need to be accessible to produce a comprehensible utterance or to comprehend the utterance (e.g., Wagers, Lau, & Phillips, 2009). Because anaphoric pronouns can occur even in nonadjacent sentences, agreement-relevant information needs to be retained over a considerable distance.

Agreement principally relies on both syntactic and conceptual information (e.g., Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001; Bock, Eberhard, & Cutting, 2004; Eberhard, Cutting, & Bock, 2005). With respect to number, grammatical and conceptual information usually converge: The expression “one car” is not only syntactically singular but also refers to just one entity, whereas “two cars” is syntactically plural and refers to more than one entity. Knowledge of whether one wants to refer to one entity or to more than one entity is thus in most cases sufficient for correct number agreement. Because memory capacity is limited, not all types of information that are activated during discourse comprehension and production can be kept activated for an unlimited time. Remembering conceptual information is also essential for purposes other than agreement and should thus be prioritized; grammatical number information can in principle be forgotten at little expense.

Classic approaches suggest that syntactic information in general is retained only until the propositional structure of a sentence has been built, meaning that it is in many cases forgotten beyond sentence boundaries: Whereas the content of a sentence can be reliably recalled and semantic changes can be detected after a considerable delay, word order and syntactic structure are often altered in recall, and respective changes are detected only at chance level after a brief delay (Jarvella, 1971; Sachs, 1967, 1974). In addition, the choice of syntactic structure in delayed recall of sentences is influenced by conceptual factors such as imageability and prototypicality (Bock & Irwin, 1980; Bock & Warren, 1985; Kelly, Bock, & Keil, 1986; McDonald, Bock, & Kelly, 1993). For instance, Kelly et al. (1986) demonstrated that participants more often recalled a passive sentence in active voice if, as a consequence, a more prototypical noun was produced earlier than a less prototypical one (e.g., “[…] hats were outsold by shirts […]” recalled as “… shirts outsold hats […]”) than if an inversion placed the less prototypical noun earlier (e.g., “[…] iron was surrounded by nickel” recalled as “[…] nickel surrounded iron”). These findings suggest that grammatical number information is not retained for long and that its availability for establishing agreement over a distance is therefore limited. Consequently, long-distance agreement should rely on conceptual number. Yet, counter to explicit tests of memory for grammatical information, priming studies demonstrated a high probability of producing previously encountered syntactic structures rather than alternatives over long delays (up to 10 sentences between prime and target; Bock & Griffin, 2000), suggesting longer availability of syntactic information and thus also a potentially longer availability of syntactic number information.
The rationale of the present study is based on two related assumptions: (1) the degree to which number agreement is based on grammatical number (partly) reflects the availability of grammatical number information in working memory, and (2) the retention characteristics vary between different kinds of grammatical information and depend on whether and how long that specific type of grammatical information needs to be kept available for language comprehension and language production (Schweppe, Rummer, & Fürstenberg, 2009). In other words, depending on how necessary access to certain types of information has previously been for processing, these are more or less likely to be retained. Such an experience-based approach assumes a language processing system that learns with each utterance it encounters so that frequency influences the strength of phenomena (e.g., Haskell, Thornton, & MacDonald, 2010; MacDonald & Christiansen, 2002). When a speaker has frequently experienced that conceptual number is sufficient for computing number agreement in pronoun production as well as for anaphor resolution in comprehension, on the aforementioned assumption it is implicitly learned that syntactic number need not be maintained for further processing. One can thus assume that grammatical number information is only briefly retained and that its influence on agreement decreases over time. This implies that with increasing distance (e.g., with more than one sentence boundary between the agreement controller and the agreement target), number agreement is guided by conceptual rather than by syntactic number information.

Similar assumptions—although not related to availability in working memory—were made by Corbett (1979, 2006) in his agreement hierarchy, according to which conceptual as compared with grammatical agreement becomes more probable as the syntactic distance between controller and target increases. This basic assumption results in a hierarchy in which attributives such as determiners are most likely to agree syntactically (e.g., “this committee” versus “these committee”) and the probability for conceptual agreement increases from predicates/verbs (e.g., “the committee has decided” versus “the committee have decided”) over relative pronouns to personal pronouns (“the committee stated its disapproval” versus “the committee stated their disapproval”). According to Corbett, predictions about the type of agreement (syntactic vs. conceptual) can thus be made based on syntactic distance. Cornish (1986) suggests that the increasing probability of conceptual agreement described in the agreement hierarchy reflects the “increasingly greater independent reference potential, correlating with increasingly higher degree of structural distance from their controllers, exhibited by their exponents” (p. 205). We emphasize another aspect of structural distance, namely that structural distance is closely related to the availability of morphosyntactic information on which grammatical agreement is based (or, more precisely, to the delay over which it needs to be kept available).
Because grammatical and conceptual number usually go hand in hand, research that aims at contrasting the two types of number agreement concentrates on types of nouns in which they diverge: collective nouns such as “committee” or “team.” Collective nouns are usually described as being grammatically singular and conceptually plural (Acuña-Fariña, 2009; Berg, 1998; Corbett, 2006) because they mostly take a singular verb but refer to entities that consist of several “members.” The choice of singular forms with collective nouns would then reflect syntactic agreement and the choice of plural forms conceptual agreement (e.g., Acuña-Fariña, 2009; Berg, 1998; Bock, Nicol, & Cutting, 1999; Corbett, 2006; but see Joosten et al., 2007, who argue that the choice of singular forms reflects a conceptual focus on the group rather than on the member level).

