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RESEARCH

Grammaticalized number, implicated presuppositions, and the plural

Adam Liter[1], Tess Huelskamp[2], Christopher C. Heffner[3] and Cristina Schmitt[4]

[1] University of Maryland, College Park, Maryland, US

[2] Los Alamos National Laboratory, Los Alamos, New Mexico, US

[3] University of Connecticut, Storrs, Connecticut, US

[4] Michigan State University, East Lansing, Michigan, US

Corresponding author: Adam Liter (io@adamliter.org)

Plural morphology exhibits differing interpretations across languages. For example, in downward entailing contexts in English, the plural receives a *one or more* (or *inclusive*) interpretation, whereas in Korean-like languages the plural always receives a *more than one* (or *exclusive*) interpretation, regardless of context. Previous experimental work using an artificial language suggests that such differences may follow from structural properties of these languages (Liter, Heffner & Schmitt 2017), namely lack of grammaticalization of the plural/singular distinction. In this paper we adopt Sauerland, Anderssen & Yatsushiro's (2005) implicated presupposition analysis of the plural (the English plural is semantically unmarked, whereas the Korean plural is semantically marked, carrying a presupposition that the cardinality of its referent is greater than one) in order to test two hypotheses about the interpretation of the plural. Using an artificial language learning paradigm identical to that in Liter, Heffner & Schmitt (2017) with non-grammaticalized number but with a much greater frequency of singular/plural NPs in the input, we test (i) whether semantic markedness of the plural should be linked to the non-grammaticalization of the number paradigm; or (ii) whether semantic markedness follows from insufficient statistical evidence for simplifying the lexical entry for the plural. Our results show that participants continue to assign an exclusive interpretation to plural morphology under the scope of negation, which is compatible with the hypothesis that non-grammaticalized number entails semantic markedness.

Keywords: number; implicated presupposition; grammaticalization; semantics; language universal; artificial language learning

1 Introduction

If we were to ask a speaker of English what the plural means, we would presumably hear that the plural means more than one. This intuition is perhaps correct at a surface level of description, but the plural morpheme in English does not always receive such an interpretation. The interpretation actually depends on the environment. For example, in downward entailing contexts such as under the scope of negation, the plural actually receives an interpretation of *one or more* (henceforth *inclusive interpretation*) and not the intuitive *more than one* interpretation (henceforth *exclusive interpretation*) that most speakers might attribute to the plural (see, e.g., Sauerland, Anderssen & Yatsushiro 2005).[1] On

[1] Recently, it has been argued that downward entailment is not the only type of environment that triggers the inclusive interpretation; rather, it has been claimed that any environment that supports weakly referential NPs will allow plural NPs to have an inclusive interpretation, and environments that support strongly referential plural NPs will give rise to inclusive interpretations (cf. Grimm 2013; Mathieu 2014). We will return to this below. For now, what is important is that there is such a distinction between an inclusive and exclusive reading of plural noun phrases and that, in all analyses, negation favors the inclusive interpretation.

the other hand, the pluralizer morpheme in a language like Korean always receives an exclusive interpretation, regardless of context (see, e.g., Kang 1994; Kwon & Zribi-Hertz 2004; Nomoto 2013).[2] This is illustrated in (1).

(1) a. John didn't see friends last night.
b. Con-un eceyspam chinkwu-tul-ul manna-ci anha-ss-ta.
John-TOP last.night friend-PL-ACC meet-NMLZ NEG-PST-DECL
'John didn't see friends last night.'

(1a) cannot truthfully be used to describe a scenario in which John saw one friend last night, whereas (1b) can truthfully describe such a scenario. This shows that, under the scope of negation, the plural morpheme in English can receive an inclusive interpretation. This contrasts with the interpretation that is assigned to the plural morphology in Korean under the scope of negation, since it can truly describe a scenario in which John saw one friend last night. That is, even in the scope of negation, the Korean plural receives an exclusive interpretation.

An interesting question is whether the inclusive/exclusive interpretation of plural morphology in different languages can be inferred from particular properties of the different languages. Because Korean and English have many different properties, trying to answer this question by inspecting the natural languages themselves is quite complicated, as there are many confounding factors such as the existence of classifiers, case, lack of definite and indefinite determiners, and so on, which make the comparison more difficult.

If we concentrate our attention on how Korean differs from English with respect to number, we find two important differences. First, Korean is a language without grammaticalized number; that is to say, number morphology is not obligatorily expressed on most noun phrases, and noun phrases do not trigger obligatory verbal agreement. English, on the other hand, has grammaticalized number; number morphology is necessarily expressed on the count nominals and triggers verbal agreement.

The second difference is that Korean noun phrases are number-neutral by default and can refer to either a singleton or a plurality. Singular and plural morphemes can be added to disambiguate whether the referent is to be interpreted as a singleton or a plurality (Kang 1994; Kwon & Zribi-Hertz 2004), whereas, in English, bare count nominals with number-neutral interpretations are generally disallowed. Excluding mass nouns, all English nominals appear with number morphology, and number morphology is not linked to a definite or indefinite interpretation.[3] Given that there is no numberless alternative, number morphology is obviously *much* more frequent in English than in Korean, where the bare nominal is quite free and takes on a multiplicity of interpretations.[4]

[2] We use the term *pluralizer* to refer to optional plural morphology that is not part of a grammaticalized singular/plural paradigm.

[3] In this paper, we set aside the distinction between count and mass nouns. In some theories mass nouns are the default, and in some other theories they are marked. For production and processing purposes, the evidence seems to suggest that they are lexically marked as mass or count. See Fieder, Nickels & Biedermann (2014) for a review and a proposal.

[4] We assume that singular count nouns in English have a singular morpheme, spelled out as a zero morpheme. For example, the singular morphology could be inferred from the determiner used or, alternatively, could be realized as portmanteau determiners (e.g., Borer 2005). Crucially, this way of calculating singular and plural naturally excludes mass nouns, which we assume have a special syntax. In this paper we leave the issue of mass nominals aside, since it is not part of the tested language (see note 3). If one grants that English has a singular morpheme, it seems clear that number morphology is more frequent in English than in Korean. A reviewer also asked whether we can report any data to support this claim. While we are not aware of any corpus study counting the number of bare nominals in comparison with singular- and plural-marked noun phrases in Korean, we did count the number of bare nominals in a Korean version of the story of *The Three Little Pigs* and found that they amount to half of all noun phrases in the text. Additional evidence for the wide use of the bare nominals can be found in Suh (2008). In a cloze test with native speakers of Korean, participants left the noun phrase bare around 50% of the time where the other option was to pluralize the noun phrase.

These basic facts become somewhat confounded when we consider issues of (in)definiteness in Korean: first, because the language does not have overt definite and indefinite determiners, bare noun phrases without any number information can be interpreted not only as singular or plural but also as definite or indefinite, depending on the context. The plural and singular morphemes, on the other hand, are quite restricted. The pluralizer seems to require D-linked contexts and the singularizer is obligatorily indefinite. These restrictions on overt singular and plural marking in Korean, together with the high use of the bare nominal, make number marking much less frequent than in English.

Because of these and other divergent properties, it is not easy to readily determine which of these properties might cause Korean speakers to always interpret the plural as exclusive, but English speakers to interpret the plural as inclusive in certain contexts. One way to test which properties contribute to the relevant interpretations is to use artificial language learning paradigms. Artificial language learning paradigms allow for complete control of the properties of the input that learners are exposed to, in ways that are impossible in experiments using natural language acquisition settings.

Moreover, and perhaps more interestingly, experiments using the artificial language learning paradigm are known to produce results in many domains of linguistics that are convergent on what are known to be robust typological tendencies, if not language universals. Culbertson (2012) provides a review of studies that have used the artificial language learning paradigm and produced such results in the domains of phonology (e.g., Wilson 2006; Moreton 2008; Finley & Badecker 2010), syntax (e.g., Cook 1988; Culbertson, Smolensky & Legendre 2012), and morphology (e.g., Hupp, Sloutsky & Culicover 2009; St. Clair, Monaghan & Ramscar 2009; Bruening 2010; Fedzechkina, Jaeger & Newport 2012). At least one further artificial language study that postdates Culbertson's (2012) review also reports results that converge on language universals. Namely, Culbertson & Adger (2014) found that participants did not learn a word order in the nominal domain that is thought to be impossible (cf. Greenberg 1963; Cinque 2005).

In Liter, Heffner & Schmitt (2017), we used an artificial language learning experiment to examine to what extent the interpretation of a pluralizer morpheme could be inferred from properties of a linguistic system designed to mimic some properties of a Korean-like system. Despite being native speakers of English, a language where the plural receives an inclusive interpretation in certain environments, participants (without overt training) adopted an exclusive interpretation of plural morphology even under the scope of negation. We argued that our results suggested an entailment relation between having a Korean-like number system and having an exclusive interpretation of plural morphology in all contexts. Since this indeed seems to be the case cross-linguistically, as Mandarin and Japanese also only allow exclusive interpretations of their pluralizers, our study added to the artificial language studies that converge on typological tendencies and language universals. It was also rather striking that participants in our previous study did not transfer the interpretation of plural morphology from their native language to the plural morphology in the artificial language, given that transfer effects in second language learning are quite prevalent (see, e.g., Odlin 2003; Schwartz & Sprouse 1996; Jiang 2004) and have also been claimed to account for some artificial language learning results (e.g., Goldberg 2013).

In our previous work, we sketched a rough account of the entailment relation between having a Korean-like number system and having an exclusive interpretation of plural morphology in all contexts on the basis of Sauerland, Anderssen & Yatsushiro's (2005) account of the plural (explained in more detail below, in §2.1).

