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To cite this article: Adam Liter, Christopher C. Heffner & Cristina Schmitt (2017) The Interpretation of Plural Morphology and (Non-)Obligatory Number Marking: an Argument from Artificial Language Learning, Language Learning and Development, 13:4, 451-480, DOI: 10.1080/15475441.2017.1324307

To link to this article: http://dx.doi.org/10.1080/15475441.2017.1324307

Published online: 19 Sep 2017.
The Interpretation of Plural Morphology and (Non-)Obligatory Number Marking: an Argument from Artificial Language Learning

Adam Liter, Christopher C. Heffner, and Cristina Schmitt

ABSTRACT
We present an artificial language experiment investigating (i) how speakers of languages such as English with two-way obligatory distinctions between singular and plural learn a system where singular and plural are only optionally marked, and (ii) how learners extend their knowledge of the plural morpheme when under the scope of negation without explicit training. Production and comprehension results suggest that speakers of English did learn a system with only optional marking of number. Additionally, subjects did not accept an inclusive ("one or more than one") interpretation of the plural when under the scope of negation, as in their native language, but rather assigned it an exclusive ("more than one") interpretation. The results are consistent with the hypothesis that the meaning assigned to plural morphology is sensitive to the architecture of the system. In a binary number system with obligatory number marking, plural morphology can sometimes receive an inclusive interpretation. However, in a system where plural marking is never obligatory, plural morphology has an exclusive interpretation.

Learning the morphology of a language is more than just learning morphological forms and their distributions. It also entails learning how these forms partition the semantic space and how they are organized with respect to each other in different contexts. An interesting instance of morphological learning is the acquisition of number. Number systems differ cross-linguistically along a series of dimensions, beyond the simple surface distinctions in the numbers and types of morphological forms in play within a language (cf. Corbett, 2001). In some languages, number information is an obligatory feature of a noun phrase; in other languages, number is only optionally present; and in yet others, number information is obligatory in some types of noun phrases but not others. The interpretation of different morphemes also varies cross-linguistically. In some languages, plural morphology can be interpreted as meaning "one or more than one" (e.g., English); but, in other languages, the interpretation is always "more than one" (e.g., Korean). But how do these different interpretations arise? One possibility is that the interpretations of the different number morphemes within a linguistic system are simply the result of arbitrary pairings between meanings and forms. An alternative possibility is that their interpretations are a necessary consequence of the interaction between the learning system and properties of the input, such as the number of distinctions between number morphemes and the obligatoriness (or lack thereof) of number morphology. Unfortunately, it is difficult to distinguish between these two possibilities in a natural setting, since languages are never minimal pairs of one another. This makes it impossible to make proper comparisons without results becoming muddled by other differences that must also be learned and may interfere with number.

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/hlld.
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In this article, our goal is to contribute to the debate of how learners decide the underlying meaning of particular pieces of number morphology. To that effect, we constructed an artificial language to examine how speakers of English, which obligatorily encodes number in the noun phrase, learn a language where number is only optionally marked on the noun phrase. We ask two questions. First, can speakers of a language that makes an obligatory distinction between singular and plural learn a system in which number is only optionally encoded without regularizing the system to something more like their native language? Second, if they can learn such a system, does the morphological partition of the new language shift how the plural morphology of the system is interpreted? Specifically, since English is a language in which the plural can sometimes be interpreted as meaning “one or more than one” (more on this below), will learners retain the possibility of this interpretation or not?

We find that English speakers do learn a system with optional number marking and are able to treat number-neutral noun phrases as compatible with both plural and singular interpretations. Furthermore, the results are consistent with the hypothesis that learners do not treat the plural marker in this language as meaning “one or more than one”, as they do in some contexts in English, but rather interpret it as meaning “more than one”. Taken together, these results suggest that the differences in interpretation of the plural morphemes cross-linguistically may depend on properties of the available alternative in the input and/or the learning system and are therefore not just an arbitrary pairing of form and meaning.

This article proceeds as follows. First, we describe some properties of English-like number systems and other types of number systems that served as models for the artificial language created. Next, we discuss different hypotheses and their predictions for our experiment. The next section presents the study and results, and the last section concludes with a general discussion.

Cross-linguistic variation in number systems

Number can be obligatory or optional

Number systems can vary in terms of morphological form (e.g., suffixation, reduplication) and in terms of the number of distinctions that are present in a language (e.g., singular, dual, plural). Another way that number systems can vary is by whether number is obligatorily marked on a noun phrase. In languages such as English, there is a two-way morphological distinction that is obligatorily marked in the syntax. That is to say, a noun phrase that is an argument of a verb must be treated syntactically as either singular or plural; there is no optionality on the morphological instantiation of number. On the other hand, in languages like Korean, Mandarin, and Japanese, number information is not obligatorily marked on a noun phrase (see Cheng & Sybesma, 1999; Chierchia, 1998; among others).1 A noun phrase in these languages may not have any number information and may be interpreted as singular or plural depending on the context. Noun phrases that have no information about number are called number neutral. In these languages, optional morphemes can be added to disambiguate whether the noun phrase refers to a singleton or to a plurality. The number systems of Korean-like languages served as the basis for the number system in the artificial language that we created.

Variability in the interpretation of the plural

Plural morphology can also vary in terms of its interpretation, both intra- and cross-linguistically. On the surface, one might think that the singular in English means “one” and the plural means “more than one”. However, under closer inspection it becomes clear that matters are more complicated, as can be seen in (1). While (1a) cannot felicitously be uttered in a situation where John saw

1On a terminological note, what we refer to as non-obligatorily marked number has also been called common number form (Jespersen, 1924, p. 198), unit reference (Hayward, 1979), transnumeral (Biermann, 1982), and general number (Corbett, 2001, pp. 9–10).
only one friend, (1b) can be felicitously and truthfully uttered in a situation where John did not see one friend; in fact, (1b) can only be truthfully uttered if John did not see even a single friend.

Cases such as (1b) suggest that the interpretive difference between singular and plural in English is not always an opposition between “one” and “more than one”; rather, at least in certain cases, the interpretive difference seems to be an opposition between “one” and “one or more than one”. In (1b), for example, the plural noun phrase friends can describe both sets containing more than one friend—multiple-item sets—and sets with only one friend—singleton sets. This interpretation of the plural is called inclusive, as it includes the singleton sets of friends as well.

Sauerland, Anderssen, and Yatsushiro (2005) argue that the “more than one” interpretation of the English plural morpheme arises as a pragmatic inference. In other words, the exclusive interpretation—that is, the interpretation that excludes the singletons—arises because the listener makes an inference about a plural noun phrase based on the contrast with the singular morpheme, which they take to mean “one”. A listener reasons that the speaker would have used the singular noun phrase if there were exactly one object in the context being discussed. However, since the speaker instead used the plural morpheme, there must have been more than one of the objects being discussed, giving rise to the exclusive interpretation. In simple positive declarative contexts in English, the exclusive interpretation is the most likely interpretation of the plural morpheme, as in (1a). However, as was shown in (1b) above, there are contexts in English where the plural morpheme may receive an inclusive interpretation. On Sauerland et al.’s (2005) analysis, this is because the pragmatic inference that the speaker would otherwise make may be cancelled in environments where making the pragmatic inference would actually generate a weaker statement, and so the inference is not made. For instance, the example in (1b) rules out the situation in which John saw one friend, the situation in which John saw two friends, the situation in which John saw three friends, and so on. However, if one were to interpret the plural noun phrase friends as having an exclusive interpretation, then it would not rule out the situation in which John saw one friend. In other words, under the scope of negation, the inclusive interpretation of the plural morphology actually gives rise to a stronger statement, as it rules out more situations than if the plural noun phrase were interpreted as having an exclusive interpretation. What is important for present purposes is that, in English, the plural morpheme often receives an exclusive interpretation but can sometimes receive an inclusive interpretation, one of the contexts in which it can receive an inclusive interpretation being under the scope of negation.

Before we examine the interpretation of the plural morpheme in languages in which number marking is not obligatory, it is important to note that the claim that plurals allow inclusive interpretations has been tested for English in a variety of experiments using slightly different methodologies and materials (Anand, Andrews, Farkas, & Wagers, 2012; Pearson, Khan, & Snedeker, 2010; Sauerland et al., 2005; Tieu, Bill, Romoli, & Crain, 2015). The results show that both English-speaking children and adults allow inclusive interpretations of the plural in negative contexts and other contexts of the same type—namely, downward entailing contexts. However, different contexts seem to trigger the inclusive interpretation to differing degrees; that is to say, the exclusive interpretation is harder to cancel in some contexts (see, in particular, Pearson et al., 2010). Interestingly, children allow the inclusive interpretation even in contexts where adults prefer the stronger, exclusive interpretation (Sauerland et al., 2005; Tieu et al., 2015). Since children are known to have trouble calculating implicatures, these results are used as part of the evidence in favor of the exclusive interpretation being derived by an implicature, as in Sauerland et al.’s (2005) analysis.

