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Semantic and morphophonological productivity in the Kĩĩtharaka gender system: A quantitative study

Patrick Kanampiu, Center for Language Evolution, University of Edinburgh; Tharaka University, Kenya, patrick.kanampiu@tharaka.ac.ke

Alexander Martin, Center for Language and Cognition, University of Groningen, alexander.martin@rug.nl

Jennifer Culbertson, Center for Language Evolution, University of Edinburgh, jennifer.culbertson@ed.ac.uk

Nominal classification systems are characterized by diverse and sometimes complex gender assignment rules that interact in dynamic ways. The specifics of how gender assignment works can vary widely from language to language. Nominal classification systems of Bantu languages in particular have been the subject of long-standing debate. Traditional accounts of gender assignment are based principally on abstract semantic features which have been found to be unreliable in at least some present-day Bantu languages. Such analyses, in addition to relying on arbitrary sets of semantic features, are problematic, since they provide no clear definition of what it means for a particular feature to be productive. Here we follow a more recent approach, using corpus data to evaluate productivity. We compiled a corpus of 2,327 Kĩĩtharaka nouns, each coded for a set of semantic and morphophonological features. We then used the Tolerance Principle (Yang 2016) to measure the predicted productivity of each feature. Our results indicate that morphophonological features are highly productive in Kĩĩtharaka. However, of the tested semantic features, relatively few were predicted to be productive, including *Human*, and some evaluative features (*Augmentative*, *Pejorative*, *Diminutive*). The feature *Human* is in fact only productive for a specific subset of nouns, indicating a possible interaction between features. We discuss why this might be, and highlight the implications of this approach for Kĩĩtharaka, and for the study of gender assignment in Bantu more broadly.

1 Introduction

In many languages, nouns are categorized into classes on the basis of the agreement patterns they trigger on nominal modifiers and in some cases the verb (see, e.g., Hockett 1958; Dixon 1986; Corbett 1991; Aikhenvald 2006; Wechsler 2009: and others). This phenomenon is known as grammatical gender and includes the social gender or sex-based grammatical agreement systems commonly found in Indo-European languages (characterised by 2–3 genders comprising masculine, feminine and neuter) along with noun class systems (which include at least 2, to more than 20 nominal classes). The agreement the noun triggers is in most cases associated with the form of the noun or its semantic features (see e.g., Lang 1976; Corbett 1991; Konishi 1993; Katamba 2003; Irmen & Kurovskaja 2010; Aikhenvald 2012). In French for instance, nouns with the suffix *-ette* are typically feminine (e.g., *camionnette* "van" takes the feminine definite determiner *la*); by contrast nouns ending in *-on* are mostly masculine (e.g., *le ballon* "the ball"). At the same time, nouns which refer to referents with female or male social gender also almost categorically trigger feminine and masculine grammatical agreement, respectively. Despite these form-based and meaning-based cues to gender in French, there are typically many exceptions. For instance, *le squelette* "the skeleton" takes the masculine determiner despite ending in *-ette,* while *la maison* "the house" takes the feminine determiner despite having ending in the *-on* typically associated with the masculine nouns. Likewise, a noun like *la personne* "the person" takes feminine agreement even when referring to male individuals.