In the present paper, we report a new study aimed at examining to what extent the exclusive interpretation of the plural is a natural consequence of the non-grammaticalization of number marking in a language or whether the exclusive interpretation results from the lower frequency distributions of plural and singular morphology in comparison to number-neutral bare nouns. In other words, we ask whether the architecture of the system (with bare nouns and optional plural and singular morphemes) is responsible for the exclusive interpretation independent of issues of frequency distributions, namely the overwhelming use of bare nominals in the artificial language.[5]

The paper proceeds as follows. §2 fleshes out the two accounts of the proposed language universal in terms of semantic unmarkedness and implicated presuppositions. §3 presents the present experiment in comparison to the experiment reported in Liter, Heffner & Schmitt (2017) in order to discriminate between the two hypotheses from §2, and §4 concludes.

2 The plural and implicated presuppositions

For concreteness we assume Sauerland, Anderssen & Yatsushiro's (2005) theory of the plural. Their theory relies on the notion of implicated presuppositions (see also Sauerland 2008). Implicated presuppositions are analogous to scalar implicatures (cf. Horn 1972; 1989) except that they are calculated in the domain of presupposition rather than in the domain of assertion; they are calculated in accordance with the pragmatic maxim, Maximize Presupposition, proposed by Heim (1991).

(2) Maximize Presupposition
Make your contribution presuppose as much as possible.

According to Sauerland, Anderssen & Yatsushiro, the English plural is semantically unmarked, and its usual meaning of more than one is derived via an implicated presupposition that is calculated against the singular, which presupposes that the cardinality of the referent is one (2005: 411–412). On the other hand, in contexts such as under the scope of negation, the implicated presupposition is not calculated because the environment is downward entailing and would thus actually make the assertion weaker were it calculated (2005: 417–420). As a consequence, the plural in English is interpreted inclusively under the scope of negation.

Although there is some controversy about what the exact triggers for inclusive and exclusive interpretations are and about what the correct formal analysis of these two interpretations is, it is worth noting that there is some experimental evidence which supports Sauerland, Anderssen & Yatsushiro's (2005) view of the plural. Pearson, Khan & Snedeker (2011) report an experiment where they find that participants accept a singular referent for a plural noun phrase in a context which facilitates the cancellation of an implicature significantly more than they accept it in contexts that do favor the calculation of the implicature.[6] Adjudicating between the many different analyses of the plural is, however, beyond the scope of this paper. Again, in this paper, we are assuming Sauerland, Anderssen & Yatsushiro's (2005) analysis.

Now, while Sauerland, Anderssen & Yatsushiro do not explicitly address plural morphology in Korean, we can infer what their analysis of this pluralizer would probably be. Recall that (1b), repeated here as (3), can truthfully describe a situation in which John saw one friend last night; that is, the plural morphology in Korean receives an exclusive interpretation.

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[5] It should be clear that in Korean there are certain types of nominals that require the pluralizing morpheme, such as certain pronouns and demonstratives. In our artificial language we do not have pronouns or demonstratives. The only types of noun phrases the participants hear are bare nouns, plural-marked nouns, and singular-marked nouns, used in exactly the same types of sentences and discourse conditions. In principle, this should preclude participants from making distinctions based on definiteness.

[6] To be fair, this study also supports the analyses of the plural advanced in Spector (2007) and Zweig (2009), which, although implemented differently, assume that the exclusive interpretation of the plural is derived by some inferencing process.

(3) Con-un eceyspam chinkwu-tul-ul manna-ci anha-ss-ta.
John-TOP last.night friend-PL-ACC meet-NMLZ NEG-PST-DECL
'John didn't see friends last night.'

Since implicated presuppositions are not calculated in downward entailing environments, the more than one interpretation cannot be the output of an implicated presupposition. Therefore, the relevant difference between the plural in English and the plural in Korean must be that the English plural is semantically unmarked whereas in Korean it is not. In Korean, the plural is semantically marked, being associated to a cardinality greater than one; in other words, its meaning is not derived by calculating an implicated presupposition against the meaning of the singular, like in English.

This is the categorical difference between the semantics of English plural morphology and the semantics of Korean-like plural morphology that we will assume going forward.[7]

The issue is whether this difference is a natural consequence of the architecture of the number system of Korean-like languages or whether this difference is to be linked to the frequency distribution of the various forms, which could lead learners to reinforce particular hypotheses.

In the next two subsections, we consider these two hypotheses about Korean-like number systems that would account for the differences in the semantics of their plural morphology that we are assuming. In §2.1, we consider the hypothesis that non-grammaticalization of the number paradigm is the relevant factor. In other words, we ask whether exclusive interpretations are a natural consequence of the architecture of the system. In §2.2, we consider the hypothesis that the relative frequencies of the different types of noun phrases drives the learner to an exclusive interpretation of the plural, independently of the architecture of the system. Both of these hypotheses would account for the results reported in our previous study. In §3, we report a new experiment aimed at teasing apart these two hypotheses.

2.1 Non-grammaticalized number and semantic markedness

One possible explanation for why Korean-like languages have an exclusive interpretation of plural morphology in all contexts has to do with the non-grammaticalization of number. Kwon & Zribi-Hertz (2004: 151–154) argue that the morphosyntactic difference between the French/English plural and the Korean plural is that the former is realized as an inflectional functional head (e.g., NumP) with both positive and negative featural values (e.g., +PL and –PL), whereas the latter is not the realization of an inflectional head but is instead a lexical plural marker with no corresponding negative value. We adopt this account of the morphosyntactic differences between the number morphology across these languages, and we use the term *grammaticalized* to refer to languages like English where the number morphology is the realization of an inflectional head in the syntax. Korean, then, is a language where number is non-grammaticalized, as the number morphology is not the realization of an inflectional head in the extended projection of the noun phrase.

Assuming this morphosyntactic difference, we hypothesize that semantic markedness of the plural is required outside of a grammaticalized paradigm. In other words, in virtue of being a lexical plural marker, not an obligatory head in the extended functional projection of the noun phrase, the Korean plural morphology cannot be semantically unmarked like the plural in English is. This would explain why Korean does not have the same interpretation of the plural under the scope of negation that English does.

Likewise, it would also explain why participants in our previous study adopted an exclusive interpretation of the plural under the scope of negation in contradistinction to their

[7] For simplicity, we are ignoring issues linked to definiteness.

native language. In the artificial language that we taught participants in Liter, Heffner & Schmitt (2017), number marking on the nominals was literally optional. In the training input, participants heard nominals with singular or plural morphology 50% of the time, and the other 50% of the time there was no number morphology on the noun, for noun phrases in the same contexts. Moreover, there was no morphosyntactic number agreement on the verb. Both of these facts could be cues to the learner that the number morphology in the language they were learning is not the realization of an inflectional head, but rather an adjunct-like morpheme. Reaching this conclusion, the learner should hypothesize that the number morphemes in this language are independent lexical heads perhaps adjoined to the noun phrase, but crucially not different values of a functional head and thus not part of a morphological paradigm.

In sum, the hypothesis that non-grammaticalization of a number paradigm requires semantic marking of the number morphology would account for both the natural language facts of Korean (and other languages) as well as the results from our previous study. We next consider an alternative hypothesis that would also account for these facts.

2.2 Economy and semantic markedness

Another plausible hypothesis as to why participants in our study learned the plural as having an exclusive interpretation could instead be due to the way frequency affects how participants learn the plural and singular morphemes. In a language like English, the singular and the plural are in complementary distribution, share the same semantic and syntactic space, and occur in pretty much every count noun phrase in an argument position.[8] Therefore, a learner might have good reason to treat them as in a binary opposition, which may then lead the learner to reduce the properties of one of the members of the opposition pair and infer its interpretation from the other member of the pair. Since the range of interpretations for the plural can be derived by positing that it is semantically unmarked and calculating an implicated presupposition against the singular, the learner does not store a meaning for the plural. In other words, if forms are frequent enough and belong to the same semantic space (number), a learner might try to find ways to minimize what they have to store in the lexicon for reasons of economy. Under this hypothesis, it is the sheer frequency of the singular and plural that creates the conditions for treating them as a pair. In other words, if a language does not frequently mark noun phrases as plural or singular, then the learner might not have sufficient information to compress what is stored in the lexicon. On the other hand, if the language marks noun phrases as plural or singular most of the time, then the existence of number-neutral bare nominals might not interfere with compressing the semantic information stored in the lexicon.

This hypothesis could possibly explain the Korean facts. As we have mentioned before, Korean bare nominals can be interpreted as singular, plural, definite, or indefinite, since there are no definite or indefinite determiners. Determinerless number-marked noun phrases are either obligatorily indefinite (singular) or obligatorily D-linked (plural). Bare nominals therefore have a much wider range of uses and are used more frequently. Plural-marked and singular-marked NPs, on the other hand, are rather infrequent in comparison. Given the infrequent use of number morphology in Korean, a learner might not have sufficient evidence for deciding that the meaning of the plural can be left underspecified and instead derived from the competition with the singular. As a result, the Korean learner stores the meanings of both the singular and plural morphemes independently.[9]

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[8] Again, we are assuming that singular count noun phrases have a singular morpheme; see note 4.

[9] This hypothesis is also consistent with the facts that pluralizers are learned quite late in these languages and are nowhere near as frequent as plural/singular morphology in English (Munn, Zhang & Schmitt 2009; Nakano, Park & Schmitt 2009). Notably, the fact that this late learning tracks frequency in some regard

This hypothesis could also explain the results from our previous study where plural-marked NPs and singular-marked NPs were rather infrequent and only constituted 25% of the training input each.[10] Specifically, the learners of our artificial language would not have had sufficient evidence to determine whether the meaning of the plural morpheme can be derived by some means other than simply storing its meaning in the lexicon.