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(1) a. John saw friends last night.
b. John didn’t see friends last night

For alternative accounts of these facts, see Spector (2007) or Zweig (2008).
In languages like Korean, Mandarin, and Japanese, where number information is not obligatorily marked on the noun phrase, the interpretation of plural morphology differs. In these languages, a count noun is interpreted as number neutral; number information about the cardinality of the referent of a noun phrase is determined solely from the context (if at all). This number-neutral interpretation is not particular to downward entailing contexts, like in English. For example, a sentence such as (2), which is a declarative sentence with no downward entailing operators, can be interpreted as John having seen one or more friends last night. The context alone determines whether the interpretation is plural or singular (or irrelevant).\footnote{All Korean examples in this paper are presented in the Yale Romanization standard. All of the abbreviations that we use in the glosses in this article are acc for accusative, decl for declarative, neg for negation, nmlz for nominalizer, pl for plural, pst for past, sg for singular, and top for topic.}

Nonetheless, in these languages optional morphemes can disambiguate whether a referent of a Korean noun phrase is singular or plural. The disambiguating morpheme for the plural in Korean is not like the plural morpheme of English, however. Not only is it optional, but it also necessarily maps to an exclusive interpretation;\footnote{It also requires discourse-linking, much like the pluralizer in Mandarin and in Japanese. The pluralizer cannot be used with a kind interpretation in any of these languages, and in Mandarin and Japanese, the pluralizers are restricted to animate nouns (for further discussion of these facts, see Munn, Zhang, & Schmitt, 2009; Nakanishi & Tomioka, 2004; Nakano, Park, & Schmitt, 2009; Sohn, 1999; Li, 1999).} in other words, it cannot be interpreted as meaning “one or more than one” in any context. For example, unlike the English equivalent, (3) can be felicitously and truthfully uttered in a situation where John only saw one friend last night.

If the differences in interpretation of plural morphology from English to Korean are not due to mere historical accident and indeed are the result of some property of the linguistic system (perhaps interacting with the learning system), then the locus of the difference cannot be the mere existence of a noun phrase with a number-neutral interpretation in the language. This cannot be the case because there are languages, such as Brazilian Portuguese, where there is a noun phrase that receives a number-neutral interpretation, but the plural morphology nonetheless behaves like English plural morphology and receives an inclusive interpretation in negated and other downward entailing contexts (see Schmitt & Munn, 2002). If the difference between English and Korean plural morphology is driven by a property of the grammar, then the one that seems to be the most relevant is the (non-)obligatoriness of number marking, since Brazilian Portuguese differs from Korean in having number obligatorily realized in all other noun phrases. Furthermore, Brazilian Portuguese, like English, requires subject-verb agreement in number.

**Hypotheses and predictions**

To reiterate the main question of interest, we want to know whether interpretive differences of the plural across languages are solely coincidental or whether they are a necessary consequence of the way that number systems are organized. Given the discussion above, one possibility is that the inclusive interpretation of the plural in downward entailing contexts in languages like English
is a consequence of a system with obligatory number marking. Conversely, the non-obligatory marking of number in a language like Korean might lead to exclusive interpretations of the plural morpheme in all contexts, downward entailing or not. If this were indeed the case, it would be good evidence that such plural interpretations reflect something deeper about what is linguistically possible.

As pointed out by von Fintel and Matthewson (2008), there is very little known about semantic universals. In the particular case of number systems, it is also difficult to make large generalizations from typological data because in many cases the number morphology is combined with other features, and we are left with facts that cannot be easily compared. With artificial language experiments, we can simplify the system and control for the properties of the input that learners receive. In this article, we present an artificial language experiment examining how speakers of a language with a two-way obligatory distinction between singular and plural—namely, speakers of English—learn a system that is Korean-like in that it has number-neutral noun phrases and optional disambiguating plural and singular morphemes. However, our language is simpler than Korean in that the pluralizer is in free variation with the number-neutral noun phrase. In other words, unlike the pluralizer in Korean, it does not impose any extra discourse conditions for use, and it is not a portmanteau morpheme.

We are interested in two questions. First, how does a person whose native language has a two-way obligatory plural-singular distinction learn a language where plural-singular marking is optional and the majority of noun phrases is not marked for number? And, second, what type of interpretations will participants assign to the plural morphology, especially if they learn the three-way distinction between number-neutral noun phrases and the optionality of plural and singular morphology? In particular, we are interested in how they interpret noun phrases with plural morphology under the scope of negation (a downward entailment context), when they are given no explicit training on the relationship between negation and number. Will they interpret the plural as inclusive (as in English) or as exclusive (as in Korean)?

There are at least two outcomes for the first question: (i) participants will learn that this is a language with number-neutral noun phrases and also optional plural and singular marking; or (ii) participants will regularize the system into a system with either only an obligatory plural-singular distinction, ignoring one of the forms, or will reorganize the three forms in such a way that they cease to be in free variation in the same contexts. Previous work on artificial languages does show that adult learners do sometimes regularize the input by eliminating less frequent forms, although not as much as children (Hudson Kam & Newport, 2009). Adults have also been shown to regularize input in directions that are consistent with typological tendencies (Culbertson, Smolensky, & Legendre, 2012), and given that languages with a number-neutral form are less common than languages without (cf. Corbett, 2001), one might expect regularization towards a language without a number-neutral form to occur in our study. There is also evidence from Fedzechkina, Jaeger, and Newport (2012) that learners can preserve the distinctions but reorganize the grammar in a direction that is not predicted by the input.

With regard to the second question, there are a few plausible possibilities. First, participants might simply import the interpretation of plural morphology from their native language into the artificial language, regardless of whether they learn the three-way distinction in the artificial language. This would not be surprising since transfer effects are robustly attested in second language acquisition (see, e.g., Gass & Selinker, 1992; Jiang, 2004; Odlin, 2003; Schwartz & Sprouse, 1996) and have also been argued to explain some results from artificial language experiments (e.g., Goldberg, 2013).

An alternative possibility that might also lead to participants assigning an inclusive interpretation to plural morphology under the scope of negation like in their native language is if they were to regularize the grammar by eliminating one of the forms from the grammar. If they were to do this, the artificial language would have a paradigm with an obligatory two-way distinction between singular and plural. Recall that in Sauerland et al.’s (2005) analysis of the English plural, the semantics of the plural are left unspecified. Because the plural competes with the singular in such a paradigm, absence of singular semantic features can then be interpreted as “more than one”, by pragmatic strengthening (in non-downward entailing contexts). If such obligatory linguistic paradigms universally result in one of the paradigm member’s semantics
being unspecified, we would predict our participants to have an inclusive interpretation of plural morphology under the scope of negation if they regularized the artificial language and eliminated one of the noun phrases from its grammar.

Finally, and relatedly, if participants do not regularize the grammar of the artificial language and do in fact learn the three-way distinction with number-neutral bare noun phrases and optional number morphology, then we might expect that they would assign an exclusive interpretation to plural morphology under the scope of negation since they will not have created a paradigm and therefore will not leave the plural or the singular semantically unspecified.

The differing predictions for our second question about how participants will interpret plural morphology in the scope of negation are summarized in Table 1. The transfer hypothesis predicts that participants will interpret it inclusively, regardless of whether they learn that the language has number-neutral noun phrases and that number morphology is optional. On the other hand, the predictions that the paradigm hypothesis makes do depend on whether participants regularize the system.

The experiment

Methods

Participants

Twenty Michigan State University students were recruited to participate in this study. Three of the 20 participants dropped out during the experiment; their data is not presented here. Participants were recruited as part of the third author’s child language acquisition class; all participants gave their informed consent to participate in this experiment. All participants were native speakers of English.

Materials

The language

A 23-word artificial language, dubbed “Lablish”, was created for this experiment. The language’s lexicon consisted of 16 nouns, 2 transitive verbs, 2 intransitive verbs, 2 number morphemes, and 1 negation particle. The complete lexicon is available in Appendix A.