These kinds of exceptions, found in French and in almost all other languages with grammatical gender, have raised theoretical and empirical questions as to how language learners and users form generalizations about these kinds of systems (see e.g., Karmiloff-Smith 1981; Zapf & Smith 2007; Coppock 2009; Gagliardi & Lidz 2014; Björnsdóttir 2021: among many others). For example, a number of theories have been proposed to explain what makes a given generalization *productive* in the face of exceptions. Specifically, theories of morphological productivity are designed to predict when a rule (e.g., that nouns with a given form trigger a given agreement pattern) can be applied to novel lexical items (see, e.g., Aronoff 1976; Baayen 1993; Bauer 2001; Yang 2016). This general approach, which we follow in the present paper, assumes that users of a language may memorise the gender or class of some (or all) nouns (see e.g., Bauer 2001), but that they also have knowledge of productive cues, like aspects of nominal form and meaning, which they can use to predict the class of a new noun. This idea is supported by experimental studies which show consistent patterns of class assignment of novel nouns in the presence of such cues, even in relatively young children (e.g., Karmiloff-Smith 1981; Pérez-Pereira 1991; Gagliardi & Lidz 2014). It can also be revealed in patterns of loanword adaptation. For example, a well-known example is the Swahili word *kitabu* (book), borrowed from Arabic into a gender class based on its initial *ki* which matches a nominal prefix in Swahili. In Kîîtharaka, similar examples are *mûciki* (music), *mûgate,* (bread), and *mûbira* (ball), all loanwords

borrowed into a single class based on the initial prefix and showing the agreement pattern of that class.[1]

Here we make use of a well-known theory of morphological productivity, the Tolerance Principle (Yang 2016). The Tolerance Principle is essentially an evaluation metric which can be used (e.g., by language learners) to determine when to generalise a potential rule to novel items and when not to. The Tolerance Principle provides a threshold number of exceptional cases, past which a rule is predicted not to be productive. For instance, according to the Tolerance Principle, a learner of English whose lexicon includes 7 verbs forming the past tense with the *-ed* inflection and 3 exceptional cases (i.e., irregular verbs) should generalise the *-ed* rule: for a set of 10 items the Tolerance Principle specifies a threshold of 4 exceptions. The theory stipulates:

> Let a rule R be defined over a set of N items. R is productive if and only if e, the number of items not supporting R does not exceed θN. Thus, $e \leq \theta N = N/\ln(N)$
>
> (Yang 2016: 64; 2018: 1)

θN here stands for the tolerance threshold, which is based on a theory of lexical search and processing (Sternberg 1969; Foster 1976). Two values are important for calculation of the tolerance threshold— N (the number of items that follow the rule) and e (the number of items that do not follow the rule, i.e., exceptions). The formula $N/\ln(N)$ (total number of items divided by the natural logarithm of the total number of items) thus determines the number of exceptions past which a rule is not predicted to be productive.

The theory is based on several assumptions. First, that the distribution of lexical items follows Zipf's law (Zipf 1949). Zipf's law states that the rank of a word in a naturally occurring corpus is inversely proportional to its frequency. Items in the lexicon are therefore considered to be listed in order of frequency, with the most frequent and the least frequent appearing first and last, respectively. Secondly, access to these lexical items during lexical processing is assumed to take place in a frequency-sensitive serial search fashion, following earlier work by Sternberg (1969) and Foster (1976). Items are frequency ranked and accessed starting with the highest ranked item, proceeding through the lexicon to the lowest. If there are exceptions, they are also evaluated separately, in order of their frequency. This follows the well-known Elsewhere Condition (Kiparsky 1973; 1982), which states that exceptions to a linguistic rule are considered to be listed and evaluated first before the rule is applied.

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[1] We remain agnostic here as to what degree adult users of a language might actively use these learned associations to derive agreement patterns for known nouns during normal comprehension and production. This is assumed to be the case by e.g., Yang (2016) where the focus is on generalisation during learning. However, in theories of gender and the mental lexicon, gender is often assumed to be a stored feature of known nouns (e.g., Harris 1991; Clahsen et al. 2001; Alexiadou 2004; Gor 2017; Ellingson Eddington 2022), and there is evidence that speakers of Zulu for example access the lexicon to determine the gender even when productive rules apply (Zeller et al. 2022).