2.3 Teasing apart the hypotheses

Given that both the optionality and the lower frequency would explain the lack of inclusive readings for the plural morphology in natural languages, as well as the results from the artificial language learning paradigm from our previous study, it would be nice if we could tease these two hypotheses apart by finding languages that would support one hypothesis or the other. Unfortunately, we are not aware of a natural language useful for distinguishing between these two hypotheses. In Korean, number is not grammaticalized, and it is also not frequent. So we cannot decide on the basis of Korean which of the two hypotheses best explains the data.

Brazilian Portuguese would seem to be a good testing case as it has grammaticalized number but also has bare count noun phrases. In other words, every noun phrase (except for bare singulars) is marked as singular or plural; there is subject-verb agreement, and adjectives agree with the noun phrases they modify. However, number-neutral bare nominals—which can be interpreted as singular or plural depending on the context, as illustrated in (4)—are much less frequent than singular-and plural-marked noun phrases (Schmitt & Galves 2014). In other words, grammaticalization correlates with frequency of plural/singular marking.

(4) O João não encontrou amigo ontem de noite.
the John NEG meet friend yesterday at night
'John didn't see friends last night.'

Again for Brazilian Portuguese both hypotheses make the same prediction, namely that Brazilian Portuguese would have an inclusive interpretation of the plural morphology under the scope of negation, just like English. And that is in fact what we find: (5) is a false description of John having seen one friend last night.

(5) O João não encontrou amigos ontem de noite.
the John NEG meet friend.PL yesterday at night
'John didn't see friends last night.'

This shows that the plural in Brazilian Portuguese is semantically unmarked like in English. Because the use of plural-marked and singular-marked NPs is much more frequent in Brazilian Portuguese than in Korean (Schmitt & Galves 2014) and because Brazilian Portuguese has grammaticalized number, we cannot use Brazilian Portuguese to distinguish between the two hypotheses discussed above.[11]

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should not be taken to mean that learning is primarily/exclusively frequency driven. It is uncontroversial that learners use statistical properties to test particular hypotheses, but they do so in a linguistically informed manner and do not track superfluous patterns (e.g., Yang 2002).

[10] We are aware that 25% is large when we consider that the plural in English likely appears between 10% and 15% of the time in child-directed speech (we are not aware of a study that counts the token frequency of plural forms in child-directed speech for English, but see Ravid et al. 2008: 41, for frequency counts in other Germanic languages that range between 10% and 15%). However, the learners of this artificial language receive a very small amount of input overall when compared to what a child immersed in a linguistic community receives as they acquire an adult grammar.

[11] A reader may ask what is the difference between (4) and (5). We argue that while (4) completely excludes any cardinality comparison and information about number, (5) includes a *one or more than one* interpretation. The interpretations overlap extensionally, but when a bare singular is used all reference is to the kind.

Because we are unaware of a natural language that would allow us to distinguish between these two hypotheses, we conducted a follow-up artificial language learning experiment, where we change the proportion of bare number-neutral noun phrases in relation to singular- and plural-marked noun phrases. Specifically, we significantly decreased the frequency of number-neutral nominals and increased the frequency of singular- and plural-marked NPs in order to determine how this affects the learning outcomes.

3 The experiment

In order to determine whether frequency plays a part in the interpretation assigned to the plural, we conducted a follow-up study to the study reported in Liter, Heffner & Schmitt (2017). With the exception of two differences, the studies were the same, in order to make the comparisons easier. The two differences are that, in the present study, we greatly increased the frequency of plural/singular-marked NPs (cf. §3.1.2), and we also introduced a new test (cf. §3.1.3). Importantly, other than the different relative frequencies of noun types, all other aspects of the artificial language that participants were taught remained the same, including the non-grammaticalization of number. That is to say, there were no cues in the input language that number morphology was the realization of an inflectional head. There was no agreement between the verb and nominals, and number marking was still optional, although bare nominals did occur much less frequently. Importantly, bare nominals occurred in exactly the same contexts as the singular- and plural-marked NPs, suggesting to the learner that number marking really is optional and not that there is a specialized meaning of the bare form.

Given the significantly increased frequency of number-marked nominals in the present study, we can use this follow-up study to distinguish between the two hypotheses discussed above in §2. Specifically, if semantic markedness is necessitated by non-grammaticalization (cf. §2.1), then we expect participants in the present study to interpret the plural exclusively under the scope of negation, just like they did in our previous study. On the other hand, if semantic markedness of plural morphology in Korean-like languages is the result of insufficient evidence for compressing the lexicon by treating the singular and plural morphemes as a pair at some level (cf. §2.2), then, unlike in our previous study, we expect participants to interpret the plural inclusively under the scope of negation in the present study because number-marked NPs are much more frequent and so learners would have more evidence that would warrant compressing the lexicon.

Throughout this section, we present the results from our previous study alongside the results of the current study in order to facilitate comparison of the two studies. More detailed information about the previous study can be found in Liter, Heffner & Schmitt (2017).

3.1 Methods

3.1.1 The language

We taught participants in the present study the same 23-word artificial language from our previous study. The language had 16 nouns, 2 transitive verbs, 2 intransitive verbs, 2 number morphemes (a singular and a plural), and 1 negation particle.[12] The word order of the artificial language was (NEG)-VSO; that is, when negation occurred, it occurred presententially. Additionally, number morphology, when present, occurred postnominally.

3.1.2 Training

The experiment was administered using E-Prime 2.0 Professional Edition software (Psychology Software Tools, Inc., Sharpsburg, PA). Participants were trained on the

[12] For a complete list, see Appendix A, referenced in the Supplementary files section.

language over the course of ten sessions with testing occurring throughout. All training was passive; there was no explicit instruction. Participants saw animated events on the screen that were paired with sentences and had to learn the meanings of all of the words in the sentence by making inferences based on the event that it described.

Sessions 1–6 and sessions 8 and 9 were sessions with training, whereas sessions 7 and 10 were exclusively testing sessions (for a complete experiment schedule, see Table 2).

3.1.2.1 Basic training

In the training that occurred in sessions 1–6, participants were introduced to the basic vocabulary of the language, the grammar, and the number morphology. In each session, participants heard 128 sentences (half intransitive, half transitive) paired with an animated event on the computer screen and had to infer the meaning of the morphemes in the sentence that they heard.

In the sentences that a participant heard, nouns marked with the singular morpheme, *paya*, always corresponded to singleton referents, and nouns marked with the plural morpheme, *koho*, always corresponded to multiple-item referents with between two and four entities. A noun without number morphology was number-neutral and occurred with singleton referents half of the time and multiple-item referents half of the time.

The breakdown of the frequencies between the previous study and the present study is given in Table 1. The main difference in the training input in the current study compared to the previous study is that, out of the entire input, singular- and plural-marked NPs were much more frequent. Specifically, in the previous study, 25% of the NPs in the input consisted of *paya*-marked nominals paired with singleton referents, 25% consisted of *koho*-marked nominals paired with multiple-item referents, 25% consisted of bare nominals paired with singleton referents, and 25% consisted of bare nominals paired with multiple-item referents. In the present study, on the other hand, 43.75% of the NPs in the input consisted of *paya*-marked nominals paired with singleton referents, 43.75% consisted of *koho*-marked nominals paired with multiple-item referents, 6.25% consisted of bare nominals paired with singleton referents, and 6.25% consisted of bare nominals paired with multiple-item referents.

Moreover, everything was counterbalanced so that each noun occurred equally with all three types of number (*paya*, *koho*, and bare) in all three grammatical positions (intransitive subject, transitive subject, and transitive object).

3.1.2.2 Negation training

In both studies, it was not until sessions 8 and 9 that participants were introduced to the negative particle, again without explicit instruction. In order to facilitate the learning of negation, the 128 training sentences were grouped into blocks of 4 sentence-event pairings. For example, in order to train participants on negation involving a negated transitive

Table 1: Frequency of the different nominals in the training input.

		Liter et al. (2017)		Present study	
Heard	**Saw**	**%**	**Total**	**%**	**Total**
NP-∅	Singleton referent	25%	50%	6.25%	12.5%
NP-∅	Multiple-item referent	25%		6.25%	
NP-*paya*	Singleton referent	25%	25%	43.75%	43.75%
NP-*koho*	Multiple-item referent	25%	25%	43.75%	43.75%

verb, participants would first hear 'a snake is covering a mouse' and would see a snake covering a mouse. On the next slide, they would then hear 'a snake is circling a mouse', and they would see a snake circling a mouse. On the third slide, they would hear 'a snake is not covering a mouse', and they would see a snake circling a mouse again. Finally, on the fourth and last slide in the block, participants would hear 'a snake is circling a mouse' and see a snake circling a mouse (cf. Figure 1, row 2). Participants received evidence in their input that the negative particle could negate the verb of an intransitive sentence (Figure 1, row 1), the verb of a transitive sentence (Figure 1, row 2), and the head of the object nominal of transitive sentences (Figure 1, row 3).

Crucially, however, participants never received any training trials where the thing being negated by the negative particle was the number marker on the object nominal. This way, there was nothing in the training input that would bias participants toward assigning a particular reading to plural morphology in a downward entailing environment (i.e., under the scope of negation).

3.1.3 Testing

Sessions 7 and 10 were exclusively testing sessions. In sessions 2–6, 8, and 9, testing occurred prior to training so that the testing was indicative of the participants' knowledge at the end of the previous session. When multiple tests occurred in the same session, the tests occurred in the order that they are discussed below. See Table 2 for a complete training and testing schedule.