Labish’s word order was always verb-subject-object (VSO). Negation was sentence initial, occurring before the verb. Whenever the number morphemes were present, they always occurred immediately after the noun they modified. These number morphemes were optional. When present, the singular morpheme, paya, always modified a noun referring to a singleton picture, and the plural morpheme, koho, always modified a noun referring to a multiple-item picture with between two and four entities, with the precise number of items being randomly determined (with equal probability) for each picture. Varying the number of entities was designed to prevent learners from interpreting plural as a specific quantity; as there did not appear to be significant fluctuation in the proportion of trials correct across different entity
numbers for multiple-item pictures, we collapse across entity numbers when reporting results. A noun without a number morpheme—called both a “number-neutral NP” and “bare NP” throughout this article—was number neutral and could refer to either a singleton picture or a multiple-item picture. 50% of the nouns that the participants heard were bare NPs, 25% were plural-marked NPs, and 25% were singular-marked NPs. Moreover, half of the bare NPs were paired with singleton pictures, and half were paired with multiple-item pictures (see Appendix B for more details).

Intransitive verbs always appeared with one argument (a subject), while transitive verbs always appeared with two arguments (a subject and an object). Either type of sentence could be negated using a sentence-initial negation particle, te; the frequency of negation is described in full in the Training and Testing sections.

**Presentation**

Participants were told that they were to learn a novel language and be tested on their learning of the language. They were exposed to the language over the course of ten sessions, administered using E-Prime 2.0 Professional Edition software (Psychology Software Tools, Inc., Sharpsburg, PA) on computers. Each session took approximately 30 min. Participants generally participated in one session a day when possible and never participated in more than two a day. Sessions were spread out over the course of three weeks, although most participants (13 of 17) completed all sessions within two weeks. Despite the variation in the length of training between participants, exploratory analyses with the days elapsed from the first session used as a factor in subsequent modeling rather than session number itself showed that session number was a better predictor of variation in the rate and quality of learning than time elapsed; as such, we only report analyses with session number in the subsequent discussion.

During the experiment, participants saw animations on the screen and heard sentences corresponding to the animated event. Sentences were spoken at a rate appropriate for language pedagogy by a female adult native speaker of American English, with slight emphasis on the negation particle in negated sentences. The number morphemes were pronounced as part of a prosodic phrase with the nouns they were affixed to. For sessions in which both training and testing occurred, participants were tested before they were given subsequent training. For example, the testing performed in session 2 was dependent on the training done in session 1. A basic outline of sessions, along with the tasks performed in each session, is shown in Table 2. The training and testing tasks are described in subsequent sections. The rationale for organizing the training and test sessions in this way was two-fold. First, we wanted to see how learners

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*Table 2. Distribution of practice and testing across sessions. Check marks represent the existence of that type of practice or test within the session signified by the column.*

A reviewer asked whether participants might be interpreting koho as English’s many, rather than as a plural morpheme. Under this account, one would expect participants to use koho more often when a larger number of objects was presented on the screen (i.e., more often when 4 objects were presented when there were 2). However, there was little evidence for this; when participants used the morphemes correctly, they used them in 49% of the trials when they saw 2 or 3 items on the screen, and 52% of the trials when they saw 4 items on the screen.

Thanks to an anonymous reviewer for raising this possibility.
develop their knowledge of the three types of noun phrases: plural, singular, and number-neutral noun phrases. Second, since we wanted to test their interpretation of number morphology under negation we needed to make sure that participants made a distinction between singular and plural and also had a reasonable command of negation, vocabulary, and argument structure before they were tested. Since knowledge of negation depended also on some knowledge of grammar and vocabulary, negation was introduced late in the training. These goals required a good deal of both testing and training, resulting in a 10-session experiment.

**Training**
During the training sections, participants were instructed to pay attention to the screen as events were depicted on the screen, paired with audio recordings of sentences in Lablish. They were also instructed to repeat the sentence aloud to themselves in order to facilitate learning. After each sentence, participants were asked to press the space bar, so the session was self-paced. The training in each session consisted of a training set of 128 sentence and event pairings; the makeup of these training sets are described in detail in Appendix B.

**Testing**
Testing preceded training during the sessions in which both occurred, such that participants’ responses on testing sections represented information about the language that they had retained from previous sessions. Where multiple types of tests were given (see Table 2), they occurred in the order that they are discussed below.

**Vocabulary and number morphology.** In sessions that included these test items, the vocabulary and number morphology test items were administered first. Participants were instructed to listen to a phrase that was paired with two pictures, a singleton picture and a multiple-item picture. Both pictures always depicted the same noun. They were then told to press a key on their keyboards indicating which of the pictures on the screen matched the word or phrase they heard. For example, a participant might hear the word *hatepi “cow”* and see a picture of a singleton cow and a picture of multiple cows. The most complete response would be to press the key on the keyboard corresponding to “both”, indicating that both pictures could be described by the word *hatepi “cow”*. Alternative options were to select only the singleton picture and to select only the multiple-item picture, which were not necessarily incorrect responses since the bare NP can refer to both singular and plural referents. The incorrect response would be to select the option indicating that neither picture was described by *hatepi “cow”* (see Figure 11 in Appendix B for an example of what the participant saw on the screen).

Most obviously, participant responses in this section allowed for testing acquisition of the basic noun inventory of the language. If a noun phrase were paired with an incorrect image (say, if the word *hatepi “cow”* were paired with a singleton picture of a cat and a multiple-item picture of cats), participants should indicate that neither image matched the word they heard; conversely, if a noun phrase were paired with images that actually corresponded to the referent of the noun, participants should not choose the neither option and should instead choose either the singleton picture, the multiple-item picture, or the option that indicates both.

Of course, this only indicates that the participant knew the referent of the noun. Depending on whether the participant chooses the singleton picture, the multiple-item picture, or the “both” option, we can further determine how the participants are interpreting the three types of NPs—namely, the bare NP, the singular-marked NP, and the plural-marked NP. For example, in cases where participants chose the singleton picture, we can reasonably infer that they assigned a singular interpretation to whichever type of NP that they heard on those trials. Similarly, in cases where participants chose the multiple-item picture, we can reasonably infer that they assigned a plural interpretation to whichever type of NP that they heard on those trials. And in cases where participants chose the option indicating both the singleton and the multiple-item
picture, we can reasonably infer that this is evidence for the participants having assigned a number-neutral interpretation to whichever type of NP that they heard on those trials.

**Argument structure task.** This task was used to examine participants’ knowledge about the basic argument structure of Lablish. Participants were given 24 trials in all of the sessions in which this test was found (see Table 2). For each trial, participants saw an event on the screen and heard two sentences that might possibly be paired with that event. They were told to select the sentence that sounded most like a sentence of Lablish that would describe the picture on the screen, using the keyboard in front of them to indicate either the first or the second sentence. The order of trials varied randomly within each session. For each trial, one of the presented sentences was grammatical, while the other was ungrammatical due to a defect in the argument structure of the sentence (for further details, see Appendix B).

**Free response production task.** The free response task was used to determine participants’ abilities to spontaneously produce Lablish sentences, including whether they use all three possible NP types present in their training input. Participants were shown a picture, which was accompanied by a sound clip of the verb that described the action in the picture. They were then asked to complete the sentence with the noun phrases that could correctly describe the scene in front of them (recall that word order in Lablish is VSO). Participants’ responses were recorded and later transcribed. Participants were instructed to say the non-word “X” in cases where they had trouble recovering a lexical item but knew other parts of the sentence (as was done in Hudson Kam & Newport, 2005, 2009).

Participants were given 24 free response items (12 transitive and 12 intransitive) in each session that this task occurred. The sentences were balanced for number for both subject and object nouns, with half being singular and half being plural. Nouns were used as equally as possible across subject and object positions.7

**Verb and object negation.** The negation task was used to assess participants’ acquisition of negation in Lablish independently of the interaction that negation might have with number morphology. For each of 48 trials, participants saw an event on the screen and heard a sentence that might describe that event. The sentence involved the negation particle te. Participants were told to indicate whether the sentence they heard matched the event on the screen. There was a key on the keyboard that indicated that the sentence they heard was a true description of the event on the screen and another key that indicated that the sentence they heard was a false description of the event on the screen.

The basic negation test was divided into two halves. In one half (made up of 24 trials), listeners were tested on the negation of sentences due to a deviation from the onscreen event in the verb being used. If a participant heard the sentence in (5), with the screen showing a cow circling cats, this sentence correctly described the picture and is thus a “true trial”. The part of the sentence being negated was the identity of the verb. However, this same sentence was incorrect when paired with a picture of a cow covering cats, which would be a “false trial”. One half of the 24 verb negation trials were true trials, and the other half were false trials.