What is the evidence for distance effects on the degree of grammatical number agreement that can be interpreted as due to decreasing availability of grammatical number information?

Corpus data investigating the agreement hierarchy with collective nouns demonstrate that verbs, which tend to be close to the agreement controller, indeed more often agree syntactically with collective nouns than do personal pronouns, the production of which occurs at a greater distance (for an overview see Corbett, 2006). In addition, there is also one corpus study that finds distance effects for the same type of agreement targets: With personal pronouns, the proportion of plural agreement increases with increasing distance (in terms of more intervening words) between collective noun and anaphoric pronoun (American English, British English, and Australian English, Levin, 2001; cited after Corbett, 2006).

Psycholinguistic studies that investigate grammatical versus conceptual number agreement allow only for indirect conclusions regarding (potential) distance effects because only rather short distances are investigated and their focus is on differences between verbs and pronouns. Yet, as the agreement hierarchy emphasizes, an important difference between verbs and pronouns—with respect to agreement—is that verbs are closer to their antecedent than pronouns. In an exemplary experiment (Bock et al., 1999), participants had to produce spoken completions to sentence fragments including collective nouns. Completion of these sentence preambles either required a verb (e.g., “the cast in the soap opera ...”), or participants were explicitly instructed to complete the sentences with a tag pronoun or a reflexive pronoun (e.g., “the cast in the soap opera rehearsed/watched ...”). It turned out that singular agreement was prevalent with verbs but plural agreement with pronouns, suggesting that

\[1\text{Languages differ in terms of their preferred reference for collective nouns: German, Dutch, and American English, for instance, have a clear preference for singular verbs, whereas in British English both plural and singular verbs are regarded as syntactically correct (Corbett, 2006). Pronouns that refer to collective nouns tend to be plural in both American and British English (Bock et al., 2006).}\]
conceptual information influences pronoun choice more strongly than verb choice (Bock et al., 1999, 2001, 2006; Eberhard et al., 2005). This data pattern is explained in terms of the most influential psycholinguistic model of number agreement in production, the marking and morphing model (Bock et al., 2001, 2004; Eberhard et al., 2005). In this model, two processes in number generation are postulated: (1) a conceptually guided process that takes place during the mapping between messages and lexical-grammatical representations (number marking) and (2) the morphological instantiation of number in the lexicon that occurs during constituent assembly (number morphing). In case of a mismatch, conceptual number of the entire phrase and morphological number need to be reconciled. Grammatical number and conceptual number contribute to agreement in both pronoun and verb number agreement. However, only pronouns can bear a number of their own, which is why pronoun number more likely reflects conceptual number than verb number. Verb number agreement occurs under the control of syntactic processes (Eberhard et al., 2005).

Analogously, subject–verb agreement in comprehension seems to be (initially) morphosyntactically driven, whereas pronoun–antecedent agreement is conceptually driven (Gernsbacher, 1991; Kreiner, Garrod, & Sturt, 2013). Kreiner et al. (2013) recorded eye movements during silent reading of sentences in which a collective or a noncollective noun was referred to by a plural reflexive pronoun (Experiment 1) or followed by a number-marked plural verb (Experiment 2). The nouns were presented in a grammatically singular and in a grammatically plural version, so that conditions with a mismatch between the grammatical number of noun and pronoun/verb could be compared with matching conditions (e.g., singular collective plus pronoun: “The class prepared themselves for the tough competition.”; plural collective plus pronoun: “The classes prepared themselves for the tough competition.”; singular noncollective plus verb: “The widow definitely and undeniably wish to avoid a court trial.”; plural noncollective plus verb: “The widows definitely and undeniably wish to avoid a court trial.”). With pronouns, mismatch costs were obtained solely for noncollective nouns but not for collectives. With verbs, earlier measures showed mismatch costs for both noncollective and collective nouns, whereas in later measures (second-pass reading time) mismatch costs were restricted to noncollectives.

Thus, there is by and large converging evidence from production and comprehension experiments that verbs agree with collective nouns syntactically and pronouns agree conceptually. Because verbs tend to be closer to their agreement controllers than pronouns, this may well reflect the decreasing availability of grammatical number information with increasing syntactic distance. Because there is a confound between type of agreement target and distance between agreement controller and target in these studies, however, the findings can just as well be explained solely in terms of processing differences.
between verbs and pronouns, as assumed in the marking and morphing model. Furthermore, in these experiments, even the pronouns occur rather close to the collective nouns. Thus, the influence of distance cannot be specified based on experimental data.

So far, the corpus study by Levin (2001) is the only direct evidence for an influence of distance on the probability of syntactically based number agreement. It is therefore imperative to test conceptual versus syntactic number agreement with collective nouns when distance is experimentally manipulated. In this case, the context can be controlled for and the same agreement target referring to the same noun can be investigated in a short- versus a long-distance condition. To this end, the distance between a collective noun and a pronoun that refers to it was manipulated in two experiments: in Experiment 1, pronoun production was elicited by having participants read a short text in which a collective noun occurred. They were asked to fill in the gaps that occurred either in an adjacent or in a nonadjacent sentence, but only when the sentence with the collective noun was no longer visible on the screen. Decreasing accessibility of grammatical number information with increasing distance would result in a lower proportion of singular completions in the nonadjacent sentences relative to the adjacent ones. Experiment 2 tests the same basic assumption for pronoun comprehension by measuring reading times for the texts used in Experiment 1 with singular versus plural pronouns referring to the collective nouns.