We included a variety of tests in our previous study and in the present study in order to be able to ascertain whether participants learned the language that they were being taught. If participants, for example, did not learn the basic vocabulary or grammar of the language, we cannot meaningfully interpret their performance on the plural morphology under the scope of negation. Most importantly, through pilot testing, we learned that negation was quite difficult to teach without overt instruction. Thus, it is very important to include basic negation tasks to ensure that we only include participants who successfully learned negation in the final analysis. The question of interest is how participants interpret the plural morpheme in a downward entailing environment. If participants did not learn negation, then the environment would not be downward entailing in the task

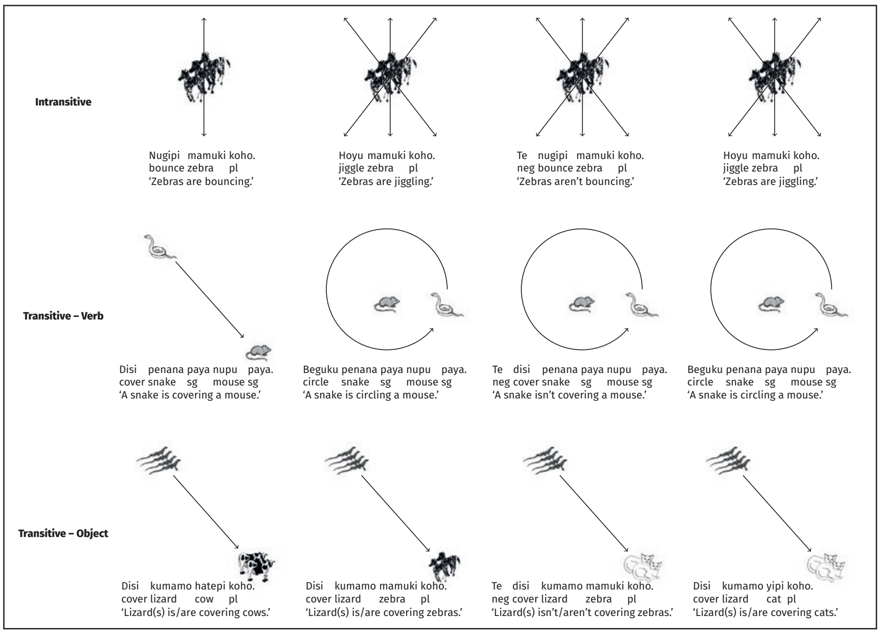

Figure 1: Examples of negation training in sessions 8 and 9.

Table 2: Schedule of testing and training.

Task	1	2	3	4	5	6	7	8	9	10
Training	✓	✓	✓	✓	✓	✓		✓	✓	
General grammar		✓	✓	✓	✓	✓	✓	✓		✓
Vocab & number morphology		✓	✓	✓	✓	✓	✓	✓	✓	✓
Sentence verification							✓			✓
Verb & object negation									✓	✓
Number negation										✓
Free response							✓			✓

of main interest, so it would not be possible to meaningfully interpret their answers with respect to our question of interest.

Having all of these different tasks therefore allows us to screen out participants who did not learn basic aspects of the language, which ensures that, when interpreting the results of interest, our interpretation meaningfully bears on the two hypotheses we are evaluating in this paper. Below, we describe all of these different tests.

3.1.3.1 Vocabulary and number morphology

In this task, participants heard a noun phrase that was either marked with *paya* (the singular morpheme), *koho* (the plural morpheme), or bare. On the screen, they saw a singleton referent and a multiple-item referent. They had to choose which referent the noun phrase they heard referred to, and there were also options for saying that the noun phrase could refer to both the singleton referent and the multiple-item referent or that it referred to neither. In sessions 7 and 10, there were 64 trials each; in all other sessions that this test occurred in, there were 32 trials each.

3.1.3.2 General grammar

The general grammar task tested participants' knowledge of the argument structure of the artificial language. In each trial, participants saw an event on the screen and heard two sentences. They had to choose the sentence that sounded most like a sentence in the language that they were learning and that described the event on the screen. The ungrammatical sentences were ungrammatical because they either (i) had one too many arguments, (ii) had one fewer argument than required, or (iii) were missing a verb. There were 22 trials in every session that this test occurred in.

3.1.3.3 Bare nouns in sentence verification

In addition to manipulating the frequencies of the different NP types in the input, the addition of this sentence verification test is the only other difference between the design of the previous study and the design of the present study. In the present study, we added this task only in the testing sessions (7 and 10). In each session, there were 32 trials. All trials consisted of a bouncing event on the screen paired with a sentence that used the intransitive verb *nugipi* 'bounce' and a bare nominal as the subject. Participants had to say whether the sentence they heard described the event that they saw on the screen. 16 of the trials involved a mismatch between the identity of the referent and the subject noun, 8 trials involved a match between the identity of the referent and the subject noun and the referent was a singleton referent, and the remaining 8 trials also involved a match between the identity of the referent and the subject noun but the referent was a multiple-item referent.

3.1.3.4 Free response

This task also only occurred in sessions 7 and 10; there were 32 free response trials in each session (half intransitive, half transitive). Participants saw an event play on the screen and were given the first word in the sentence that described that event. They had to then complete the sentence. Recall that the word order for this artificial language was VSO, so this task particularly tested how participants would produce NPs in the artificial language. Participants were also instructed to use the non-word "X" in case they could not recall a particular lexical item (as was done in Hudson Kam & Newport 2005; 2009). This allowed them to complete the sentence even if they did not happen to remember one of the particular words.

3.1.3.5 Verb and object negation

The verb and object negation tasks occurred in sessions 9 and 10. Participants were asked whether the sentence that they heard matched the event that they saw on the screen. There were 24 verb negation trials, and there were 24 object negation trials. Half of the trials were true, and half of them were false.

The verb negation trials involved the negative particle, *te*, negating the verb, and the object negation trials involved the negative particle negating the object. For example, a true verb negation trial would have involved a participant hearing the sentence *te disi hatepi paya yipi koho* 'NEG cover cow SG cat PL' and seeing an event where a cow was circling multiple cats. That is to say, this trial would have been true because the cow was circling (not covering) the cats. On the other hand, object negation trials manipulated the identity of the object. For example, if participants heard the same sentence in a true object negation trial, it would have been paired with an event of a cow covering ladybugs. That is to say, it would have been a true trial because the cow was covering ladybugs (not cats). This is summarized in Figure 2.

3.1.3.6 Number negation

The number negation task occurred only in session 10. In this task, participants were asked whether the sentence they heard matched the event that they saw on the screen. Recall that participants never received training sentences in their input where the negative particle negated the number morpheme on the object of a transitive verb. Because of this, the number negation task consisted of four different trial types. The crucial trial type involved a plural-marked NP, but we also had three other trial types in order to establish whether participants would allow the negative particle to negate the number morpheme at all. If not, it's not clear that we can meaningfully interpret their results on the crucial trial type of interest.

The four different trial types involved all possible combinations of number-marked object NPs crossed with the (non-)plurality of the referent object. We refer to these trials with shorthands of the form '¬number-morpheme X plurality-of-referent'. '¬' is a reminder that the sentence is negated, the number morpheme indicates which number morpheme occurs on the object nominal, and SG and PL indicate the cardinality of the referent (either a singleton referent or a multiple-item referent, respectively).

The crucial trials were thus the ¬*koho*XSG trials, which were trials where the object was marked with the plural morpheme, *koho*, and the corresponding referent in the event on the screen was a singleton referent. Recall that these sorts of trials are where languages like English and Korean differ. An English speaker would say that this is a false description of the event on the screen whereas a Korean speaker would say that it is a true description of the event on the screen (cf. (1)).

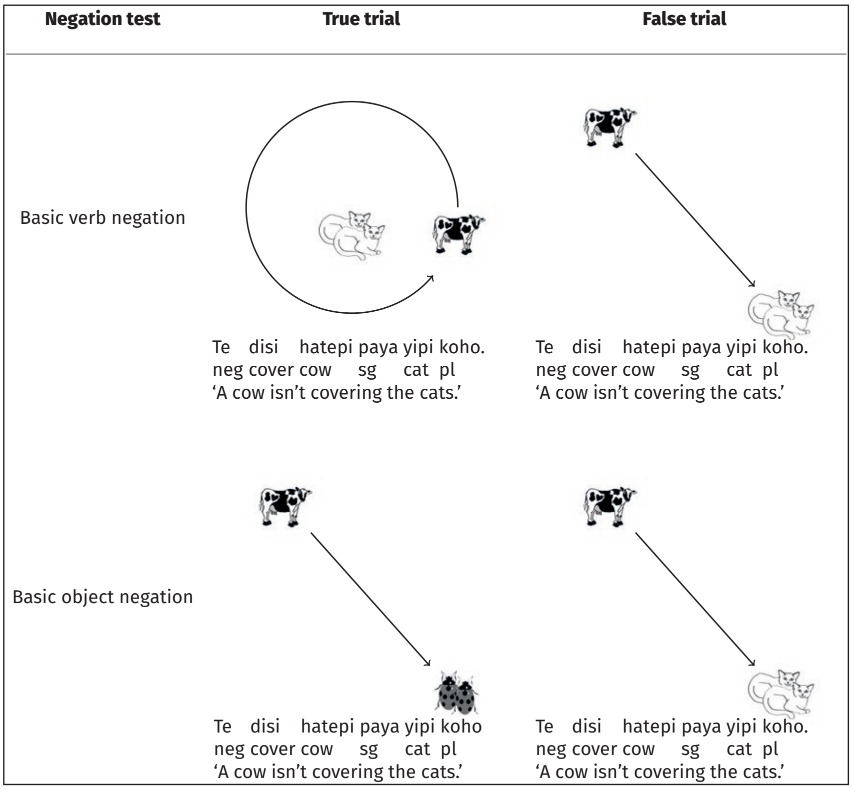

Figure 2: Examples of verb and object negation trials.