In the other half of the basic negation testing, listeners were tested on the negation of sentences due to a deviation from the onscreen event in the identity of the object. One half of these trials were also true

(5) Te disi hatepi paya yipi koho

NEG cover cow SG cat PL

“A cow didn’t cover cats”

7A reviewer asked why we did not ask participants to produce negative sentences. The main reason is that asking someone to describe an event by stating what did not happen in the event is pragmatically odd, so it would have been hard to design an optimal way of eliciting such sentences. Additionally, negation was taught rather late in the study and there were only a certain number of things we could reasonably test in session 10 without exhausting the participants.
trials, and the other half were false trials. In a true trial, participants should have indicated that the sentence in (5) correctly described the event of a cow covering ladybugs, for example, because the cow is not covering cats. Whereas, in a false trial, (5) would be paired with an onscreen event of a cow covering cats, and so (5) would falsely describe the event on the screen. Figure 1 summarizes all of this.

**Number negation task.** Number negation tested participants’ ability to extend negation to the number morphology on the object of the verb; it only occurred in the final session of the experiment, after participants had a chance to learn negation. Crucially, participants were not overtly trained on whether negation could take scope over the number morpheme; participants were only ever trained on the ability of the negation particle to take scope over the verb and over the head noun of the argument in object position in transitive sentences (cf. Figure 10 in Appendix B). Importantly, they therefore did not receive any evidence in their learning input as to the interpretation of the plural morpheme when under the scope of negation. The number negation test thus provided a crucial test of whether English-speaking participants would allow an inclusive interpretation of the plural under the scope of negation (as in their native languages) or whether they would have an exclusive interpretation of the plural under the scope of negation, as in Korean. Of course, it was first necessary to determine whether participants generalized that the negative particle could target the

![Figure 1](image_url)

**Figure 1.** Examples of trials used for the negation testing sessions. The first row gives examples of true and false trials for the basic verb negation trials, and the second row gives examples of true and false trials for the basic object negation trials.
number morpheme on the object of a transitive sentence, since they were not overtly trained on this. To this end, there were four different trial types with 12 trials each, making 48 number negation trials in total. All of these sentences had bare NP subjects, were transitive, and had objects with either a singular or plural morpheme. They were otherwise balanced for subject, object, and verb identity and subject number.

For ease of reference, we refer to the four trial types as follows: “¬kohoXpl”, “¬kohoXsg”, “¬payaXpl”, and “¬payaXsg”. In both types of koho trial, the objects were marked with the plural morpheme, koho. In both types of paya trial, the objects were marked with the singular morpheme, paya. In both types of pl trial, the objects in the onscreen event were multiple-item pictures; conversely, in both types of sg trial, the objects in the onscreen event were singleton pictures. Listeners were asked whether the sentence they heard matched the event on the screen. If participants did, in fact, generalize that negation could target the number morpheme on the object argument of a transitive verb, then all participants should have judged ¬kohoXpl and ¬payaXsg trials as falsely describing the event on the screen. For example, in a ¬kohoXpl trial, the participant would hear a sentence like A rabbit isn’t circling mice paired with an event of a rabbit circling a multiple-item picture of mice. Since the sentence is negated, this is a false description of the event; a rabbit is in fact circling mice. For ¬payaXsg trials, the participant would hear a sentence like Ladybugs aren’t circling a duck paired with an event of ladybugs circling a singleton-item picture of a duck. Since the sentence is negated, this is a false description of the event; ladybugs are in fact circling a duck. On the other hand, participants should have judged ¬payaXpl trials as truthfully describing the event on the screen. For example, in such a trial, a participant would hear a sentence like A zebra isn’t covering a boy paired with an event of a zebra covering a multiple-item picture of boys. This can be a true description of the event; the zebra is not covering just one boy but is instead covering multiple boys. 8

If participants responded to these three trial types as expected, it would suggest that they did generalize that the negative particle could target the number marker on the object of a transitive sentence. This would then warrant looking at the trial type of interest where we do see variation between English and Korean—namely, the ¬kohoXsg trials. In English-like number systems, as noted above, the sentence Lions aren’t covering girls is false even if the lions are just covering only one girl; in English, the plural morpheme may be assigned an inclusive interpretation under the scope of negation. Thus, pairing a negated sentence with a plural-marked object when the onscreen event uses a singleton picture as the object should be judged as a false description of the event if participants are importing their interpretations of plural morphology from their native languages and cancelling the “more than one” implicature. On the other hand, if participants were to learn the Lablish number system as a Korean-like number system, we would expect them to judge such a sentence as truthfully describing the event because Korean-like number systems assign an exclusive interpretation to the plural morpheme in all contexts, even under the scope of negation. This, in addition to the expected judgments from the preceding three trial types, is summarized in Figure 2.

Results

Before we get to the negation results, we first need to establish that participants did learn the basic properties of the language they were being taught by discussing the results from the general grammar task, the vocabulary task, and the free response task.

8For some readers, the ¬payaXpl trials might be false, if the English translation we’ve given is interpreted as A zebra is covering no boy. Such a judgment is driven by allowing negation to scope over the entire object, not just the singular morphology. However, as we will see below, our participants do not do this. To avoid this problem with the English rendering of the different trials in the number negation task, perhaps a better translation would have used one instead of a, since with one it is less likely that the “no boy” interpretation would be preferred.
Argument structure grammar results

The results from this task are shown in Figure 3; most participants did in fact learn the basic argument structure of the language. We used a generalized linear mixed model to investigate learning over time across the language groups and sessions (Baayen, Davidson, & Bates, 2008; Quené & van den Bergh, 2008). We report $b$ values for relevant fixed effects and corresponding $z$ values and $p$ values for each fixed factor. We ran a model that incorporated a fixed effect of session, which tested whether participants as a whole learned over time. Because the test of basic grammatical knowledge was repeated across many sessions, we coded session as a continuous variable, ranging from 1–10. The model we used also included random intercepts for participants and items, as well as random slopes by participant for session. In other

Figure 2. Example trials for number negation. Each example includes a depiction of the event, the sentence that the participant would hear, and the associated judgments for all four number negation trial types.

Figure 3. Average accuracy on general grammar trials by session. Error bars in this graph and error bars in all subsequent graphs represent one standard deviation of the mean.
words, participants were allowed to vary randomly in how accurate they were across the course of the experiment as well as how quickly they learned, and items were allowed to vary in their difficulty. In this case, and in all models subsequently reported in this article, we included the maximal random effects structure that successfully converged, in line with previous guidance on using the maximal effects structure (Barr, Levy, Scheepers, & Tily, 2013). We obtained a significant positive estimate for the fixed effect of session \((b = 0.536, z = 4.17, p < .001)\), indicating that participants improved in their performance on basic grammatical judgments over time. A model summary for this model, and all subsequent models, is available in Appendix C.

The fact that most participants improved in their performance on the test of basic grammar indicates that they were actively participating in the experiment and warrants the analysis of the rest of their data. However, we also wanted to ensure that subsequent findings were not affected by participants who were not attending enough to the task to even understand basic facts about the grammar of the artificial language used in instruction. For this set of results, as well as many subsequent ones, two-sided sign tests targeting each individual participant’s frequency of correct responses were performed. We were concerned that participants who failed to show mastery of basic aspects of the language would not give us interpretable behavior for more complex parts of Lablish. If a participant showed a Korean-like interpretation for the koho morpheme under the scope of negation yet failed to understand that the word for “bounce” in Lablish was intransitive, it does not at all seem clear that that participant’s koho interpretation was really the result of familiarity with Lablish rather than some other strategy. We used a comparison to chance, rather than a more standard criterion (e.g., being more than two standard deviations from the mean), because many of the distributions of participant scores were not normally distributed, with many participants near the floor or ceiling, for example.

The two-sided tests revealed that by the final session all participants were responding significantly above chance to questions examining their basic comprehension of the grammar of the artificial language. The proportion of correct responses ranged from 79–100%. This indicates that all participants learned something of the argument structure of the language—for example, that transitive verbs required two arguments, but intransitives only required one. This shows that they had mastered the basics of the grammatical structure of Lablish. Further, as we might expect, their mastery of Lablish had improved over time.

**Vocabulary use results**

The graph in Figure 4 shows the average accuracy on simple noun recall—that is, whether participants were correctly mapping between the nouns in Lablish and their meanings (see Appendix B for details about the coding of these results).

As can be seen in the graph, participants approach ceiling for their recall of the noun meanings in Lablish. All participants were significantly above chance (.75) on tests of their vocabulary acquisition after at most 7 sessions of training, with responses ranging from 94% correct to 100% correct.  