The third assumption is that language learners have at their disposal two possibilities—they can generalise (hence apply a rule for the majority of the items on the basis of positive evidence, and additionally list only the exceptions), or they can memorise all the lexical items individually. The choice depends on the cost of processing. The former option will use a function of time, $T(N, e)$, to check off all the exceptions before applying the rule whereas the latter (where all words are treated like exceptions), will require a different function of time, $T(N, N)$, to process). Yang (2016), using a model lexicon size of 100 words, shows that the processing time between two grammar options achieves equity when $e = 22$, beyond which it becomes more costly to generalise (pp. 60–65). In this case, 22 is the tolerable number of exceptions required for a rule to be productive in a lexicon of 100 words. The learner thus applies an evaluative metric (the Tolerance Principle) to determine what the tolerance threshold is. Both Zipf's law and the Elsewhere condition are fundamental in the derivation of the formula for calculating this threshold. The threshold is a probabilistic expression of time complexity in accessing a random i^{th} ranked word, which is $1/_{i}H_N$, where H_N is the N^{th} harmonic number (see, e.g., Yang 2016; 2018: for additional details on calculating this probability and the discussion therein). The time complexity of accessing all the nouns *(N)* in the non-productive rule option is therefore N/H_N. For mathematical efficiency, H_N can be substituted with the natural logarithm, $ln(N)$, because the two are known to approximate, thus $N/H_N \approx N/ln(N)$. Hence, productivity depends on computational efficiency, calculated by comparing the time involved in processing linguistic items in a lexical search process. The Tolerance Principle makes testable predictions about what generalisation learners will form, and how language users represent and generalise their knowledge. It has been used to study a wide variety of empirical phenomena (e.g., Coppock 2009; Yang 2016; Emond & Shi 2020; Björnsdóttir 2021; Li & Schuler 2023). Let us now consider why an evaluation metric such as the Tolerance Principle is critical for studying nominal classification systems characterised by multiple assignment rules, and many exceptions, as found in Bantu languages.

1.1 Theoretical approaches to the study of gender and noun classes in Bantu

Bantu languages in particular have drawn much attention for the complex behaviour of their nominal systems. One major locus of debate revolves around what motivates the categorization of nouns into classes in the systems found in the languages of this large family. All Bantu languages are characterized by a set of prefixes that attach to stems (e.g., *mû-rîmi*, "farmer", *kî-baŋga*, "machete" [Kîîtharaka]) in addition to prefixal agreement markers which appear on dependent words (e.g., demonstratives, adjectives, possessives) (see e.g., Bleek 1862; Guthrie 1948; Corbett 1991; Carstens 1991; Katamba 2003). These nominal prefixes have sometimes been treated as class markers, i.e., indicating the class of the noun and in turn triggering agreement on dependent words. However, they are in fact very similar to nominal endings like *-ette* found in French (or *-o/-a* in Spanish): a given prefix tends to be *associated* with a given agreement pattern (see e.g.,

Harris 1991: on why the Spanish *-o* and *-a* should not be considered gender markers per se but as predictors of gender). For this reason, we treat the ubiquitous nominal prefixes in Bantu as potential predictors or cues to agreement class and/or gender. Examples of noun class agreement in Kîîtharaka are given in (1), (2) and (3).[2] Example 3 illustrates a case, similar to the French exceptions provided above, where the nominal prefix (class 9) and the agreement prefix (class 1) are not aligned. In this case, therefore, the gender of the noun cannot be predicted based on the form of the noun.

(1) rû-rara rû-ûra rû-tuune
11-palm.leaf 11-DEM.DIST 11-red
'That red palm-leaf'

(2) gî-kombe kî-mwe kî-nene
7-cup 7-one 7-big
'One big cup'

(3) n-dagitaarî w-a mw-ekûrû
9-doctor 1-CONN 1-female
'A female doctor'