However, to reiterate, in order to meaningfully interpret the results from the ¬*koho*XSG trials, we must first establish that participants did in fact learn that the negative particle can negate the number morpheme on the object of a transitive verb since this is something for which there was no evidence in their input. To this end, there were three other trial types where the judgments were not expected to differ based on the interpretation that participants assigned to the number morphology (¬*koho*XPL, ¬*paya*XSG, and ¬*paya*XPL trials). This allowed us to determine whether participants did indeed generalize that the negative particle could negate the number morpheme on the object of a transitive verb. Specifically, if a participant correctly inferred that the negative particle could negate the number morphology on an object in a transitive sentence, they should judge ¬*paya*XPL trials to be true and *paya*XSG and ¬*koho*XPL trials to be false.

There were 7 ¬*paya*XPL trials, 5 ¬*koho*XPL trials, and 6 trials of ¬*koho*XSG and ¬*paya*XSG each, for a total of 24 trials in the number negation task.[13] Examples of each trial type and the expected judgments are given in Figure 3.

3.1.4 Participants

In the previous study, 20 adult native English speakers were recruited to participate in the study. However, only 17 completed the experiment and so only the data of those 17 participants is considered. In the present study, 16 adult native English speakers were recruited to participate in the study. All 16 participants completed the present study.

In both studies, participants generally did one session per day, occasionally two. Each session lasted approximately thirty minutes, and all 10 sessions were generally completed

[13] There should have been 12 trials of each type. However, due to a small coding error in the design of the experiment, a ¬*paya*XPL trial was incorrectly coded as a ¬*koho*XPL trial. Furthermore, there was another coding error in the design of the experiment that required half of the trials to be thrown out. (They could not be recovered after the fact because the coding error was in the experimental design and how the stimuli were presented, not in how the data was coded).

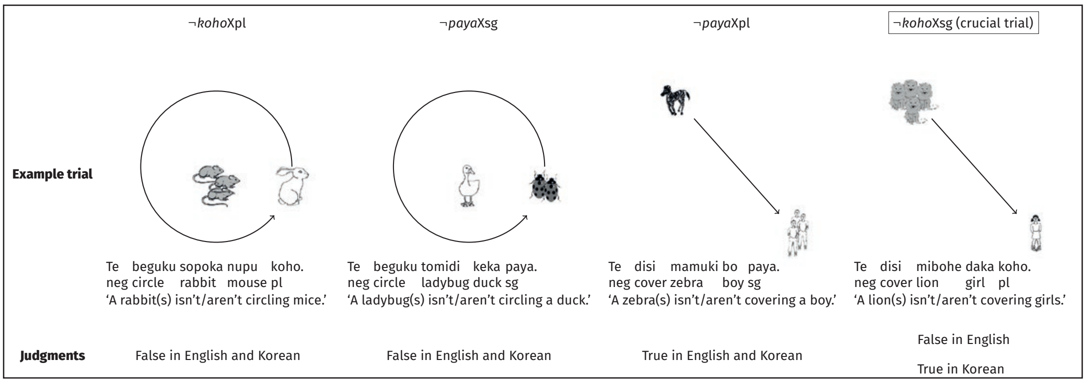

Figure 3: Number negation trial types and expected judgments.

over the course of two to three weeks, with most participants finishing within a two-week timeframe. Most participants received extra credit in a course for participating; a few participants were compensated monetarily.

3.2 Results

The main results of interest are the ¬*koho*XSG trials from the number negation task. However, in order to ensure that the results are meaningful, we first want to establish that participants successfully learned the artificial language. Therefore, we first analyze the results from the other tasks, and we exclude participants who were not above chance on the tasks that tested the basic properties of the language from subsequent analyses. This ensures that the interpretation of the results is meaningful and that the results are not simply the result of chance, for example. Throughout, we also compare the results from the present study to the results from our previous study.

3.2.1 Grammar task

The grammar task establishes whether participants learned basic properties of the grammar of the artificial language. Recall that this task tested basic argument structure of the artificial language.

Two-sided sign tests on each individual's responses in the final session were performed for this and subsequent analyses in order to determine if participants were above chance performance on a facet of the language (in this case, whether the participants had successfully learned the basic argument structure of the language by the end of the experiment). All of the participants in both the previous study and the present study were significantly above chance in their responses to the grammar task. It therefore seems that all participants learned the basic argument structure of the language, so no participants are excluded from future analyses on the basis of not knowing the argument structure of the language.

To compare the participants from the previous study to the participants from the present study, we performed model comparison using generalized linear mixed-effects models (cf. Baayen, Davidson & Bates 2008; Quené & van den Bergh 2008). We compared two models that explained trial-by-trial variation in accuracy on the grammatical responses. Both had identical random effects structures, with random intercepts for session and study and random slopes for session by participant. This was the maximally complex random effects structure possible given the data, as items were not consistently repeated across sessions or studies, and nobody participated in both experiments. Session was coded continuously.

The two models that were run varied instead in their fixed effects: one incorporated fixed effects for session (i.e., whether participants learned over time), for study (i.e., whether the participants in the previous study differed from the participants in the present study), and for the interaction between these two fixed effects, and the other had only a fixed effect of session. A significant difference in model fits between these two models would show that including the study factor significantly improved model fit, and thus that accuracy differed between each study. However, no significant difference was found in model fit between the two models ($\chi^2(2) = 0.318$, $p = .85$), indicating that the study factor did not influence participant accuracy in the grammatical task. This indicates that the best-fitting model only included a significant effect of session ($b = 0.424$, $p < .001$); participants improved in their grammaticality judgments over the course of the experiment.

3.2.2 Vocabulary and number morphology task

The vocabulary and number morphology task allows us to determine whether participants learned the meanings of the basic nouns in the language. Recall from above that participants heard an NP and were asked to choose whether that NP referred to a singleton referent, a multiple-item referent, both, or neither.

Regardless of their interpretation of the number morphology, we can use these results to determine whether they knew the base meaning of the noun. If the NP they heard did match either the singleton or multiple-item referent on the screen, choosing one of those referents (or both) would indicate that the participant at least knew the base meaning of the noun, even if they incorrectly interpreted the number morphology. The trials where participants chose the neither option were only informative if the base noun they heard actually did match the referents on the screen, as this suggests that the meaning participants had assigned to the nominal was incorrect. However, when the correct option was not displayed on the screen and participants rightly chose the neither option, it is not possible to know what offscreen referent they had in mind. These trials are therefore not informative and were discarded for the purposes of ascertaining whether participants knew the basic nominal vocabulary of the language.

14 of 16 participants were significantly above chance by the end of the experiment in the present study, suggesting that the vast majority of participants successfully learned the basic vocabulary of the language (chance was set at 75% since three out of the four onscreen options were correct for the purposes of ascertaining whether participants knew the meaning of the base noun). The two participants that were at chance on this measure are not considered for further analyses. This compares to a 100% success rate in the previous experiment.

We also ran generalized linear mixed-effects models like we did in the grammar task to see if participants differed across studies or across sessions (coded as a continuous variable). As before, both models run included random intercepts by item and participant, and random slopes by participant for session. The models that were compared differed in the fixed effects included within each model; one model included fixed effects of session and study and an interaction component between them, and the other included only fixed effects of session. This allowed for the assessment of the effects of study on model fit.

Unlike with grammaticality, the ANOVA comparing the model fit of these two models showed a significant decrease in model fit when removing the fixed effect of study ($\chi^2(2) = 22.0$, $p < .001$), indicating that study did play an explanatory role for some of the variation present in the dataset. This indicates that the acquisition of vocabulary did depend on the study. Inspection of the parameter estimates within the full model indicates that this significant difference was primarily driven by the interaction between session and study ($b = -0.323$, $p < .001$), as there was no significant effect of study ($b = 0.424$, $p = .34$). The negative coefficient on the interaction term indicates that participants in the present experiment tended to learn slower than participants in the previous experiment. Session was also a significant predictor of accuracy on basic vocabulary trials, with accuracy generally increasing across sessions ($b = 0.513, p < .001$).

In addition to allowing us to determine whether participants knew the base meaning of the noun, the vocabulary and number morphology task also provides information as to how participants interpret the three different types of NPs with respect to number. Regardless of whether the participant got the base meaning of the noun correct, we can infer that participants have assigned a singular meaning to an NP if they choose the singleton referent upon hearing that NP; such a response was coded as a *singular* response. Likewise, we can infer that participants have assigned a plural meaning to an NP if they choose the multiple-item referent upon hearing that NP; such a response was coded as a *plural* response. Similarly, we can infer that participants have assigned a number-neutral interpretation to an NP if they choose the option that indicates the NP they heard can refer to both the singleton and the multiple-item referent; such a response was coded as a *both plural & singular* response. Again, when the neither option was chosen, the trial was uninformative because it is not possible to determine the cardinality of the offscreen referent that the participant had in mind; such responses were therefore discarded in this analysis.