EXPERIMENT 1: PRODUCTION

The experiment was based on a one-factor design with the within-participant factor of distance between anaphoric referent and pronoun (one sentence/short vs. two sentences/long). The number of singular pronoun completions served as the dependent variable.

Method

Participants. Twenty-nine students from Saarland University participated in this experiment. They were native speakers of German and were awarded course credits for their participation.

Materials. Participants were presented with 120 texts consisting of three sentences each (60 experimental and 60 filler items). Each sentence was presented separately on a computer screen. The first sentence of the experimental items always contained a collective noun. Either the second (short distance) or the third sentence (long distance) contained two gaps, which were expected to be filled with a pronoun referring to the collective noun and a verb marked for
number. Because, unlike in English, there are no number-neutral verb forms in German, the verb following the pronoun had to be omitted from the texts as well. The remaining sentence occurred either as an intervening sentence (in the long-distance condition, 30 trials) or as a succeeding sentence (in the short-distance condition, 30 trials). Across participants, each text was presented equally often in both the short-distance and long-distance versions. Because in German the plural pronoun is the same as the feminine singular pronoun ("sie"), it was ensured that none of the collective nouns was feminine and that no feminine noun preceded the critical pronoun. In addition, no noun of the same grammatical gender as the collective noun and no plural noun were presented before the pronoun.

Example (1) illustrates a short-distance text (a) and a long-distance text (b).

A list of all items can be found in the Appendix.

(1a) Das Militär war noch immer preußisch organisiert. /__ ___ Wert auf eine kaisertreue Gesinnung. / Daran hatte sich nichts geändert.
(The army was still organized in a Prussian way. /__ ___ a high value on loyalty to the emperor. / Nothing had changed.)

(1b) Das Militär war noch immer preußisch organisiert. / Daran hatte sich nichts geändert. /__ ___ Wert auf eine kaisertreue Gesinnung.
(The army was still organized in a Prussian way. / Nothing had changed. /__ ___ a high value on loyalty to the emperor.)

In the filler texts, different structures and different types of gaps were used to avoid participants guessing the nature of the gaps beforehand.

Procedure. Participants started each trial by pressing the space bar of the computer keyboard. The first sentence was then presented at a predetermined pace of 250 ms per syllable. After presentation of the first sentence, the second sentence appeared on the screen. In the long-distance condition, this was the intervening sentence that was also presented at a pace of 250 ms per syllable, followed by presentation of the final, critical sentence, which included the gaps. Participants’ task was to complete the target sentence at their own pace on a prepared answer sheet that included a number and two empty lines for each trial, as soon as the sentence with the gaps was presented. As each sentence was presented separately, the collective noun as the anaphoric referent was no longer on the screen by the time participants had to produce the pronoun plus verb. Agreement thus had to rely on a memory representation of the previous discourse. Participants were not explicitly told to produce pronouns and verbs, but the texts were constructed such that this was the most probable syntactically correct completion. After having completed the sentence, participants initiated presentation of the next sentence (here: the next trial) by pressing the space bar. In the short-distance condition, the order of nontarget and target sentences...
was reversed. In addition, 60 filler texts were presented. The order of the 120 texts was determined at random. Before the experiment started, two practice trials were presented to the participants.

The dependent variable was the number of singular pronouns produced. It was predicted that a higher proportion of singular pronouns (agreeing with the collective nouns in syntactic number) would be produced in the short-distance relative to the long-distance condition.

Scoring. The 1,740 (29 × 60) responses were scored as either singular, plural, or other responses. In total, there were 570 singular completions (33%), 651 plural completions (37%), and 519 other responses (30%). Mostly, the other responses were completions with “man,” which is similar to the English “one” (and can be regarded as a kind of collective pronoun so that it cannot be scored unequivocally as a singular or plural response).

Results

In the short-distance condition, 363 completions (42%) were singular pronouns and verbs, 275 (31%) were plural completions, and 232 (27%) were classified as other responses. For the long-distance condition, 207 gaps (24%) were filled with singular pronouns and verbs, 376 (43%) were completed with plural pronouns, and 287 (33%) responses were scored as other completions. The odds ratio for singular responses in the short-distance condition compared with the long-distance condition was 2.29 (95% CI, 1.87–2.82).

Participants’ responses were analyzed using linear mixed effects regression (LMER) analysis with a logistic link function (Baayen, 2008; Baayen, Davidson, & Bates, 2008; Jaeger, 2008), using the lme4 R package (Bates, 2005; Bates & Sarkar, 2007). LMER allows the simultaneous consideration of participants and items as random factors in a single analysis, avoiding the need for separate $F_1$ and $F_2$ analyses, and allows the analysis of categorical dependent variables. According to Barr, Levy, Scheepers, and Tily (2013), LMER models generalize best (and do not inflate Type I error rates) when they include the maximal random effects structure. Thus, a maximal LMER model was constructed, which incorporated “distance” as a fixed effect as well as random intercepts and slopes for both participants and items in a single step. Singular responses were coded as 1 and plural and other responses as 0. Factor labels were transformed into numerical values and centered before analysis to have a mean of 0 and a range of 2 (short distance coded as “$-1$”; long distance coded as “1”). A negative regression weight for distance thus indicates that a short distance makes a singular response more likely than a long distance.

Table 1 summarizes the parameter estimate beta for the fixed effect in the model, as well as the estimate of its standard error, the associated Wald’s $z$-score, and the significance level. As expected, distance is a significant predictor of
singular responses such that singular responses are far more likely when the antecedent is close to the pronoun.2

Discussion

The findings support the assumption of distance affecting the relative impact of syntactically and conceptually based number agreement: The same anaphoric expressions (personal pronouns) referring to the same collective nouns agreed less often syntactically when the controller and target were in nonadjacent sentences relative to when they were in adjacent sentences. Because the referent was no longer visible on the screen at the time of pronoun production, its number had to be accessed from working memory. The findings thus indicate that grammatical number information is lost to a strong degree with an intervening sentence between referent and anaphoric pronoun.