Just as in other gender systems, like French, both *form* (the morphophonological shape of the noun) and *meaning* have been argued to play a role in Bantu gender assignment systems. Early research argued for a semantically arbitrary system, where class is determined purely based on noun prefixes (e.g., Krapf 1850; Bleek 1862; Meinhof 1906: among others). However, later influential research argued that noun classes are actually associated with semantic regularities (e.g., Guthrie 1967; Richardson 1967; Welmers 1973; Zawawi 1974). This motivated a reconstruction of Proto-Bantu, placing semantics at the centre of its nominal classification system (e.g., Givón 1971b; Givón 1971a; Welmers 1973; Denny & Creider 1986). For example, Denny & Creider (1986) suggested a two-way, semantically-motivated system for count and mass nouns in Proto-Bantu. Count nouns were argued to be broadly categorised on the basis of *kind* (i.e., animate vs. inanimate) and *configuration* (i.e., solid objects versus objects with a clear outline, edges, or distinct inside and an outside). Mass nouns were argued to be categorised based on whether they are *cohesive* or *dispersive*.

However, as in many complex nominal systems, descriptions of Bantu nouns classes based purely on noun form or on semantics are problematic in several respects. First, similar to the French examples given above, nominal prefixes in Bantu languages do not always deterministically align with agreement patterns. In these cases, researchers typically consider

[2] In Kîîtharaka and several other Bantu languages, the vowel <û> [o] is realized as <w> before a vowel, with the exception of <u>.

that agreement, not the noun form, indicates its class/gender (see e.g., Herbert 1985; Corbett 1991). That is, the agreement pattern a given noun will take is not always straightforwardly determined from the nominal prefix (see e.g., Msaka 2019: for how the prefix-based system fails to characterise the Chichewa nominal classification system). We will further illustrate this using Kîîtharaka data in the next section. Secondly, there are many nouns in Bantu languages without overt prefixes that nonetheless trigger agreement on nominal dependents. This complicates a purely form-based system (though of course positing something like a null prefix, or a default class is possible). At the same time, the productivity of semantic rules in Bantu nominal systems has been a subject of rigorous debate, with some scholars (e.g., Richardson 1967) arguing that the semantic foundation of the Proto-Bantu system is empirically unverifiable, and others concluding that it is only relevant for animate/human nouns (see, e.g., Crisma et al. 2011; Msaka 2019). Regardless, it is clear that, like for nominal prefixes, the semantic features of nouns do not always perfectly align with the agreement patterns they take.

Typological studies of nominal classification systems have, nonetheless, highlighted the fact that in most complex gender systems, both semantics *and* morphophonology interact to determine a noun's gender, i.e., the agreement class it belongs to (see e.g., Corbett 1991; Di Garbo 2014; Corbett & Fedden 2016; Güldemann & Fiedler 2019: and others). As such, a nominal classification system can be considered as having both a set of *agreement classes* and a set of *nominal form classes* (Güldemann & Fiedler 2019). Agreement classes are comprised of nouns that share similar agreement across all agreement targets. For instance, the Kîîtharaka noun phrases *muntû û-mwe*, "one person" and *antû ba-îrî*, "two people" indicate that the stem *-ntû* takes agreement *û-* in singular and *ba-* in plural. Pairing of nouns on the basis of singular and plural agreement indicates the abstract *gender* of a noun called *target gender* in (Corbett 1991: et seq.). In this way, gender can be seen as an abstract feature of a stem, stored in a speaker's mental lexicon. On the other hand, nominal form classes are based on shared morphophonological attributes of *nouns*, e.g., nominal prefixes. The Kîîtharaka nouns *î-thaga*, "metal" and *î-rema*, "tent" belong to the same form class, while *ma-thaga* "metals" and *ma-rema* "tents" belong to another one. Pairing nouns on the basis of singular and plural nominal forms gives rise to what has been called *deriflection classes*—the morphophonological equivalent of gender (Güldemann & Fiedler 2019).[3]

[3] Form classes which constitute deriflection in Bantu are equivalent to what has been called inflectional classes in languages like Russian or Icelandic (see e.g., Bjarnadóttir 2012; Madariaga & Romanova 2022; Markússon 2023). Although agreement classes may be sufficient to describe the gender system of Bantu, distinguishing gender from deriflection highlights aspects of the system that differ from traditional descriptions of Kîîtharaka and other Bantu languages, based on the nominal prefix alone. Of course, the distinction between gender, inflection, and deriflection is a complex issue, and inflectional class status has been widely debated cross-linguistically (see e.g., Corbett 1991; Harris 1991; Carstairs-McCarthy 1994; Bonami & Beniamine 2016; Stump 2016). Here, we treat them as potential cues to gender assignment (see e.g., Corbett 1991; Harris 1991; Kanampiu et al. 2025). How they are acquired and represented by speakers, we leave to future research.