Again, we computed a generalized linear mixed model to examine these results across sessions. We used a model with random intercepts for participants and items as well as a fixed effect of session (with many different relevant sessions, again coded continuously). Here, there was a fixed effect of session (continuously coded, ranging from 1–10, \(b = 0.426, z = 10.6, p < .001\)). This indicates that vocabulary learning improved over time. To summarize, participants were successfully learning the meaning of the base vocabulary of the language, suggesting that they learned not just the number of arguments necessary to build a Lablish sentence but also had discovered the meanings of the individual words within that sentence.

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\(^9\)Chance was set at 75% because there were three options to choose that would have indicated a participant knew the meaning of the base noun (but not necessarily the meaning of the number morphology). In this task, participants were presented with a single-item picture, a multiple-item picture with the same animal, and an option to indicate that “both” of these pictures could be described by the NP that they heard (for the number-neutral NP). The fourth option, “neither”, would indicate that the participants did not correctly understand the meaning of the base noun. Thus, there was a 75% chance that the participant would get the trial correct merely by guessing from one of the four options. Also, see Appendix B for a more detailed description of this task.
To examine the number morphology interpretation results, we also used a generalized linear mixed model, using accuracy as our dependent measure. A trial was considered accurate if participants gave a singular response—i.e., if they chose the singleton picture—for a noun phrase marked with paya, a plural response—i.e., if they chose the multiple-item picture—for a noun phrase marked with koho, or a response of “both” for a bare noun phrase, regardless of whether the head noun within the noun phrase actually matched the picture on the screen. Responses of “neither”, which were not informative as to whether the participant knew the correct number interpretation of the NP type, were not considered. We included fixed factors of session (again, coded as a continuous variable, ranging from 1–10) and number morphology (paya, koho, or the bare NP) as well as the interaction between these factors. We were able to include random intercepts by participant and item and random slopes for session and for number morpheme (i.e., paya, koho, or the bare NP, which were deviation-coded) by participant.

The model yielded a main effect of session (continuously coded, $b = 1.40, z = 4.19, p < .001$) and a main effect of the number morphology used (relative to the grand mean, using deviation coding, $b_{\text{bare}} = -1.74, z = -3.72, p < .001; b_{\text{koho}} = 2.36, z = 3.88, p < .001; b_{\text{paya}} = -0.617, z = -1.37, p = .17$). Participants improved over time. Further, some number morphemes were harder to learn than others; the main effect for the koho morpheme indicated it was easier than the average of the three number morpheme possibilities to learn, while the main effect for the bare morpheme showed that it was the hardest one to learn. Additionally, there were no significant interactions between session and any of the number morphemes ($b_{\text{sess} \times \text{bare}} = 0.075, z = 1.18, p = .24; b_{\text{sess} \times \text{koho}} = -0.02, z = -0.199, p = .84; b_{\text{sess} \times \text{paya}} = -0.06, z = -0.881, p = .38$). That is, the rate of learning did not deviate from the average rate for any of the number morphemes considered in isolation.

Given the effect of session, we looked at the responses by session. We present three graphs, one for each type of NP and the interpretations that participants assigned to that particular NP across sessions (see Appendix B for further details about how these responses were coded). First, in
Figure 5, we see that participants had no trouble immediately assigning a plural interpretation to the plural-marked NP. That is to say, participants nearly always chose the multiple-item picture when presented with an NP that was marked with *koho* in the vocabulary and number morphology task, even at the outset of the experiment.

Second, Figure 6 shows the interpretations that participants assigned to the bare NP across sessions. In particular, we see that participants initially assigned singular interpretations to the bare NP with a relatively high frequency (above 50%). This is despite the fact that there was positive evidence in their input that the bare NP could also refer to a plurality (in fact, exactly 50% of the time that participants heard a bare NP, it was paired with a multiple-item picture). Nonetheless, we do see the preference to treat the bare NP as singular decrease as the experiment progresses. In particular, the disappearance of this behavior trades off with participants assigning a number-neutral interpretation to the bare NP. By about session 6 of the experiment, participants largely made the most correct mapping from the bare NP to a number-neutral interpretation by choosing the “both” option when presented with a bare NP in the vocabulary and number morphology task.

Finally, the third graph shows the interpretations of the singular-marked NP across sessions. The graph in Figure 7 shows that participants actually initially assigned a plural interpretation to the singular-marked NP. That is to say, they chose the multiple-item picture when presented with an NP that is marked with *paya*, the singular morpheme. This is surprising given that there was no evidence in the input that *paya*-marked NPs could refer to a plurality. Nonetheless, we see this behavior

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10It is possible this singular interpretation of the bare NP may have persisted because a singular interpretation is compatible with a scene in which there are multiple referents (though this would have required the participant to make a pragmatically odd assumption, given that the other noun phrases consistently appear with singleton or pluralities).
Figure 6. Responses for NP-∅ trials in the vocabulary and number morphology task by session. The graph shows the frequency that participants assigned a plural interpretation, a singular interpretation, and a both plural and singular (i.e., number-neutral) interpretation to the bare NP.

Figure 7. Responses for NP-paya trials in the vocabulary and number morphology task by session. The graph shows the frequency that participants assigned a plural interpretation, a singular interpretation, and a both plural and singular (i.e., number-neutral) interpretation to the singular-marked NP.
eventually trade off with participants assigning the correct singular interpretation to the singular-marked NP by session 6 of the experiment.

What all three of these graphs show, then, is that by about session 6 and at least by the end of the experiment, participants had learned the correct interpretations of the three different types of NPs. To substantiate this claim, we compared individual participants’ performance in session 10 to chance, using two-sided sign tests. Given that trials where a response of “neither” was given were thrown out, chance was set at 33% for each test, as all remaining responses would be equally probable under situations where a participant was guessing. We found that 16 of 17 participants were above chance in these trials (with correct response proportions ranging from 59–100%), while 1 was at chance (with a correct response proportion of 35%). This participant is not considered in further analysis. Besides this single participant, all participants learned the interpretations of the three different NP types that we were training them on. These tests indicate that all but one participant learned something about the number morphemes used in the experiment. By the end of the study, the vast majority of participants had learned that the bare NP could be used to refer to either one or multiple entities, but that the *paya* morpheme referred specifically to single entities while the *koho* morpheme referred to multiple. Additionally, participants improved in their understanding of this over time.

**Free response results**

In the free response results, it is furthermore evident that participants are productively using all three possible NP types. Figure 8 shows the average frequency that participants used the three different NP types to refer to either a multiple-item picture (left side of graph) or a singleton picture (right side of graph).

![Figure 8](image_url)

**Figure 8.** Usage of three NP forms in the free response task. Participants’ average use of the three NP forms in the free response task in sessions 7 and 10 for singular reference (“singleton referent”) and for plural reference (“multiple-item referent”).
We used a generalized linear mixed model to examine whether the production of morphemes in the free response task differed between sessions, number, and noun position. To do this, we first removed trials where participants responded with an incorrect number morpheme (i.e., koho for a singleton picture or paya for a multiple-item picture); this removed less than 1% of all trials in both sessions 7 and 10. Next, with the remaining words for each trial, we indexed whether the word was used with the appropriate number morpheme or with the bare form of the noun; this became our dependent measure. We also labeled fixed effects: whether each word within the trial appeared as the subject of an intransitive sentence, the subject of a transitive sentence, or the object of a transitive sentence (position, which was deviation-coded); whether the word was paired with a singleton or multiple-item picture (number, also deviation-coded); and what session the trial came from (session, now deviation-coded with two possible values: session 7 and session 10, as the number of sessions with free response testing was insufficient to encode session as a continuous variable).

We fit a model that included random intercepts by participant and by item and random slopes for number by participant. In other words, participants and items could vary in their baseline propensity to use determiners, as well as their change over time in that tendency and their likelihood to use determiners more often for singleton or multiple contexts. The model also included fixed effects for position, number, and session and a two-way interaction between number and session. We did not include interactions between position and the other variables, as we had no a priori reason to suspect that such an interaction would exist, nor would such an interaction tell us much about the questions our experiment was designed to answer.