Furthermore, in a sentence following the collective noun, singular pronouns outnumbered plural pronouns. This pattern was reversed with increasing syntactic distance, that is, when the pronoun was to be produced in a nonadjacent sentence. Based on previous (English) studies (e.g., Bock et al., 1999), it is a surprising finding that with pronouns as the agreement target there was a condition in which singular completions were more frequent than plural completions. This issue is discussed in the General Discussion.

A factor that may compromise interpretation of the findings is that the intermediate sentence could have induced a change of focus or a topic shift in addition to increasing the distance between agreement controller and target. With respect to gender agreement, Cornish (1986) suggests that the change from a

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2 Additional, analogous analyses were computed in which (1) plural responses were coded as 1 and singular and other responses as 0 and (2) other responses were coded as 1 and singular and plural responses as 0. In each case, there was a significant effect of distance (1: beta = 0.39, SE = 0.22, z = 4.07, p < .001; 2: beta = 0.24, SE = 0.07, z = 3.20, p = .001). The positive regression weights indicate that the number of both plural and other responses increases from short to long distance. The increase of plural responses can be interpreted as an increasing preference for conceptual agreement, whereas the increase in other responses may reflect greater numerical uncertainty or greater unwillingness to produce an anaphoric pronoun at all.
grammatically agreeing pronoun to a conceptually agreeing one in a discourse can indicate a change in focus: When referring to a female person with a gender-invariant masculine noun (e.g., the French “le ministre[masc]”—the minister), the choice of a female pronoun reflects a focus on the individual, whereas the choice of a masculine pronoun reflects a focus on the individual’s function (Cornish, 1986). For number agreement with collective nouns, Joosten et al. (2007) argue that a preference for the singular need not reflect grammatical number agreement but should rather be regarded as conceptual individuation. In light of these considerations, the interpretation of the collective noun might have changed due to the content of the intermediate sentence, from a focus on the group level to a focus on the member level. If this is the case, the increase of plural pronouns after processing that sentence would reflect a within-semantics change rather than a change from grammatical to conceptual agreement.

To test for such an influence of the intermediate sentence, 38 additional participants received the experimental items (except the sentences including the gaps) in one of two versions and were asked to indicate on a scale from 1 to 10 whether they thought the collective nouns represented “one thing” or “more than one thing” in this particular context. Each participant judged half of the collective nouns in a short context (i.e., with only the first sentence presented) and the other half in a long context (i.e., with the first sentence and the intermediate sentence presented). Across participants, each item was presented equally often in a short and in a long context. Collective nouns were rated equally irrespective of whether they were assessed in a short context (4.7, $SD = 0.9$) or in a long context (4.8, $SD = 1.0; p > .3$). There is thus no reason to assume that the interpretation of the collective noun changed systematically as a function of the intervening sentence. It is also possible that when processing the intervening sentence induced a topic shift, recovering the referent became easier via a conceptually matching pronoun. This effect of the intermediate sentence is hard to rule out but is in principle in line with the idea that after a distance (which may or may not be accompanied by a change of topic) the conceptual number of the referent is more easily accessible than its grammatical number.

Another problem might be that only a small portion of the agreement production process was realized here (production of the pronoun itself), whereas the message as well as the agreement controller were given and thus not under control of the speaker. Such a procedure is often applied in agreement production experiments with collective nouns, in which participants produce the agreement targets (pronouns or verbs) as completions of sentence fragments given by the experimenter (e.g., Bock et al., 1999). Even though a completion procedure allows for control over the context, it may nonetheless compromise the implications for and the generalizations to real-life production. Yet the present findings are augmented by those of a previous corpus study, in which syntactic agreement with pronouns referring to collective nouns was also found to decrease
as a function of distance (Levin, 2001). Complementary to the experimental procedure applied here, corpus studies have the disadvantage of less control over the context but the advantage of being based on real-life discourse production. Taken together, the only two studies that directly address the influence of distance on pronoun agreement thus provide converging evidence using diverging methods.

As described above, the decreased availability of grammatical number information should not only affect pronoun production but also pronoun comprehension. Whenever one has to rely on a memory representation of potential referents and their number, increasing distance between referent and anaphoric expression should result in a weaker reliance on syntactic number information and, complementarily, in a stronger reliance on conceptual number information. One of the few comprehension studies in this area (Gernsbacher, 1991) found that sentences with collective nouns as antecedents were rated as more natural and were read faster with a plural anaphoric pronoun than with a singular one, indicating a preference analogous to the one in (English) pronoun production.

Recently, Kreiner et al. (2013) further demonstrated that agreement in comprehension resembles agreement in production in that, at least during initial reading, subject–verb agreement is not affected by conceptual number, whereas noun–pronoun agreement is driven by conceptual number. However, analogously to the production studies, the comparison of verbs and pronouns does not allow for unequivocal conclusions concerning the importance of distance on the availability of morphosyntactic information. In addition, the short-distance condition of Experiment 1 indicates that German is not characterized by an overall preference for pronouns to agree conceptually, a difference that could also apply to pronoun comprehension. The processing of pronouns agreeing with collective nouns either syntactically or conceptually as a function of the distance between controller and target was thus investigated in a self-paced reading study. Prolonged reading times are in general interpreted as processing difficulties. Here, they can be taken as evidence that the number of the anaphoric expression mismatches the mental representation of the referent’s number. Consequently, reading times for singular phrases should increase more strongly from the short-distance to the long-distance condition than reading times for plural phrases.