Recent research on Bantu nominal classes has used corpus evidence—in particular, lists of nouns along with their nominal form and agreement classes—in order to quantitatively evaluate how both morphophonological and semantic cues together can predict the gender of a noun (e.g., De Schryver & Nabirye 2010; Ngcobo 2010; Taljard & De Schryver 2016; Msaka 2019). However, while these analyses increase the reliability of the data on which theories of nominal classes are based, there has not yet been research applying any specific quantitative theory of productivity to a Bantu gender system.

Therefore, the goal of this paper is first to characterise the nominal classification system of Kîîtharaka, in terms of both **gender** and **deriflection**. We will then endeavour to determine whether morphophonological features of nouns (i.e., nominal prefixes) and particular aspects of noun meaning (i.e., noun semantics) are productive cues to gender, i.e., to the agreement patterns that a given noun displays. To do this, we will use the Tolerance Principle, described above, which allows us to evaluate the empirical data we have from a large list of Kîîtharaka nouns, and make predictions about productivity in the face of exceptions in this complex system. We introduce the Kîîtharaka nominal classification system and its particular complexities in the next section.

1.2 The Kîîtharaka nominal classification system

Kîîtharaka [Bantu, E54] is spoken in Tharaka Nithi County in Kenya by about 215,000 Atharaka people who mainly live in Tharaka North, Tharaka South and Chiakariga Sub-Counties (KNBS 2019: 424).[4] The language is relatively understudied, though there is some previous work describing its nominal system (see e.g., Bible Translation & Literacy 1993; wa Mberia 1993). In a brief description, wa Mberia (1993) for example, characterises Kîîtharaka as having 17 "noun classes", based on the nominal prefix, most of which can be organized as singular/plural (deriflection) pairs as is traditional in the Bantuist literature. Notably, he also outlines a set of potential semantic features, such as cultivated fruits, shrubs and trees, birds, insects, human beings, etc., that characterize the noun system in Kîîtharaka.

As with many semantic accounts of noun class systems in Bantu, this characterisation is largely based on subjective impression or intuition. Further, wa Mberia (1993) notes that there are many exceptions in each class—i.e., nouns which do not share the relevant semantic feature(s). Many of the semantic features he mentions are also invoked for multiple classes. As discussed above, exceptions are common in these types of systems, and that is part of what makes quantitative evaluation using a theory of morphological productivity important. Therefore, we will return to these issues below. **Table 1** shows the kind of description of Kîîtharaka given by wa Mberia (1993), with a list of the class numbers for reference. The table includes the nominal prefix

[4] A part of the population living in Maara and Meru South Sub-Counties, and another population mainly occupying Tharaka Sub-County in Kitui County are also considered to speak Kîîtharaka.

Class number	Nominal Prefix	Agreement Prefix	Sample nouns and agreement	Gloss
1	**mû(u)-**	û-	muntû û-mwe	one person
(1a)	Ø	û-	chibû û-mwe	one chief
2	a-	ba-	antû ba-îrî	two people
2a	Ø	ba	chibû ba-îrî	two chiefs
3	**mû(u)-**	û-	mûtî û-mwe	one tree
4	mî-	î-	mîtî yî-îrî	two trees
5	Î-	rî-	îgûna rî-mwe	one baboon
6	ma-	ma-	magûna ma-îrî	two baboons
7	k(g)î-	k(g)î-	gîkaabû kî-mwe	one basket
8	I-	bi-	ikaabû bi-îrî	two baskets
9	**n-/Ø-**	î-	ngûkû î-mwe	one chicken
10	**n-/Ø-**	i-	ngûkû ci-îrî	two chickens
11	rû-	rû-	rûrigi rû-mwe	one thread
10	n-	i-	ndigi ci-îrî	two threads
12	k(g)a-	k(g)a-	kaana ka-mwe	one child
13	tû-	tû-	twana tw-îrî	two children
(14)	û-	bû-	ûcûrû bû-bû	this porridge
(15)	**k(g)û-**	k(g)û-	kûruga gû-kû	this cooking
16	(b)a-	a-	(b)antû a-mwe	one place
17	**k(g)û-**	k(g)û-	gûntû kw-ingî	many places