Figure 4 plots the various types of responses across sessions that participants gave for the three different types of NPs. The graphed results suggest that participants did learn the intended interpretations of the three different NP types in the language. To substantiate this inference based on inspection of the graphs, we compare individuals' performance in session 10 to chance using two-sided sign tests. In our previous study, one participant was not significantly above chance (33%) in session 10 with respect to interpreting the number of the three different NP types in the intended manner. This suggests that the participant did not learn the three-way nominal system of the language and is thus not

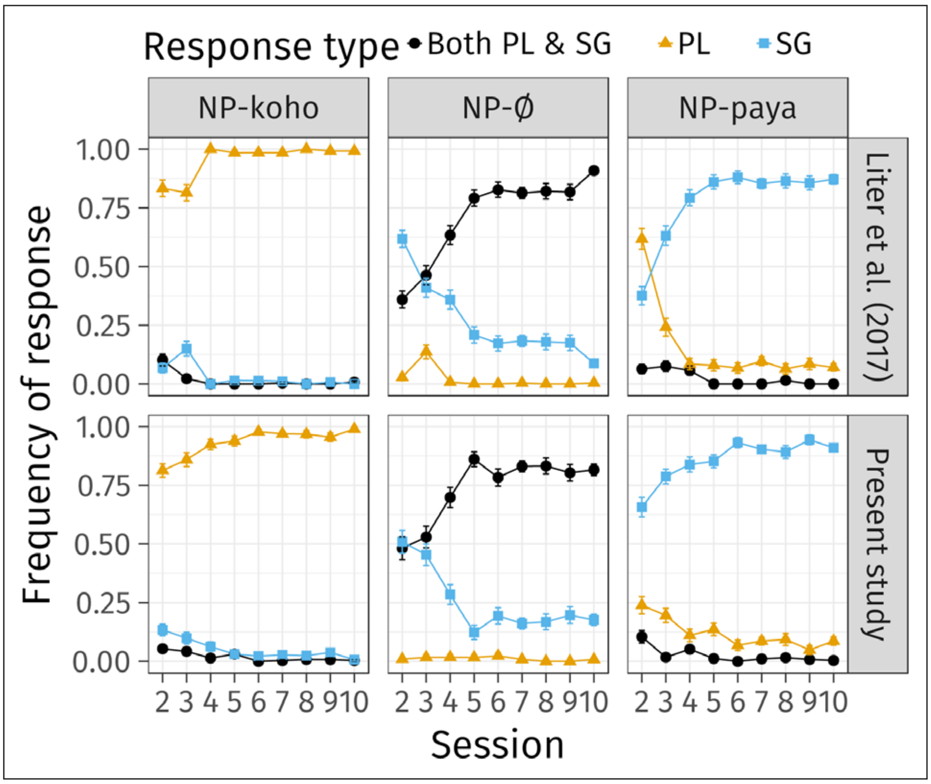

Figure 4: Responses for the three NP types in the vocabulary and number morphology task by session.

considered in subsequent analyses. In the present study, none of the 14 participants who had successfully mastered the grammar and basic vocabulary properties of the language used here were at or below chance chance in session 10 with respect to interpreting the number of the NP types in the intended manner. We only consider the 16 participants from the previous study and the 14 participants from the present study who were above chance in further analyses.

Three generalized linear mixed-effects models for the correct number interpretation of the three NP types were run. All three models included random intercepts by participant and by session, and random slopes by participant for session. The three models differed in the fixed factors included in each model. The fullest model included fixed effects for session (coded continuously), NP type (with the bare form of the noun used as a baseline and *paya* and *koho* treatment-coded), and study, as well as their interactions. Two other models dispensed with the fixed effects of session and NP type as well as their interaction components to determine the significance of each factor. ANOVAs showed significant decreases in model fit between both the full model and the model without study ($\chi^2(6) = 72.8$, $p < .001$) as well as the full model and the model without NP type ($\chi^2(8) = 303$, $p < .001$).

The best fitting model, therefore, was the full one. This model had significant simple effects for session ($b = 1.15$, $p < 0.001$), NP-*koho* ($b = 2.81$, $p < 0.001$), and NP-*paya* ($b = 0.762$, $p = .02$). Respectively, these effects indicate that participants improved in their performance over time and that performance on bare NP trials was worse (but not wrong) than that on NP-*paya* and NP-*koho* trials. There was also a significant interaction between session and NP status for NP-*koho* trials ($b = 0.318$, $p < .001$), which was related to the relatively flat learning curves present for NP-*koho* trials, relative to the other trial types. And, finally, there was a significant three-way interaction between session, NP type for NP-*paya* trials, and study ($b = 0.335$, $p = .003$). This interaction is probably due to the relatively high performance on NP-*paya* trials during early sessions in the present experiment when compared to the previous experiment; participants learned the meaning of *paya* more quickly in the present study than in the previous one.

3.2.3 Bare nouns sentence verification task

This task, which only occurred in the present study, offers further insight into how participants interpreted the bare nominal. Recall that there were effectively three different trial types: trials where the event was not accurately described by the sentence because the noun did not match the referent on the screen (ReferentMismatch), trials where the noun did match the referent on the screen and it was a singleton referent (MatchingSingleston), and trials where the noun matched the referent on the screen and it was a multiple-item referent (MatchingPlural).

Figure 5 shows quite clearly that participants in the present study interpret the bare nominal as number neutral since they say that sentences with the bare nominal can accurately describe both a singleton and a multiple-item referent. In addition to the results from the vocabulary and number morphology task, this is further evidence that the participants in the present study learned the three-way nominal system.

3.2.4 Free response task

In the free response task, we were interested in seeing how participants would use the three different NP types when presented with singleton and multiple-item referents. In Figure 6, we plot how often participants used each of the three different noun types (bare NP, plural-marked NP, and singular-marked NP) for the two different types of referents (singleton referents and multiple-item referents). Overall, the participants' production of the different NP types largely tracks the frequencies of these different NP types in their input.

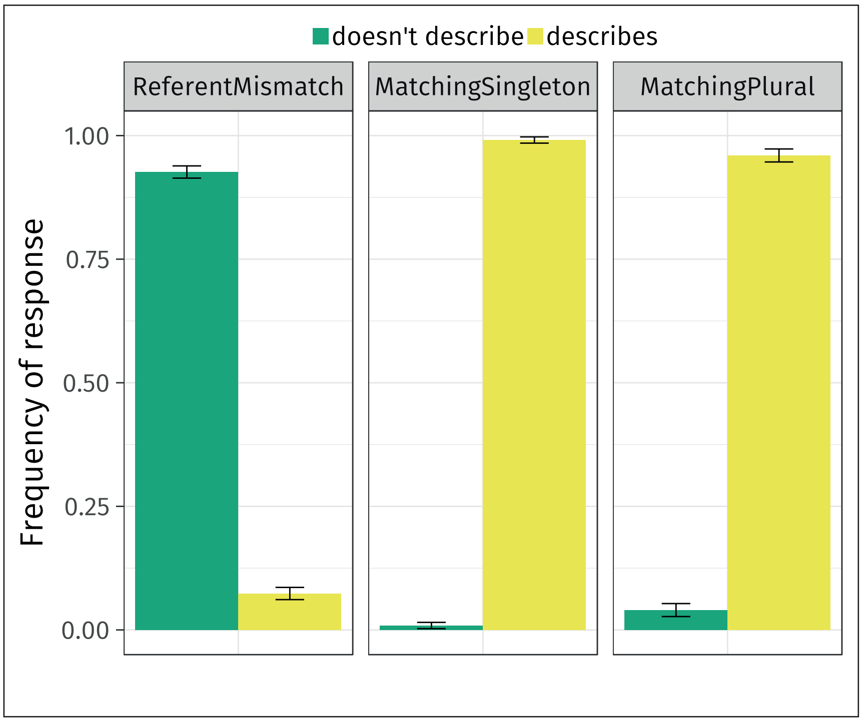

Figure 5: Responses to sentence verification task involving bare nominals by trial type collapsed across participant and session; a *doesn't describe* response means the participant said the sentence does not describe the event, whereas a *describes* response means the participant said the sentence does describe the event.

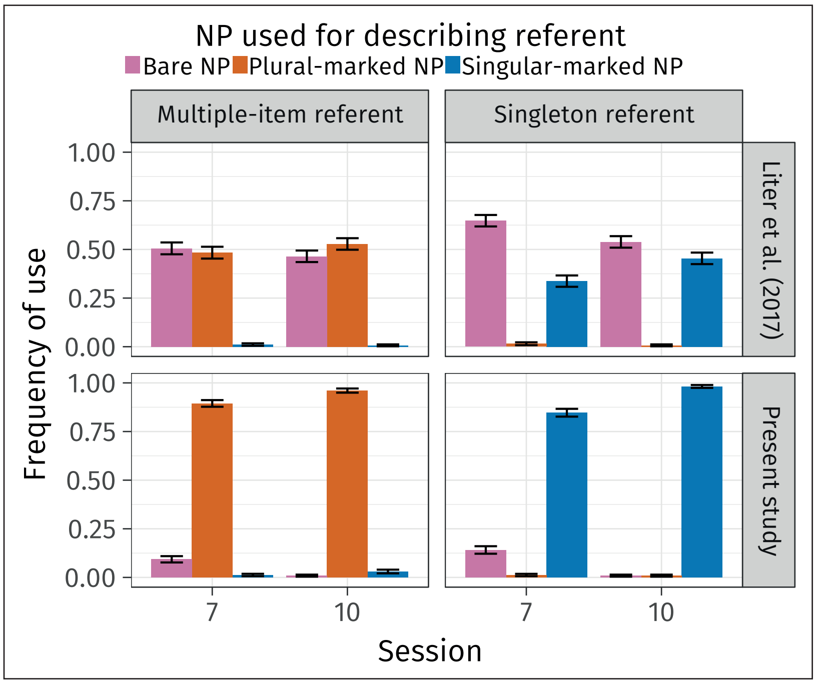

Figure 6: Usage of three NP forms in the free response task.