EXPERIMENT 2: COMPREHENSION

The experiment was based on a two-factor design with the within-participant factors of distance between referent and pronoun (short distance vs. long distance) and of pronoun and verb number (singular vs. plural).
Method

Participants. Thirty-six students at Saarland University participated in the comprehension version of the first experiment. (Due to loss of log file data, one participant could not be included in the analyses.)

Materials. The same experimental and filler texts as in Experiment 1 were used, with pronouns and verbs referring to the collective nouns instead of the gaps. One half of the 60 experimental items was presented with a singular pronoun and verb, the other half contained a plural pronoun and verb. As the distance between collective noun and anaphoric pronoun was also varied, 15 texts were presented in each condition (short distance/singular pronoun, short distance/plural pronoun, long distance/singular pronoun, and long distance/plural pronoun). Across participants, each item occurred equally often in each of the four experimental conditions. Because it was ensured that no noun of the same grammatical gender as the collective noun, no grammatically feminine noun, and no plural noun was presented before the pronoun, the collective noun was the only possible referent for the pronoun. Each text was followed by a comprehension question to avoid shallow processing of the texts. The following examples illustrate a text in the short-distance/singular pronoun condition (2a) and in the long-distance/plural pronoun condition (2b).

(2a) Das Militär war noch immer preußisch organisiert. Es legte Wert auf eine kaisertreue Gesinnung. Daran hatte sich nichts geändert.
(The army was still organized in a Prussian way. It set a high value on loyalty to the emperor. Nothing had changed.)
(2b) Das Militär war noch immer preußisch organisiert. Sie legten Wert auf eine kaisertreue Gesinnung.
(The army was still organized in a Prussian way. Nothing had changed. They set a high value on loyalty to the emperor.)

Procedure. In a self-paced reading task, all texts were presented on the screen in a word by word fashion. Pressing the space bar initiated presentation of the next word and masking of the previous word. Thus, at each point in time, only one word was displayed and the other words were replaced by asterisks (one asterisk per character) to ensure that the antecedent could not be identified via rereading previous parts of the text. At the end of each text, a yes or no comprehension question was presented on the screen to which participants responded via key presses. The order of the 120 texts was determined at random. Two practice trials preceded the experimental (and filler) trials.

Reading times for the pronoun, the verb, and the word following the verb (as the spillover region), which was the same item in each condition, were taken as
dependent variables. Longer reading times were expected in the long-distance condition as compared with the short-distance texts for singular phrases but not for plural phrases.

Results

Figure 1 reports mean reading times per word for the pronoun, the verb, and the word following the verb as a function of distance between agreement controller and target (short vs. long) and of phrase number (singular vs. plural). For each region of interest (i.e., the pronoun, the verb, and the word following the verb), reading times were analyzed using LMER analysis. A maximal LMER model was constructed, incorporating the fixed effects “distance” and “pronoun number,” their interaction, and the corresponding random intercepts and slopes for participants and items in a single step. Factor labels were transformed into numerical values and centered before analysis to have a mean of 0 and a range of 2 (short distance and singular, respectively; long distance and plural, respectively).

The analysis yields coefficients, standard errors, and t values for each fixed effect and interaction. A comparison between the maximal model and a model without the fixed effect of interest (here the interaction between distance and number) provides information about the contribution of the excluded effect. A significant difference between the fit of the models indicates that the model without the respective effect results in a significantly poorer fit than the full model. Table 2 shows the results of the LMER analysis for the fixed effects and their interaction separately for each region of interest.

**Pronoun.** Reading times for the pronouns were not affected by either factor. There was no significant interaction between distance and number and only a descriptive trend for longer reading times in the short- compared with the long-distance condition (exclusion of distance as a fixed effect did not result in a significantly poorer model fit than when both distance and number were included, \( p = .143 \)).

**Verb.** For the verbs, the interaction between distance and number only approached but did not reach significance \( (p = .099) \). Descriptively, singular verbs were read faster in the short- than in the long-distance condition (337.7 vs. 347.4 ms), whereas plural verbs were read faster in the long- than in the short-distance condition (338.2 vs. 352.4 ms).

**Spillover region.** The analyses for the word following the verb revealed a significant interaction between distance and number, indicated by the significant difference between the full model and the model with only the interaction being
FIGURE 1  Mean reading times per word in milliseconds (plus standard errors) for (a) the pronoun, (b) the verb, and (c) the word following the verb (verb + 1) as a function of distance between agreement controller and target (short vs. long) and phrase number (singular vs. plural).
removed (but the respective random intercepts and slopes still included): As predicted, reading times significantly increased from the short- to the long-distance condition after singular phrases (365.9 vs. 403.6 ms; $\chi^2 = 3.95$, $p = .047$; $d = .049$) but not after plural phrases (382.6 vs. 373.3 ms; $\chi^2 = 1.36$, $p = .243$). Descriptively, in the short-distance condition, the critical word was read faster when it was preceded by a singular phrase than when it followed a plural phrase (365.9 vs. 382.6 ms; $\chi^2 = 2.14$, $p = .144$), whereas the pattern reversed in the distal condition (403.6 vs. 373.3; $\chi^2 = 3.13$, $p = .077$).