Table 1: Kîîtharaka noun classes, as described by wa Mberia (1993). Horizontal lines delimit singular/plural pairs, with corresponding nominal and agreement prefixes. Sample nouns with agreeing numerals are also provided. Note: (i) Some nouns in classes 14/15 (in parentheses) take class 6 agreement, see below for additional discussion; (ii) Parentheses in class 16 prefix mark optional use of the initial bilabial fricative (B) across speakers.

associated with each class, and an example noun with agreement (on a numeral) in each class.[5] (vowels), prosthetic consonants [y] and [c] are inserted before a stem that starts in a vowel, to satisfy the phonological constraint that two distinct vowels cannot appear at the beginning of a word.

[5] Notes: (i) The back vowel [o] orthographically presented as *û* and mid-front [e] written as *î* are realised as *w* and *y* before another vowel. (ii) On class 2 and 10 plural agreement: because the agreement prefixes are *î-* and *i-*, respectively

Notably, **Table 1** obscures a number of more complex properties of the Kîîtharaka nominal system. First, some classes are treated as distinct despite having identical nominal prefixes—classes 1 and 3, 9 and 10, 15 and 17—unexpected if classes are defined on this basis alone. There is evidence from agreement that the class pairs 1/2 and 3/4 should be distinguished, but this is not done in all cases. For example, classes 2 and 2a are not treated as fully distinct, and many classes which share the same agreement prefix are not collapsed. This reflects the problem of combining the two different notions of gender and deriflection discussed above (as noted by Güldemann & Fiedler 2019). Moreover, what is shown here is the *typical* patterning of nouns in the system. In fact, there is quite a bit of variation. For example some nouns with the typical class 7 prefix *k(g)î-*, class 9 prefix *n-* or with no prefix actually take class 1 (*û-*) agreement.[6] Similarly, nouns in various nominal form (nominal prefix-based) classes e.g., class 1, 7, 9, take the plural agreement prefix *ma-*, the pattern that is normally used with class 5/6 nouns (see **Figure 1**, for an illustration of this class mismatch and also Section 2.2 for how such cases are accounted for in our approach).

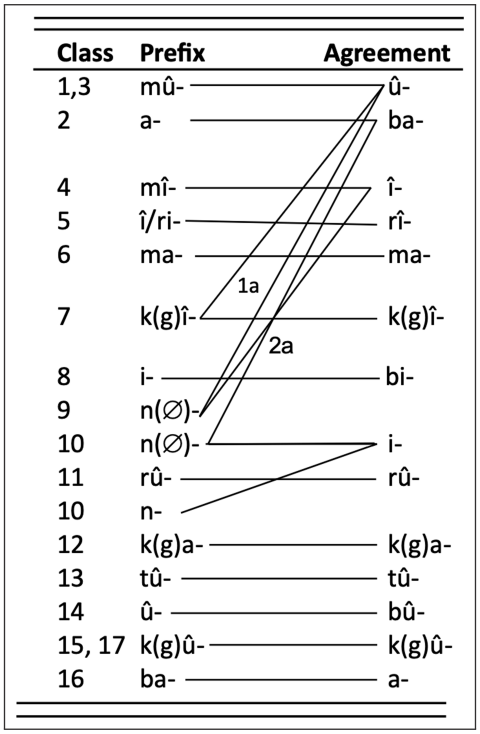

Figure 1: Prefix-agreement mismatch in Kîîtharaka. Here, we reorganise the traditional class number notation to collapse nouns that share a nominal prefix. Nouns with the same prefix can take different forms of agreement.