Moreover, generalized linear mixed-effects models for the free response task were run with the fullest model including fixed effects for session (coded discretely, as there were now only two sessions), study, referent number (using plural as a baseline), and their interactions, as well as random intercepts by participant and item and random slopes for session by participant. This model was compared to ones lacking the fixed effects of and interactions with study and referent number to determine the provenance of those effects. In both cases, the full model fit better. This was true both for the model lacking effects of study ($\chi^2(4) = 62.9$, $p < .001$) and the one lacking effects of referent number ($\chi^2(4) = 13.2$, $p = .01$). Thus, both referent number and study had a significant influence on model fit.

The best fitting model, which included all three possible factors and their interactions, had three significant fixed effects. There was a significant effect of singular reference ($b = -1.20$, $p < 0.001$), such that participants were less likely to use number morphology when the referent object was singular. There was also a significant effect of study ($b = 4.65$, $p < 0.001$), whereby participants were much more likely to use number morphology in the present study than in the previous one. Finally, there was an interaction between study and session ($b = 2.91$, $p < 0.001$), with the differences between the previous and present studies being attenuated when moving from session 7 to session 10.

3.2.5 Verb and object negation

Of crucial interest are the negation results involving number morphology. However, as noted above, pilot testing showed that negation was hard to teach without overt instruction. The verb and object negation tasks thus allow us to test whether participants learned that the negative particle could negate the verb and whether they learned that the negative particle could target the head of the object noun phrase. Participants received evidence in their input that both of these things were possible, so these tasks test whether participants acquired the basics of negation.

We performed two-sided sign tests on individuals' responses to the verb and object negation tasks in order to determine whether participants were significantly above chance on these trials.

Of the remaining 16 participants from the previous study,[14] 13 participants were significantly above chance on verb negation trials. 12 of these 13 participants were also significantly above chance in their performance on object negation. As for the present study, 8 of 14 participants performed significantly above chance on verb negation, and, of these 8 participants, 7 also performed significantly above chance on object negation trials.

Generalized linear mixed-effects models for both the verb negation task and object negation task were run with random intercepts by participant and by item and with random slopes for session by participant. The fullest model run for both analyses included fixed effects for session, study, and the interaction of these two fixed effects. When compared to a model without effects of study, there was no significant difference in model fit ($\chi^2(2) = 2.02$, $p = .36$), indicating that, although participants did improve in their performance from block 9 to block 10 ($b = 2.94$, $p < 0.001$) there was no support for a significant effect of study. The participants who were not above chance on verb negation were excluded from the models for object negation.

On the other hand, the best fitting model for object negation included both the fixed effects of session and study but not the interaction between them. That model performed no worse than the full model ($\chi^2(1) = 0.588$, $p = .44$), which indicates no support for the interaction term in the model. This model performed significantly better, though, than a model that did not include the effect of session ($\chi^2(1) = 6.36$, $p = .01$) and a model that did not include the effect of study ($\chi^2(2) = 8.14$, $p = .004$), which both indicate that each fixed factor on its own did explain significant variation in the data. The winning model

[14] Recall from above that one participant in the previous study did not demonstrate having successfully learned the three-way distinction between NP types in the language; this participant is therefore excluded. Likewise, two participants from the present study did not demonstrate having successfully learned the basic vocabulary of the language and are also excluded.

included a significant effect for study ($b = -1.72$, $p = 0.003$) and for session ($b = 0.603$, $p = 0.007$); participants performed better in session 10 than session 9 for both conditions, and participants in the previous study performed better in the mean than participants in the current study.

3.2.6 Number negation

Finally, the results of main interest are the results from the number negation task. Recall that the trial type of crucial interest is ¬*koho*XSG. These trials are the main trial type of interest because these involved a negated sentence where the object is marked with the plural morpheme and the corresponding onscreen referent is a singleton referent. In other words, responses to trials of this type tell us whether participants have assigned an inclusive or exclusive interpretation to the plural under the scope of negation. If participants say that the sentence truly describes the scenario depicted onscreen, this is evidence for participants having an exclusive interpretation, whereas if participants say the sentence does not describe the scenario depicted onscreen, this is evidence for participants having an inclusive interpretation.

Remember that, crucially, participants were not trained on the fact that the negative particle could negate the number morphology on the object of a transitive sentence lest we bias the results by introducing evidence into the input as to how the plural is interpreted under the scope of negation. Therefore, in order to ensure that the results we interpret are meaningful, three other trial types were included where the judgments are not expected to differ, regardless of interpretation of the number morphology (cf. Figure 3). By looking at these three trial types (¬*paya*XPL, ¬*paya*XSG, and ¬*koho*XPL), we can determine whether participants generalized that the negative particle could negate the number morphology on the object of a transitive sentence.

We thus inspected the performance of those participants who were above chance on verb and object negation for these three trial types using sign tests. In our previous study, all participants who successfully learned both verb and object negation performed above chance on these three trial types indicating that they generalized that the negative particle could negate the number morphology on the object. In the present study, 5 of the 7 participants who successfully learned both verb and object negation performed above chance on these trial types indicating that they generalized that the negative particle could negate the number morphology on the object.

The responses of these 12 participants from the previous study and the 5 participants from the present study are shown in Figure 7 for all four trial types. In our previous study, 8 of the 12 participants who learned that the negative particle could negate the number morphology on the object of a transitive sentence were significantly more likely than chance to give a true response to the ¬*koho*XSG trials. Likewise, in the present study, 4 of the 5 participants who learned that the negative particle could negate the number morphology on the object of a transitive sentence were significantly more likely than chance to give a true response to the ¬*koho*XSG trials.

3.3 Discussion

With respect to the interpretation of the plural in the ¬*koho*XSG trials, it is clear that the participants from both our previous study and the present study interpret *koho* exclusively under the scope of negation, like in Korean (cf. Figure 7). Recall from above that this is predicted by the hypothesis that semantic markedness is necessitated when number is not grammaticalized. On the other hand, the hypothesis that semantic markedness is the result of insufficient evidence for compressing the lexicon predicted the opposite. It predicted that participants in the present study should have diverged from participants

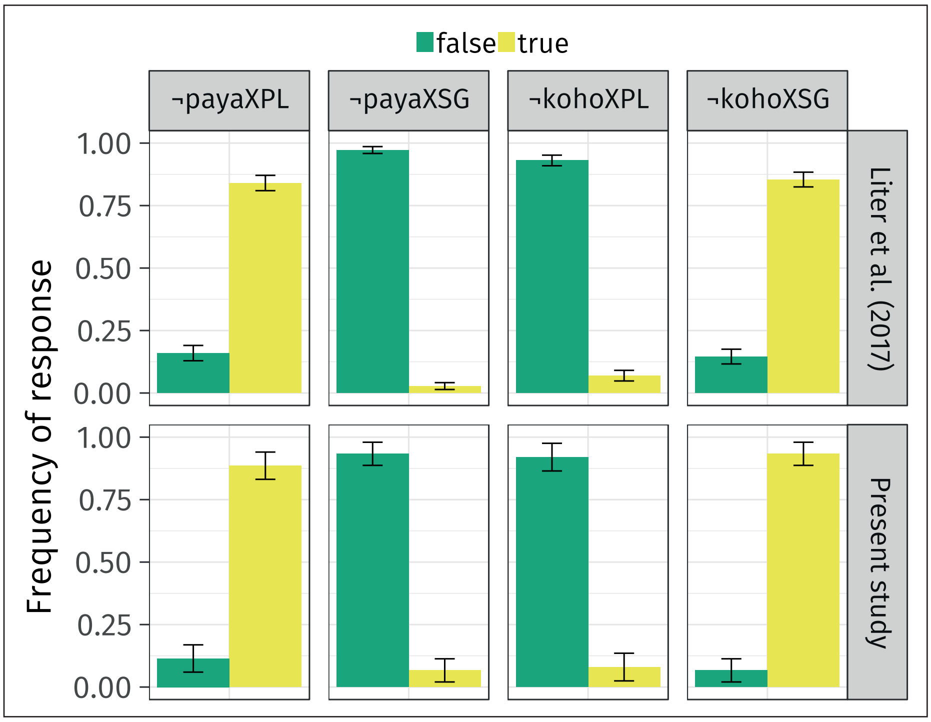

Figure 7: Responses to the number negation trials by trial type.

in the previous study on the ¬*koho*Xsg trials—namely, they should have assigned an inclusive interpretation to the plural under the scope of negation and said that these trials were false.[15]

In addition to the main results of interest, a few comments about the differences we saw across the results from the previous study and the present study are in order and may provide us with some insight about the learning mechanisms. The only tasks with significant main effects for study were the free response task and the object negation task. The results from the vocabulary and number morphology task also exhibited main effects for the interaction between study and session and the interaction between study, session, and the singular marked NP (NP-*paya*) that approached significance.

The fact that there were significant differences in the free response task is not surprising. Participants in the present study clearly used the number morphemes much more frequently than in the previous study's production task. This is unsurprising, given that adult learners in artificial language learning tasks are known to mimic frequencies in the input

[15] A reviewer asked about English speakers' judgments of the ¬*koho*Xsg trials with the same materials. We did conduct a short control experiment with 20 English-speaking participants using the same materials but with English recordings. There were 4 items per participant of the ¬*koho*Xsg trials. The 20 participants gave judgments consistent with an inclusive interpretation of the plural 25.32% of the time, and they gave judgments consistent with an exclusive interpretation 74.68% of the time (SE = 4.89%). This might initially seem unexpected; however, it would not be surprising if these results are due to something of a metalinguistic nature. The task that we asked native English speakers to do was both short and very simplistic and thus very transparent in terms of what was being tested. Moreover, a t-test comparing the 20 participants in the control experiment to the participants of both our previous and present studies shows that the participants in the control experiment were significantly more likely to give an inclusive interpretation ($t(122.38) = -2.18$, $p < 0.05$). Lastly, it is already known from the experiments reported in Pearson, Khan & Snedeker (2011) that there are certain contextual environments where the implicated presupposition that gives rise to the exclusive interpretation is hard to cancel. So given that the control task was so simplistic and transparent in virtue of using the same materials and given that the implicature is known to be hard to cancel in certain environments, these results are not entirely surprising. This makes it all the more noteworthy that participants in the control experiment were significantly more likely to interpret the plural inclusively than the participants who learned the artificial language, suggesting that the behavior of the participants who learned the artificial language is not simply a result of their native language.