**Discussion**

The results show an influence of distance between agreement controller and agreement target on the relative preference for syntactic versus conceptual number information, which was increasingly evident over the three consecutive regions of interest: Although there was no hint for such an interaction in the reading times for the pronoun, there was a trend toward an interaction for the verb and a significant interaction for the subsequent word. Thus, the processing differences for nonpreferred agreement did not show up immediately at the pronoun but later on in the phrase.

As predicted, phrases with singular pronouns were read faster in the short-distance as compared with the long-distance condition. In principle, this could also be a consequence of pronoun resolution generally being harder in the
long-distance condition. However, the fact that a disordinal interaction was obtained excludes this alternative explanation: Descriptively, reading times for the plural phrases even decreased with increasing distance, a finding that is in itself rather surprising. It may indicate the substantial mismatch costs caused by the plural pronoun in the proximal condition but should not be interpreted too strongly given that this difference did not reach significance. Put differently, singular noun phrases were read faster than plural noun phrases in the short-distance condition, whereas the pattern reversed for the long-distance condition. This indicates that reference resolution in terms of grammatical agreement was easier than in terms of conceptual agreement when the anaphoric noun phrase was close to the collective noun (in an adjacent sentence), whereas reference resolution in terms of conceptual agreement was easier than in terms of grammatical agreement with longer distances between agreement controller and target (i.e., when the anaphoric expression was in a nonadjacent sentence).

Because agreement resolution had to rely on a memory representation of the referent and its number, these findings suggest that upon encountering a pronoun phrase soon after the collective noun, the syntactic number of the collective noun (i.e., singular) was more accessible than with an intervening sentence between referent and anaphoric expression. The comprehension data thus mirror the production data in that grammatical number loses importance in agreement processes as the distance between referent and anaphoric pronoun increases. They are also similar to the production data in that, unlike in English (Gernsbacher, 1991; Kreiner et al., 2013), there was no general preference for pronouns to agree in conceptual number.

**GENERAL DISCUSSION**

The present pronoun production and comprehension experiments reveal two main findings, one expected and the other unexpected. As predicted, when a pronoun had to be produced that referred to a collective noun, the singular form was used more often in adjacent sentences than in nonadjacent sentences (Experiment 1). Likewise, after presentation of a singular pronoun referring to a collective noun, reading times were shorter in adjacent sentences than in nonadjacent sentences, which was not the case for plural pronouns (Experiment 2). The experiments thus jointly demonstrate that the impact of grammatical number on reference resolution decreases with increasing distance. This is interpreted as an effect of the accessibility of grammatical number information in working memory: Information about a noun’s grammatical number (in addition to its conceptual number) is usually only briefly retained, because grammatical and conceptual number hardly ever diverge. An unexpected finding was that in adjacent sentences singular pronouns were preferred over plural pronouns in
production as well as in comprehension. We first address the implications of the latter finding for theories of agreement and then turn to a discussion of the distance effects.

Even though conceptual agreement was preferred for long-distance anaphora, there was no overall prevalence of conceptual number agreement with pronouns, either for production or for comprehension. This contrasts with previous studies (e.g., Bock et al., 2006; Kreiner et al., 2013) and also with the assumptions based on the marking and morphing model (Bock et al., 2001, 2004; Eberhard et al., 2005). One explanation might be that this is because in the present experiment the collective nouns were always presented with a singular verb. Yet this is the case for every occurrence of a collective noun plus verb in German and thus representative for German collective-noun processing, because German—unlike English—does not provide the opportunity to present "number-neutral" verb forms and because collective nouns require a singular verb in German. In addition, Kreiner et al. (2013, Exp. 3) found that the use of a singular verb did not affect the processing of plural versus singular reflexive pronouns that were controlled by the same collective noun, concluding that their “findings provide no evidence that subject-verb agreement modulates subsequent anaphoric agreement” (p. 28).

According to the marking and morphing model (e.g., Bock et al., 2001), number agreement in production is a function of marking, a conceptually guided process, and morphing, a morphological process. Because pronouns can bear a number of their own, the results of the two processes can differ and the conflict must be resolved. In principle, the gradient nature of the present findings (instead of a deterministic pattern) is in line with the proposed resolution of a conflict instead of a rule that is applied by default. However, the contrast between the current findings and those obtained in English (with a plural preference for proximal pronouns) calls for an extension of the marking and morphing model. Berg’s (1998) idea of differences in the syntactic force can be helpful here. According to Berg (1998), syntactic agreement plays a greater role in German than in English because syntactic influences are generally stronger in German than in English. Agreement operations are rare in morphologically impoverished languages like English and because “frequency impacts upon the strength of a phenomenon [...] the limited opportunity that the language provides for expressing syntactically based agreement relationships involves a weakening of the syntactic force” (Berg, 1998, p. 60). The weaker the syntactic force, the harder it is to resist conceptual influences and, hence, the more probable conceptual agreement is to override syntactic agreement. Because German, in contrast, has a rich inflectional morphology, syntactically based agreement processes are frequent. Consequently, the syntactic force is strong and conceptual factors have a smaller influence on agreement processes.
Yet how can the idea of a strong syntactic force be reconciled with the main finding of the present study, namely that the degree of grammatical agreement decreases for distal as compared to proximal pronouns? In other words, why does the syntactic force become weaker with longer intervening content in a language in which it is rather strong? In line with the assumption brought up and tested here, Berg (1998) further assumes that distance is one factor that determines the strength of the syntactic force within a given language. Put differently, when the accessibility of syntactic number information is reduced in the course of subsequent discourse processing, the syntactic force will be weak even in a language in which it is otherwise strong and there is no longer a prevalence of syntactic agreement. The marking and morphing model can therefore account for the present findings by including the assumption that the degree to which syntactic number information has the potential to influence the agreement process differs—as a function of the language and as a function of the distance between agreement controller and target.