[6] Note that class 1 agreement on the verb is usually *a-*, but here we focus on the agreement on the nominal dependents, which is usually *û-*.

Second, although it appears that nouns in classes 14 and 15 do not have plural counterparts, this is not entirely correct. For example, the bulk of nouns in class 15 are derived from verbs (specifically infinitives) but there are also some body parts e.g., *gûtû* "ear", *kûgûrû* "leg" which take class 15 agreement in the singular and class 6 *ma-* agreement in the plural.[7] Similarly, class 14 includes mainly abstract nouns but there are some others as well, which either take *ma-* agreement, if interpreted as collective plural, and otherwise *n-* plural agreement.

To capture these patterns, we therefore describe Kîîtharaka using both nominal form and agreement classes, which respectively correspond to a deriflection and a gender system (Güldemann & Fiedler 2019). We leave aside here nouns that do not have plural or singular versions either because they are singulare/plurale tantum or because they do not make number distinctions. We treat such nouns as *transumerals* following Güldemann & Fiedler (2019), hence outside the gender system, together with infinitives. We therefore consider the agreement triggered by such nouns to constitute general agreement classes (GAC) (see Msaka 2019: for a similar treatment of infinitives, locatives and CPs). This results in 8 deriflectional and 8 gender categories for Kîîtharaka, shown in **Table 2**. Following the established tradition in Bantu (see

Gender	Agreement class prefixes	Traditional class number pairs
A	û—a	1/2
B	û—î	3/4
C	rî—ma	5/6
D	k(g)î—k(g)î	7/8
E	n—n	9/10
F	rû—n	11/10
G	k(g)a—k(g)a	12/13
H	a—k(g)û	16/17
GAC	bû—bû	14
GAC	k(g)û—k(g)û	15
GAC	all transnumerals (TransN)	

Table 2: Genders of Kîîtharaka, based on pairing of singular and plural agreement form classes. The agreement indicated is in line with the traditional accounts. **Note:** class 15 and 17 plural agreements are the same. Henceforth, we will refer to both as class 15. The singular agreement of classes 1 and 3 are also the same orthograhically, but in speech, the class 3 agreement is articulated with a higher tone. For this reason, we retain the distinction in our analyses.

[7] wa Mberia (1993) notes these exceptional nouns but does not classify them into any class. Under a Tolerance Principle approach, these are cases that won't be productive for any rule, and are thus likely acquired through lexicalization/memorization.

e.g., Carstens 1991) we label the genders as presented in **Table 2**. Diagrammatic representations of the deriflection and gender system are shown in **Figure 2**.

An obvious observation from **Figure 2** in reference to **Table 1** is that class 17 has disappeared and class 3 is expressed in the same way as class 1—both take the agreement *û-* in singular. We have only come across one exceptional case—in the context of numeral 1 "one", the class 3 agreement is articulated with a high tone. For the purpose of comparisons with the set tradition in these analyses, we do not dissolve these classes but position them together to show that they share similar agreement patterns. From this analysis, Kîîtharaka can be characterized as having a "crossed" gender system according to the terminology of Corbett (1991), with variable convergence at classes 6 and 10. Class 6 has elsewhere in the Bantu literature been argued to function as a default plural (see e.g., Bosire 2006; Ström 2012; Fuchs et al. 2018; Fuchs & van der Wal 2022). However, outside of regular class 5 nouns, many of the other nouns that pluralise in this class have a collective interpretation in the plural. Another observation is that