The results of this model yielded significant fixed effects of number (with multiple-item coded as 1.0 and singleton as −1.0, b = 0.46, z = 4.09, p < .001). NPs describing multiple-item pictures were more often produced with number morphology (51%) than NPs describing singleton pictures (40%). The model also showed a main effect of position (relative to the grand mean, using deviation coding, b_{intr-subject} = 0.37, z = 3.02, p = .003; b_{tr-subject} = −1.29, z = −9.32, p < .001; b_{tr-object} = 0.92, z = 7.16, p < .001). Number morphology was used more often than the grand mean with transitive objects (58%) and intransitive subjects (50%), and used less often than the mean with transitive subjects (30%). Finally, the model showed a significant effect of session (with session 10 coded as 1.0 and session 7 as −1.0, b = 0.36, z = 4.01, p < .001). Number morphology was more often used in session 10 (49%) than session 7 (42%). There was also a significant interaction between number and session (b = −0.18, z = −2.00, p = .045). Participants showed a larger increase in number morphology use from session 7 to session 10 for the singleton pictures than for the multiple-item pictures.

The free response data showed that participants were more likely to use number morphemes under a few different conditions. Participants were more likely to use koho to refer to multiple-item pictures than they were to use paya to refer to singleton pictures, showing a preference resembling the morphology of English to label the multiple-item pictures. They also were more likely to use either koho or paya at the end of the experiment than toward the middle, in session 7. And, finally, they showed some unexpected patterns in their use of the number morphemes, where they were more likely to use the morphemes in intransitive subject and transitive object positions than transitive subject position. This behavior might be explained by participants attempting to eliminate unpredictable variation in the language. While there is evidence that adults generally probability match—rather than regularize—their input in many language learning situations (e.g., Hudson Kam & Newport, 2005, 2009), there is also evidence that adults will regularize unpredictable variation in certain conditions (e.g., Smith & Wonnacott, 2010; Wonnacott & Newport, 2005). Another possibility is that participants might have had more time to plan the production of a transitive object since it comes at the end of the sentence.

Negation results
We next examined participants’ responses to verb negation trials during the final session to determine whether they had learned negation. Our dependent measure on these negation trials
was binary here, namely whether participants successfully responded to trials that tested their knowledge of negation (for example, by saying that a sentence where “a dog is not bouncing” truly describes a picture of a dog jiggling). A generalized linear mixed model with random intercepts for items and participants and random slopes for session by participant was computed. The model had a fixed effect for session (treated as a nominal variable here, as only two sessions included a test of basic negation). The model yielded both a fixed effect of session (with session 10 coded as 1.0 and session 9 coded as −1.0, $b = 1.92$, $z = 3.10$, $p = .002$). Accuracy was better in session 10 than in session 9.

On a participant-by-participant basis, 13 of the 16 participants who were above chance on previous tasks showed evidence of learning negation. One participant was at chance (with 42% of responses correct), indicating that the participant may not have posited a consistent representation for the negative morpheme. Two participants were below chance, with a proportion of correct responses near zero (to be precise, 4% and 8%), which meant that they probably ignored the negative morpheme, or understood it in a way unrelated to negation, as they consistently and repeatedly treated sentences such as “a dog is not bouncing” as false when seeing a picture of a dog jiggling. We did not consider the participants at or below chance on basic verb negation trials in further analysis, as the interpretation of subsequent negation results is contingent on the participant learning something about negation. Given the close proximity of the negative particle to the verb, a failure to learn anything about negation with regard to the verb likely entails uninterpretable results when negation was applied on other portions of sentences. For the most part, though, it appears that participants learned the meaning of the negative particle at least with regard to whether it could modify the meaning of the verb.

As for the basic object negation results, we once more fit a generalized linear mixed model with random intercepts for participant and item as well as random slopes for session by participant. We considered a model with fixed effects for session. Unlike previous models, this analysis did not show a significant fixed effect of session (with session 10 coded as 1.0 and session 9 coded as −1.0, $b = 0.16$, $z = 0.51$, $p = .61$). That is, the participants who showed above-chance performance on their basic learning of negation did not significantly improve in their learning of the negation of objects across the two sessions we tested them in. One participant was at chance on the acquisition of basic object negation (with 67% accuracy), leaving 12 participants (all with at least 83% accuracy on this test) who successfully mastered all of the facets of Lablish that have been discussed so far. Thus, almost all participants who learned that the negative particle could affect the interpretation of sentences with regard to their verb also learned that the same was true for interpretation with regard to the identity of the object noun.

What is mainly of interest, however, are the results from the number negation trials; the results of all four trial types are shown in Figure 9. This graph only includes results from those 12 participants who showed evidence of having learned negation by performing above chance on the basic verb and object negation trials. Since participants were not overtly trained on the fact that the negation particle could target the number morpheme of the object of a transitive verb, we need to first establish that participants did in fact make this generalization. Recall that if participants successfully make this generalization, then they ought to judge $¬$kohoX$_{pl}$ and $¬$payaX$_{sg}$ trials as falsely describing the paired events that play on the screen. Alternatively, participants ought to judge $¬$payaX$_{pl}$ trials as truthfully describing the event that plays on the screen (cf. Figure 2). According to the results of by-participant two-sided tests, all of the participants who were above chance on basic verb and object negation trials did successfully make this generalization (with accuracy at least 83%). Therefore, participants who had learned all of the properties of negation so far all applied this knowledge to the negation of number morphemes. That is, something like “lizard koho are not covering zebra paya” could be true if the lizards were covering more than one zebra (a $¬$payaX$_{pl}$ trial).

As for $¬$kohoX$_{sg}$ trials, recall that English licenses the inclusive interpretation of plural morphology when under the scope of negation. Thus, if there were transfer effects about the interpretation of the plural morphology from our participants’ native language, we would expect participants to say that the
sentences in these trials do not match the event that they see on the screen (again see Figure 2); that is, they should judge these sentences as false descriptions of the event. However, this is exactly the opposite of what they do. In particular, 8 of the 12 English speakers who allowed negation to take scope over object identity were also significantly more likely than chance (with accuracy of at least 83%) to say that the sentence they heard in a \(\neg\)kohox\(_{pl}\) trial truthfully described the event that played on the screen, like a native speaker of Korean would do; the other 4 participants were at chance. Three of the four participants at chance responded like a Korean speaker would on 75% of these critical trials, while one participant responded like a Korean speaker would on 42% of the trials. Thus, it appears that the majority of participants who had successfully demonstrated competence with Lablish on every other facet of the language showed a Korean-like interpretation of number morphemes under the scope of negation, despite this interpretation being the opposite of the interpretation found in their native language.

**Discussion**

Returning to our first question of interest—namely, how participants whose native language includes an obligatory two-way distinction in the number domain would learn a language with a three-way distinction where number morphology is optional—we saw evidence that participants did successfully learn the three-way system and its optionality, rather than regularize and/or eliminate one of the three forms. Establishing that participants did acquire the three-way morphological distinction is important because we can only evaluate the different predictions of the transfer and paradigm hypotheses if they acquired all three forms and did not eliminate one from the grammar (cf. Table 1).

Production results from the free response task showed that participants were using all three NP forms when producing utterances in the language themselves, and comprehension results from the
vocabulary and number morphology task showed that participants learned the correct number interpretations of the three types of noun phrases. There was no attempt on the part of participants to fully regularize the system by reducing the number of contrasts in the production task. In the case of the comprehension results, we also saw evidence for learning of these distinctions over time.

This is not unexpected because each form was never used less than 25% of the time in each session and because adults are less prone to regularize (see Hudson Kam & Newport, 2005, 2009). Specifically, it was not until a form occurred with 2.5% frequency that Hudson Kam and Newport (2009, p. 45) were able to induce adults to regularize. Moreover, even with low frequencies, Hudson Kam and Newport (2009, p. 50) found that adults would not regularize if the forms were used consistently (i.e., the different determiners consistently occurred with the same class of nouns). Since our study had both a high frequency of the different NP types, and the different NP types were used in consistent contexts (i.e., *paya*-marked NPs always described singleton referents, *koho*-marked NPs always described multiple-item referents, and bare NPs equally described multiple-item referents), it is not surprising that our participants did not fully regularize.

Interestingly, however, the learning of the three-way morphological distinction in our study was not immediate. In the number morphology interpretation task, we saw a tradeoff between the interpretation that participants assigned to the bare NP and the interpretation that participants assigned to the singular-marked NP. Initially, participants interpreted the bare NP as singular and the singular-marked and the plural-marked NPs as plurals of some sort, which was somewhat surprising given that the singular morpheme was never paired with a multiple-item picture during training. A possible explanation of this behavior is transfer effects from the participants’ native language. In English, the singular form is not marked with an overt suffix, whereas the plural is. The behavior we see across sessions makes sense if participants initially tried to impose their native system onto the system of Labish. That is, they immediately took the bare NP to be singular and attempted to treat the singular *paya* as some type of plural in spite of a complete lack of evidence for a plural interpretation of *paya*. This may have been an attempt to reorganize the system. Nonetheless, we saw that this native language bias/regularization attempt disappeared. Participants did successfully learn the three-way morphological distinction and the optionality of number morphology in Labish, in most cases by about session 6, and certainly by session 10.