It is plausible to assume that agreement is constrained by what information is (still) accessible in working memory, given that not all types of information can be kept activated and thus remain accessible for an unlimited amount of time. We have argued that the decreasing influence of grammatical agreement is a consequence of the particular (ir)relevance of keeping syntactic number information available in the long-term in (German) language comprehension and production. Because conceptual and syntactic number information usually go hand in hand, it should be sufficient for the processing of long-distance anaphora to retain conceptual number information. A critical question in this context is how relevance in language processing can influence what is maintained for how long. In our view, a good candidate for an underlying mechanism is implicit learning as assumed in experience-based accounts of language processing (e.g., Chang, Dell, & Bock, 2006; Haskell et al., 2010; MacDonald & Christiansen, 2002).

Experience-based approaches assume a language processing system that learns with each utterance it encounters. Haskell et al. (2010) suggested such an implicit learning account of agreement, according to which agreement production is shaped by statistical learning from past language experience. One can assume that even though speakers of German have more often than speakers of English computed and resolved agreement based on syntax, they have frequently experienced that conceptual number is sufficient for computing and resolving number agreement—in pronoun production as well as for anaphor resolution. Therefore, it has been implicitly learned that syntactic number does not need to be maintained for further processing and that attentional resources can thus be spared for other processes. Consequently, the present findings are in line with an experience-based account of verbal working memory, in which the distribution of available resources is shaped by how to understand and produce the language one has had the most experience with in the best possible way.
In the present experiments, the availability of grammatical number has been studied via a rather marginal phenomenon: long-distance anaphora involving collective noun referents. This raises the question whether findings obtained with such a phenomenon allow for generalizing to more standard number agreement. Because of the frequent converge of grammatical and conceptual number, it is hard to address this question with more standard nouns. With respect to the question addressed here, we are, however, confident: If the influence of grammatical number decreases even in cases in which grammatical and conceptual number conflict, this should also and at least to the same extent be the case when they provide essentially the same information. Another generalization issue concerns the language under investigation, namely the question whether similar effects would be obtained in other languages. Given previous findings, it is obvious that the higher frequency for grammatical number agreement as compared with conceptual agreement with proximal pronouns does not generalize to languages such as English. There is usually a high proportion of plural pronouns even when these are in the same sentence as the collective nouns. Nonetheless, upon the assumptions presented here, this proportion should increase even further with increasing distance between agreement controller and target. Levin’s (2001) findings that the proportion of plural agreement increases with more intervening words between collective noun and personal pronoun in American, Australian, and British English corpora support the assumption that distance effects are not restricted to German, the language that was investigated here.

ACKNOWLEDGMENTS

Thank you to Paulina Boguska, Carola Brück, Dorothea Enck, Sarah Freidinger, Nikolas Leichner, Jacqueline Morell, Till Roderigo, and Daniel Wegener for their help in running the experiments and analyzing the data. In addition, I thank Anne Fürstenberg, Lena de Mol, Ralf Rummer, and three anonymous reviewers for helpful comments.

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German originals and English glosses of the experimental texts in the short-distance version (singular version of the second sentence/plural version of the second sentence; in the long-distance condition, the order of the final two sentences is reversed):

11. Das Militär[neut] war noch immer preußisch organisiert. Es legte Wert auf eine kaiserliche Gesinnung. / Sie legten Wert auf eine kaiserliche Gesinnung. Daran hatte sich nichts geändert.
43. Das Management[neut] will Teile des Konzerns verkaufen. Es will die Produktion rentabler machen. / Sie wollen die Produktion rentabler machen. Der Gewerkschaftschef[masc] fürchtet den geplanten Personalabbau[masc].


1. The stack of newspapers got wet. It had been left outside. / They had been left outside. It was still raining.

2. The regulars’ table discussed the last Sabres’ game. It met every week. / They met every week. That was tradition.

3. The saxophone ensemble was not led by the conductor. It had played out of key. / They had played out of key. It was supposed to be the (group’s) last performance.

4. The class of 1992 met for a reunion. It reveled in memories. / They reveled in memories. After such a long time, there was much to talk about.

5. The company had financial problems. It was about to go bankrupt. / They were about to go bankrupt. The business wasn’t running well.

6. The British royal house had proven to be heartless. It had not uttered a word of sympathy. / They had not uttered a word of sympathy. A rebellion was looming.

7. The teaching staff ruthlessly slandered a pupil. It had no scruples. / They had no scruples. Nobody held back.

8. The staff did not work fast enough. It was unable to cope with the situation. / They were unable to cope with the situation. The pace had been increased.

9. The clientele felt dissatisfied. It complained to the insurance company. / They complained to the insurance company. A written complaint was drawn up.

10. The German class went on a trip to Vienna. It marveled at the town hall. / They marveled at the town hall. It was raining hard.

11. The army was still organized in a Prussian way. It set a high value on loyalty to the emperor. / They set a high value on loyalty to the emperor. Nothing had changed.

12. The squadron flew high up in the sky. It left many white vapor trails. / They left many white vapor trails. The small boy applauded.

13. The family gathered in the dining room. It had lunch. / They had lunch. The china rattled.

14. The auditorium applauded keenly. It was delighted. / They were delighted. The speaker had been convincing.

15. The carnival procession wandered through the village. It celebrated exuberantly. / They celebrated exuberantly. The weather was pleasant.