(cf. Hudson Kam & Newport 2005; 2009) and the frequency of the number morphemes in the input was much greater in the present study than in the previous study. It is interesting though that in the present study, by session 10 participants were basically not using the bare nominal any longer, suggesting that frequency did play a role and that, in the task, participants did prefer to be as explicit as possible in their production. However, the results from comprehension tasks show that this does not mean that they did not learn the interpretation of bare nominals.

For the vocabulary and number morphology task, there were interesting effects that approached significance between the two studies. Writ large, participants exhibited the same learning trajectory with regard to the interpretation of the three different NP types from the previous study to the present study (cf. Figure 4). In both studies participants initially treated *paya* as plural in the first testing sessions, despite there being no evidence in the input for *paya* ever being plural. In Liter, Heffner & Schmitt (2017), we attribute this to an initial transfer effect from participants' native language of English that is washed out over time. Since the singular has no overt morphology marking in English but the plural does, we suspect that participants might have initially treated the bare nominal as singular and both *koho* and *paya* as plural. Over time, this behavior disappears, and participants come to learn the three-way nominal system.[16] These same trends are exhibited in the present study, but they are weaker and disappear much more quickly. This is again unsurprising given that there was much more quantitative evidence in the input for the present study that *paya* really did mean singular.

As for the significant main effect of study in the object negation task, it is not clear why there would have been a difference from the previous study to the present study in this task. Perhaps this is related to the fact that participants took longer to learn the vocabulary of the language, and so negation of the object referent was harder for the participants in this study; however, this is just speculative.

In sum, we find that the learning trajectories are the same independent of the differences in frequencies between the two studies. What changes seems to be the speed in which certain interpretations are learned and the frequency with which the forms are used. Furthermore, the frequency of use of plural and singular forms in relation to bare nominals was not enough to change the interpretation assigned to the plural.

4 Conclusion

To recapitulate, the present work fleshes out two possible accounts of why languages like Korean appear to always have semantically marked plural morphology. The first hypothesis is that non-grammaticalization of number entails semantic markedness (cf. §2.1), and the second hypothesis is that semantic markedness is the result of insufficient evidence for compressing the lexicon (cf. §2.2). Both hypotheses would account for the natural language facts and our previous artificial language learning results, since, in these cases, lack of grammaticalization correlates with a lower frequency of the forms. In the study we presented in this paper, we increased the frequency of singular- and plural-marked noun phrases, but we maintained the non-grammaticalization of number marking.[17]

We found that native English speakers assumed the plural was semantically marked when learning both artificial languages, independent of the frequency with which the

[16] A reviewer asks why some studies show transfer effects and others do not. Although a full analysis of different results is beyond the scope of this paper, we suspect that our effect washed out as the participants learned that *paya* was singular. Treating the bare nominal as singular would amount to violating the principle against same meaning for two different forms.

[17] It is important to reiterate that, in this case, it was a case of true optionality given that both the bare nominal and the number-marked noun phrases occurred in exactly the same contexts and had no (in)definiteness confounds.

forms appeared and despite the fact that the plural is semantically unmarked in their native language. The results are consistent with the idea that what matters is the non-grammaticalization of number. In other words, the results did not support the hypothesis that semantic markedness is the result of infrequent number-marked NPs constituting insufficient evidence for compression of the lexicon.

Nonetheless, there are two issues that can be raised when we examine our results in light of the hypotheses tested. The first issue has to do with the underlying assumption that we have made about the analysis of the interpretation of the plural, and the second issue has to do with the underlying representations that participants may have had of the plural.

Remember that both hypotheses assumed an implicated presupposition account of the number interpretation facts in English (Sauerland, Anderssen & Yatsushiro 2005). More specifically we assumed that (i) the plural is semantically unmarked in English and receives an inclusive interpretation in downward entailing contexts in which the implicated presupposition gives rise to a stronger statement; and (ii) if the plural allowed an exclusive interpretation in downward entailing contexts, that would mean that the plural was semantically marked. However, as mentioned before, Grimm (2013) and Mathieu (2014) have recently argued that an implicature-based (or implicated-presupposition-based)[18] analysis of the plural is wrong and that the correct analysis is in terms of weakly and strongly referential NPs, with plural instances of the former having an inclusive interpretation and plural instances of the latter having an exclusive interpretation.

As noted above, it is beyond the scope of this paper to adjudicate between this analysis, on the one hand, and the implicature-based analyses on the other hand (Sauerland, Anderssen & Yatsushiro 2005; Spector 2007; Zweig 2009). Nonetheless, it is worth noting that the papers of Grimm (2013) and Mathieu (2014) are concerned about the correct analysis of English. In this paper, we are ultimately concerned about ascertaining why languages like Korean always seem to have an exclusive interpretation of their plural morphology. If Grimm (2013) and Mathieu (2014) are ultimately correct about English and if the weakly/strongly referential distinction is also relevant to explaining the Korean facts (rather than semantic markedness), then this suggests that our first hypothesis might need to be reframed in terms of weakly and strongly referential NPs. Specifically, it would suggest that non-grammaticalization of number may entail that plural-marked NPs are always strongly referential and therefore disfavored in downward entailing contexts, among other contexts. Alternatively, if we take Mathieu's (2014) analysis it would suggest that Korean-like languages only have one type of plural (the referential one) and that learners would need some type of evidence to postulate a second type of plural (the non-referential one).

Thus, we think that the import of our results does not rest entirely upon Sauerland, Anderssen & Yatsushiro's (2005) analysis of the plural being correct. And we leave deciding whether the Grimm (2013) and Mathieu (2014)-style analyses are correct and, if so, whether they are relevant to the Korean facts, to other work.

The second issue has to do with the actual representation of the plural in the study presented. Based on our assumptions, we argued that the learner did not infer that plural and singular were grammaticalized based on the fact that participants did not treat the plural as unmarked and the fact that they did learn a three-way distinction, even though they basically did not produce bare nominals by session 10.[19] The small

[18] Recall that an implicated presupposition is just an implicature calculated in the domain of presupposition, rather than the domain of assertion (see, for example, Sauerland 2008).

[19] Of course, as pointed out by a reviewer, we cannot ensure independently of our assumptions that participants did not grammaticalize number. One could imagine a situation in which there could be a grammaticalized three-way distinction with bare nominals being akin to the plural in English. However, we think this is unlikely because there would be too much overlap between the bare nominal and the other two

amount of bare nominals in the production component of the study presented here is not however unexpected and should not be used as evidence for grammaticalization. As the studies by Hudson Kam & Newport (2005; 2009) pointed out, adult participants tend to match input frequencies, and they are also known to try to be as informative as possible (cf. Fedzechkina, Jaeger & Newport 2012; Kurumada & Grimm 2017); both of these facts would lead to the bare nominal being dispreferred. That is, the smaller frequency of bare nominals in the present study combined with its less informative nature may have led participants to use it less often. Nonetheless, the results from the comprehension task suggest that they did learn that bare nominals could be used for singletons and pluralities, after they overcame the bias towards treating them as singular. The only difference between the two studies is that this bias went away faster when the frequencies of marking singular and plural were higher. Thus, an interesting question for future work (also asked by a reviewer and discussed briefly in note 16) would be to investigate how much input is necessary to undo the initial biases a learner might have from their native language and whether all of the L1 biases have the same signature. What our study tentatively suggests with regard to these questions is that implicature-dependent interpretations are calculated on the options available and do not transfer, but more studies need to be done in order to replicate these results with both plurals and other types of linguistic features.

With regard to our main question (namely, whether the non-grammaticalization of number drives the semantic markedness of plural morphology or whether infrequent use of singular and plural morphology does), we have shown that our results are consistent with the hypothesis that non-grammaticalization entails semantic markedness, and we have given an account of why there is such an entailment relation in terms of Sauerland, Anderssen & Yatsushiro's (2005) analysis of the plural.

Abbreviations

The following abbreviations are used: NP = noun phrase, NumP = number phrase, VSO = verb-subject-object (word order). Moreover, the following abbreviations are used for glossing morphosyntactic features: ACC = accusative, DECL = declarative, NEG = negative, NMLZ = nominalizer, PL = plural, PST = past, SG = singular, TOP = topic.

Additional File

The additional file for this article can be found as follows:

- **Appendix A:** Artificial language lexicon. DOI: https://doi.org/10.5334/gjgl.532.s1

Ethics and Consent

All participants gave their informed consent to participate in this study. The research protocol was approved by the Michigan State University Institutional Review Board (IRB #09-020).

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forms, which would render the bare nominal redundant in our language, all things being equal. This may be relevant to explain the fact that in languages such as Korean and Japanese the plural morpheme is a portmanteau morpheme with some D-linking feature and why, in languages like Brazilian Portuguese, bare singular count nominals have an obligatory indefinite kind interpretation and tend to be used when properties of a kind are more relevant than the cardinality of the set. In other words, the true number-neutral bare nominals are not really part of the number paradigm. They reflect lack of number.

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Competing Interests

The authors have no competing interests to declare.

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