Given that participants did not fully regularize the grammar but retained all three NP types and the optionality of number morphology, the second question becomes all the more interesting. Recall that the transfer hypothesis and the paradigm hypothesis are only differentiated if no regularization occurred (cf. Table 1). Since this indeed seems to be the case, we can interpret the answer to our second question as evidence for—or at least being consistent with—one of these two hypotheses. Let us, therefore, turn to the negation results and our second question of interest—namely, the interpretation that participants assigned to the plural morpheme when under the scope of negation. We found that participants assigned an exclusive interpretation to the plural morpheme when under the scope of negation. These results are expected if it is a property of Korean-like number systems that an exclusive interpretation of the plural morpheme is required in all contexts. That is to say, these results are consistent with the paradigm hypothesis. The fact that learners were not treating the plural and the singular morpheme as entering a singular-plural binary system after about session 6 and the fact that they used and accepted bare NPs suggests that they did not treat the number morphology as obligatory and part of a paradigm, which would warrant treating one of the forms as semantically unmarked.

We also tested English speakers, in English, using the same materials in order to see whether they would treat the plural as inclusive or not in the ¬*kohoXSG* condition. Although we believe that testing English speakers in English is very different from testing English speakers learning a novel

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11 Furthermore, as pointed out by a reviewer, Greenberg’s Universal 35 states that non-singular forms tend to be marked: “There is no language in which the plural does not have some nonzero allomorphs, whereas there are languages in which the singular is expressed only by zero” (Greenberg, 1963, p. 58).
language (in the sense that the task may be too easy in English and give rise to metalinguistic
negation responses (cf. Horn, 1985)), we did conduct a shorter version of the negation task using the
same materials. With English speakers, we tested the ¬kohox<super>SG</super> condition using a bare plural object
(4 items per participant). 20 participants were tested at Michigan State University for extra credit.
Participants assigned the inclusive interpretation to the plural 25.32% of the time and the exclusive
interpretation 74.68% of the time (SE = 4.89%). At first glance, this is unexpected since negation is
supposed to cancel the implicature that generates the exclusive interpretation. However, as noted
above, it would not be surprising if these results were being driven by something of a metalinguistic
nature, especially given the simplicity and transparency of the nature of the task to a native English
speaker. Additionally, a t-test comparing these 20 participants to the participants in our artificial
language learning study reveals that the 20 participants from this control experiment were signifi-
cantly more likely to give an inclusive interpretation than learners of Lablish (t(134.65) = −1.87,
<super>p</super> < 0.05). Furthermore, 3 of the 20 participants in this control experiment categorically produced the
inclusive interpretation. Lastly, as mentioned above in the body of the article, Pearson et al. (2010)
find that this implicature is not always easily cancelled. If anything, then, these results just suggest
that it is worth further study to determine when and how easily the implicature is cancelled. Given
that the control participants produced inclusive interpretations significantly more often than the
learners of Lablish, this supports the conclusion that participants have not merely imported the
interpretation of the plural from their native language.

Before concluding, we wish to highlight that we hope to have shown that artificial language
learning experiments can also be used to investigate plausible semantic typological tendencies and/or
language universals. In a review of such studies, Culbertson (2012) highlights previous artificial
language research on phonological, syntactic, and morphological language universals. The present
study demonstrates that these types of experiments can also be used to fruitfully investigate semantic
typological tendencies and/or language universals, a heretofore underutilized avenue of linguistic
investigation.

Conclusion

The participants in our experiment learned the three types of noun phrases and also were able to
generalize that negation could scope over number morphology, something that they were not overtly
trained on. Both production data from the free response task and comprehension data from the
vocabulary and number morphology task showed that participants really did learn the three-way
distinction. Importantly, our participants did not impose the binary obligatory number system from
their native language onto the Lablish system. That is to say, they did not regularize the system by
completely eliminating one of the three types of noun phrases. This was a logical possibility and
would have been somewhat similar to what was observed by Hudson Kam and Newport (2009) or
Culbertson et al. (2012).

With respect to Hudson Kam and Newport (2009), we believe that there are many differences
between the two studies that can explain the different results. As already discussed, the high
frequency of the forms and the use of the forms in consistent contexts in our study make it unlikely
that our participants would regularize in the way that they did in the Hudson Kam and Newport
(2009) study. Additionally, in Lablish, learners had to learn the meaning of the morphological pieces
attached to the noun phrases, which may have shifted learners’ attention to meaning rather than to
frequencies in the input (in the lines of Smith & Wonnacott, 2010). And, furthermore, the number of
morphological pieces that had to be learned was much smaller than in the Hudson Kam and
Newport (2009) studies, which may have not reached the threshold that would warrant the
elimination of forms (Yang, 2016).

Additionally, despite the fact that languages with number-neutral forms are typologically less
common than languages without, our learners did not regularize in the direction of a language
without such forms, contrary to what one might have expected based on the findings reported in
Culbertson et al. (2012). However, in their study, the regularization occurred in conditions in which the typologically common forms occurred with high frequency. In our study, the typologically uncommon form (the number-neutral NP) is the one that occurs with the highest frequency. We think that this, in conjunction with Hudson Kam and Newport’s (2009) finding that adults need low frequencies and use in inconsistent contexts to prompt regularization (at least when there is only a single generation of adult learning; see Smith & Wonnacott, 2010), explains the differences between our two studies.

Moreover, our learners also did not, on the whole, reorganize the system as was observed in Fedzechkina et al. (2012). While there was what might be construed as an attempt to impose another form of organization to the system by treating the singular morpheme as a plural morpheme and the number-neutral noun phrase as a singular, this disappeared by session 6. Another possibility, however, is that this pattern of behavior in our data arose because of transfer effects from the participants’ native language of English. These differences between our study and the study in Fedzechkina et al. (2012) raise interesting questions for further research. First, do reorganization effects differ in qualitative and meaningful ways from transfer effects in artificial language learning studies? And second, if they do, do the reorganization effects persist across longer experiments? We leave these questions to future research.

Finally, our participants also did not treat the plural as speakers of English would. Instead, they treated the plural morpheme of Lablish as failing to allow inclusive interpretations in any circumstances, even when under the scope of negation. If the proposed explanation of our results is correct—namely, that the non-obligatoriness of number precludes the formation of a paradigm, which in turn entails that plural morphology will be interpreted exclusively—then our artificial language learning experiment may have provided evidence for the relation between linguistic systems and particular plural interpretations.

As noted above, one possible explanation of this entailment relation between the non-obligatoriness of number and an exclusive interpretation of plural morphology is the paradigm hypothesis, based on the account of the plural found in Sauerland et al. (2005). If a number paradigm is not formed, then the learner does not have a reason to leave the plural morpheme semantically unmarked. Since the semantic unmarkedness of the plural is what licenses the inclusive interpretation in languages like English, the inclusive interpretation would therefore not arise in languages without an obligatory number paradigm. An interesting extension of this would be to ask whether the inverse is also true. Specifically, is it the case that an obligatory number paradigm entails (the possibility of) inclusive interpretations of plural morphology? This is a question that we leave for future research.

In general, further work in this area is needed in addition to the artificial language learning study that we have reported here. One possible source of information could come from cross-linguistic first language acquisition work, which ought to test whether inclusive interpretations of plural morphology are ever hypothesized by children who are exposed to languages with non-obligatory number. Another source would be to test the same hypotheses in other domains to determine whether this is peculiar to number morphology or not (for example, Sauerland, 2008 has argued that some phi-features are semantically unmarked). A third source of information would involve in-depth cross-linguistic work in languages with optional plurals (for example, Wiltschko, 2008).

Acknowledgment

We would like to thank Kait Ayres, Karthik Durvasula, Brandon Grenier, Kenneth Hanson, Ashley Bartell Hesson, Taehoon Kim, Braden Leinbach, Alan Munn, John Sheets, and Heather Wiltse for their help in this project. We would also like to thank the audience at the Workshop on the Acquisition of Quantification held at the University of Massachusetts Amherst.


**Funding**

This work was supported by a Professorial Assistantship grant to Adam Liter from the Michigan State University Honors College, and an Undergraduate Research Initiative Grant to Adam Liter from the Michigan State University College of Arts & Letters.