16. The senate held a meeting every Monday. It did not find a solution. / They did not find a solution. There was great confusion.

17. The assembly discussed matters heatedly. It was outraged. / They were outraged. The talk was provoking.

18. The division retreated. It had come under fire. / They had come under fire. The enemy forces were superior.

19. The couple had been married for a long time. It was very happy. / They were very happy. A child was born at last.

20. The conclave had finally reached a decision. It would soon announce the name of the new pope. / They would soon announce the name of the new pope. White smoke arose.
21. The collective met for an unscheduled meeting. It had to make a weighty decision. / They had to make a weighty decision. This hadn’t happened for a long time.
22. The Bible study group met regularly. It currently studied the Book of Job. / They currently studied the Book of Job. The parish hall had recently been renovated.
23. The Parliament held a meeting. It had to reach an important agreement. / They had to make an important decision. The room was full of cigarette smoke.
24. The convoy never moved away more than a few meters. It was aware of the dangers. / They were aware of the dangers. No risks should be taken.
25. The advisory committee published the findings. It had discussed matters for a long time. / They had discussed matters for a long time. The weather had already changed.
26. The village was in an uproar. It did not know how to escape the situation. / They did not know how to escape the situation. The village elder had already disappeared.
27. The board left the room. It was happy to be able to announce a success. / They were happy to be able to announce a success. The effort had paid off.
28. The intelligence service remained quiet. It did not disclose any information. / They did not disclose any information. The dictating machine recorded in vain.
29. The cabinet drank wine. It was soon drunk. / They were soon drunk. Nobody had noticed anything.
30. The court of lay judges retired to make a decision. It was of one mind. / They were of one mind. The defendant smoked a cigarette.
31. The triumvirate sat enthroned above all else. It had taken place in the coach. / They had taken place in the coach. The train started moving.
32. The syndicate had been unmasked. It had not become suspicious. / They had not become suspicious. A mole had entered the ranks.
33. The dancing pair turned around and around. It forgot about the outside world. / They forgot about the outside world. The evening flew by.
34. The choir traveled to the south. It sang in the airplane. / They sang in the airplane. The weather was terrific.
35. The team won the competition. It threw a party in the club house. / They threw a party in the club house. Everyone rejoiced.
36. The singing duo took part in a contest. It was well received by the public. / They were well received by the public. The track became a hit.
37. The culture club held a meeting in the community building. It talked about the upcoming festival. / They talked about the upcoming festival. The gathering lasted longer than anticipated.
38. The angry mob stormed the castle. It rallied for more civil rights. / They rallied for more civil rights. The gate was torn down.
39. The swarm of bees buzzed in front of the window. It hummed loudly. / They hummed loudly. A fragrant bouquet stood on the window sill.
40. The wolf pack neared the farm. It was starving. / They were starving. The winter had been hard.
41. The nation still practiced the old custom. It maintained tradition. / They maintained tradition. At full moon, a bull is sacrificed for the sun god.
42. In times past, the Indian tribe settled in the fertile valley. It was driven away by white settlers. / They were driven away by white settlers. The land was occupied.
43. The administration wanted to sell parts of the concern. It wanted to make production more profitable. / They wanted to make production more profitable. The head of the union dreaded the planned staff cuts.
44. The city council held a meeting in the town hall. It discussed the upcoming mayoral elections. / They discussed the mayoral elections. It was dark and stuffy in the room.
45. The pressure group discussed the new Young Persons Act. It debated the matter seriously. / They debated the matter seriously. The issue was very pertinent.
46. The orchestra played with great enthusiasm. It had practiced for a long time. / They had practiced for a long time. The performance was a great success.
47. The public cheered the singer on. It was enchanted by the concert. / They were enchanted by the concert. The cheers were deafening.
48. The company arrived a bit late. It was being expected. / They were being expected. The festival took place in the open air.
49. The horse cart arrived at the courtyard. It was absolutely exhausted. / They were absolutely exhausted. It had been a long journey.
50. The book club met in a coffee shop. It wanted to review a new book. / They wanted to review a new book. Pastry was being served.
51. The nobility lost reputation. It was disregarded by the common people. / They were disregarded by the common people. A lot of money was wasted on luxury goods.
52. The welcoming committee stood in the courtyard. It greeted the arriving guests. / They greeted the arriving guests. The table was already laid.
53. The king’s entourage had to obey. It was expected to read his mind. / They were expected to read his mind. The pay was scarcely appropriate given the task.
54. The board discussed the issue of the day. It had to talk about a proposal on how to combat global warming. / They had to talk about a proposal on how to combat global warming. The problem had been avoided for too long.
55. The board of directors had something important to say. It had to announce the closure of one of the plants. / They had to announce the closure of one of the plants. The news was rather unpleasant.
56. The supervisory council had a lot to do. It had to have the books of the corporation reviewed. / They had to have the books of the corporation reviewed. The procedure was highly complex.
57. The bouquet of flowers had been taken out of the water. It had been given to the lady of the house as a gift. / They had been given to the lady of the house as a gift. The celebrations could begin.
58. The presidential convoy provided protection. It had to follow him everywhere. / They had to follow him everywhere. Somebody had made a threat.
59. The electricity cartel stood under suspicion. It is said to have participated in anticompetitive price-rigging. / They were said to have participated in anticompetitive price-rigging. The accusation was serious.
60. The entire works council had been suspected. It is said to have peculated important funds. / They are said to have peculated important funds. The distrust had grown steadily.