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**References**


Appendix A

Vocabulary

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<tr>
<td>pino</td>
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<tr>
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<td>&quot;fish&quot;</td>
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<td>Transitive</td>
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<tr>
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<td>&quot;cover&quot;</td>
</tr>
<tr>
<td>beguku</td>
<td>&quot;circle&quot;</td>
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<td>&quot;NEG&quot;</td>
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Appendix B

Experimental design details

This appendix contains further detailed information about the experimental design and coding of some of the results, in addition to what is discussed in the main body of the article.

Training set descriptions

This section of the appendix discusses in detail how participants were taught the artificial language. The training sets for sessions 1–6 were Vocabulary and Grammar Basic Training sets; the training sets for sessions 8 and 9 were Negation Training sets.

Vocabulary and grammar basic training

During basic training, participants were given the opportunity to learn basic facts about Lablish including word order, the meaning of vocabulary items, and the word order of the language. The input given to participants was strictly controlled and balanced. Within each session, half of the sentences were transitive (one-quarter using “bounce”, one-quarter using “jiggle”), while half were intransitive (one-quarter using “circle”, one-quarter using “cover”). No sentences with negation were presented in the Basic Training sets.

The referents for the nouns (for both subject nouns and object nouns, independently and when combined as a group) were singleton pictures exactly half of the time and multiple-item pictures (between 2 and 4 entities) the other half of the time. Singleton pictures were paired with the singular-marked NP half of the time and with the bare NP half of the time; likewise, multiple-item pictures were paired with the plural-marked NP half of the time and with the bare NP half of the time. These statistics held true for each individual verb and for both subjects and objects independently of each other. For example, for the 32 sentences that used “circle” as a verb, 8 of the sentences used the bare NP as a subject noun for a singleton picture; 8 of the sentences used the bare NP as a subject noun for a multiple-item picture; 8 of the sentences used the singular-marked NP for a singleton picture; and 8 of the sentences used the plural-marked NP for a multiple-item picture. The same was true for objects in sentences with “cover” as a verb. Furthermore, for
transitive sentences, subject and object number use and number morphology were crossed, with equal numbers of subjects and objects having each type of morphology and number. For example, for the 8 sentences with a plural-marked NP as its subject, 4 of them had objects with a bare NP (paired with 2 singleton pictures, 2 multiple-item pictures), 2 had a singular-marked NP as object, and 2 had a plural-marked NP as object. Overall, the NPs in the input were therefore bare NPs exactly half of the time, plural-marked NPs a quarter of the time, and singular-marked NPs the remaining quarter of the time.

Figure 10. Training used to teach negation. Each negative statement was preceded by two positive statements and followed by one positive statement in order to provide the context for negation and the relevant contrast set. These four statements were separated from the next four statements by a time delay. The first row is an example of a set of sentences that teaches that negation can target the verb. It depicts a set of four sentences with an intransitive verb and scenes depicting a congruent or an incongruent action, depending on whether it is a positive or negative statement. In the second row we have an example of a set of transitive sentences that teach that negation can target the object.

Figure 11. An example of what a trial in the vocabulary and number morphology task looked like. The single-item picture in the top left corner of the screen was always the same animal as the multiple-item picture in the top right corner. The “both” option in the bottom left corner of the screen was provided so that participants could indicate that the NP they heard in this trial could refer to both the single-item and multiple-item pictures. The “neither” option in the bottom right allowed the participants to say that the NP that they heard did not refer to either of these pictures.
Negation training

As noted above, successful learning of the three morphological forms by participants is a separate issue from the interpretation that they will assign to the plural morphology under the scope of negation. In order to determine whether participants would assign a categorically exclusive interpretation to the plural morpheme (like in Korean), we taught participants negation in the artificial language. To our knowledge, our study is the first to teach negation in an artificial language learning task without overt instruction, and pilot studies showed that teaching negation without explicit instruction is challenging, likely for pragmatic reasons. For example, it is pragmatically odd to answer the question “What did you do today?” with “I didn’t read about an artificial language experiment”, unless that is somehow a plausible and salient option for what one did that day. In order to do that, training of negation included showing actions on the screen accompanied by positive sentences in order to create an appropriate discourse context to license negation with a contrast to positive sentences. Examples of how negation training proceeded are given in Figure 10. Participants were trained on both verbal negation and object negation (but, crucially, not number negation).

Each instance of the training of negation involved a set of four sentences. First, learners heard two affirmative sentences with a matching scene and then a negative sentence with the same scene from the previous sentence. For verbal negation, the training consisted of positive sentences with intransitive and transitive verbs accompanied first by a matching action in the screen and a negated sentence that differed from their positive counterparts due to the action being performed on the screen; object negation training consisted of sets of sentence and event pairings that featured a negated sentence that differed from its positive counterparts due to the identity of the object noun on the screen.

In order to create the maximal contrast between these sets of sentences to facilitate the learning of the negation particle, te, only the relevant aspects of the sentence or event were manipulated. For example, when an NP recurred from the first sentence in the set to the second sentence in the set, we did not change the number morphology that was associated with it. Because of this, the input given during Negation Training sessions was slightly less balanced than that for Basic Training. In particular, it was not possible to counterbalance the use of number morphemes across all sixteen nouns in the language. However, the ratio of bare nouns to nouns with number morphemes, singleton pictures vs. multiple-item pictures, and the independence of number morphology use on subjects and objects were all held constant and were identical to the ratios used in the Basic Training sets.

Details about testing and coding of results

This section of the appendix discusses further details about some of the tasks that participants were asked to do to test their knowledge and further details about how the results for some of these tasks were coded.

Argument structure task

Eight of the ungrammatical sentences had too many arguments (4 transitive, 4 intransitive); 8 of the ungrammatical sentences lacked a verb (4 transitive, 4 intransitive); and 8 of the ungrammatical sentences were missing arguments (6 transitive, 2 intransitive). Both of the missing-argument intransitive sentences had a number morpheme but lacked an associated noun. Similarly, two transitive sentences with missing arguments had a number morpheme in the subject position of the sentence but lacked a corresponding noun, while two had a number morpheme in the object position but lacked a corresponding noun. Finally, two missing-argument transitive sentences were simply lacking an argument entirely, without any number morpheme or noun. Whether the grammatical or ungrammatical sentence was presented first was randomized such that it was different for each participant in each session. Moreover, every attempt was made to make the sentences in the grammatical testing part of the experiment resemble ones from training, including keeping the ratios of bare nouns to nouns with number morphemes, singleton pictures vs. multiple-item pictures, and the independence of number morphology use on subjects and objects were all held constant and were identical to the ratios used in the Basic Training sets.

Vocabulary and number morphology task

Given the nature of the vocabulary and number morphology task discussed in the main body of the article, most, but not all, trials were informative as to whether participants had learned the basic nominal vocabulary items in Lablish. If a participant heard a noun that matched the pictures on the screen, choosing one of the pictures (either the singleton or the multiple-item picture) would at least indicate that they correctly understood the head noun, regardless of whether the number interpretation was correct. On the other hand, choosing the “neither” option would indicate that the participant had not correctly learned the meaning of the head noun. For trials where the noun did not match the pictures on the screen, choosing either the singleton or the multiple-item picture would indicate that the participant had not correctly learned the meaning of the head noun. However, in this case the reverse is not informative. Choosing the “neither” option does not necessarily indicate that the participant correctly understands the meaning of the head noun, since it is impossible to determine what off-screen option the participant may have had in mind when choosing “neither”. These uninformative trials were discarded and an average accuracy was computed on all informative trials by session across native languages. Figure 11 shows an example of the options that a participant might have seen in a given trial of the vocabulary and number morphology task.
With regard to what we can infer about participants’ interpretations of number morphology from this task, the results were coded as follows. A response type of “both PL & SG” means that the participant chose the “both” option, indicating that the NP they heard can refer to both a singleton and a plurality. A “PL” response means that the participant chose the multiple-item picture, indicating that the NP they heard just refers to a plurality. Last, a “SG” response means that the participant chose the singleton picture, indicating that the NP they heard just refers to a singleton.

**Verb and object negation task**
As with other testing portions of the experiment, trials were balanced as much as possible for use of each verb, for number morphology use and plurality, and to approximately make appearance of each noun in each argument position equal.

**Appendix C**
This appendix contains summaries of each of the models we ran in this experiment, including intercepts.

**Argument structure grammar model**

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**Vocabulary use model**

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**Number morphology interpretation model**

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**Free response model**

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### Verb negation model

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### Basic object negation model

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