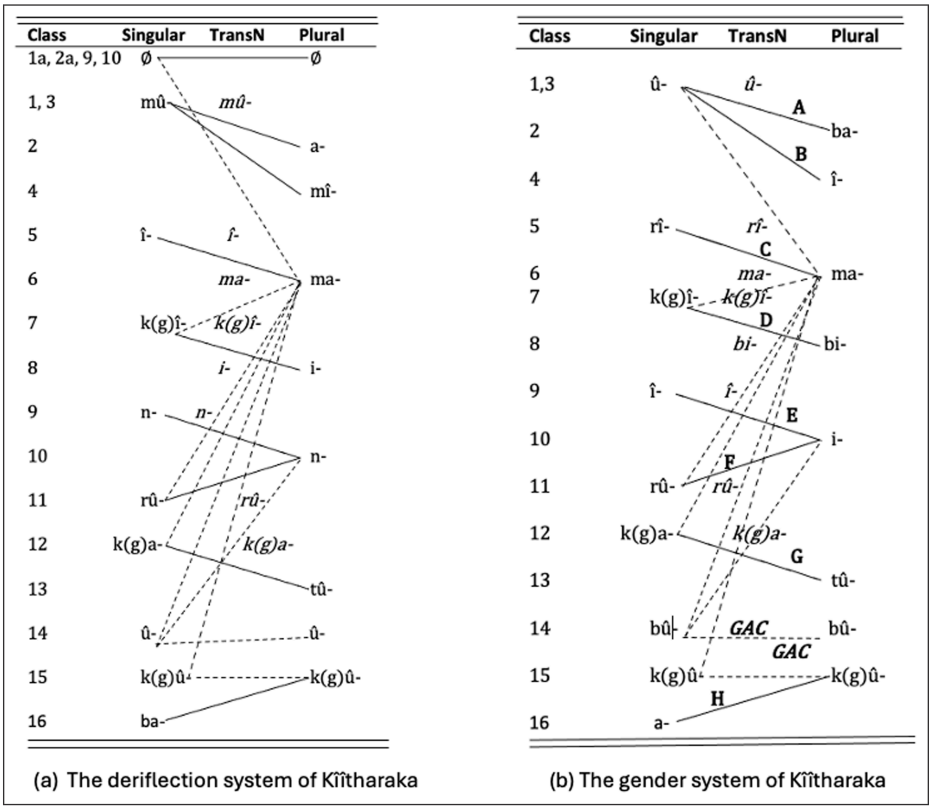

Figure 2: The gender and deriflection systems of Kîîtharaka, including an illustration of possible variation. Note: The dotted lines represent non-deriflectional/gender paradigms used with nouns which can appear variably in different classes. For example, when the plural of a noun is treated as collective, or when special humans that typically appear in class 9 are treated as normal humans or transnumerals.

the deriflection system lumps the prefix-less nouns together, but these nouns belong to different agreement classes, hence genders. These prefix-less nouns (characterized as belonging to class 1a/2a or 9/10 in the traditional prefix-based system) belong to class 1/2 or 9/10 on the basis of agreement.

A number of these observations point to the fact that, as in other Bantu languages, some of the nominal prefixes of Kîîtharaka can be characterised as multifunctional—they function as the primary prefixes for a particular set of nouns, but other nouns can also take these prefixes (either alone, or in combination with their primary prefix) in order to express particular evaluative meanings. For example, the prefix *k(g)î-* is typically associated with class 7 (Gender D) nouns. However, a noun from gender A (e.g., *mû-ana*) can take the prefix (as in *kî-ana*) to derive a pejorative meaning "ugly child". In the Kîîtharaka system, class 12/13 can be used to express diminutive meaning, class 5/6 can express augmentative meaning while pejorative meaning is associated with class 7/8. Prefixes used with this more overtly derivational function are sometimes referred to as secondary noun class prefixes (see e.g., Fortune 1970; Dembetembe 1995; Harjula 2006; Déchaine et al. 2014; Di Garbo 2014; Dube et al. 2014; Taraldsen et al. 2018: and others), or as multifunctional morphemes whose particular meaning is dependent on context (as in Di Garbo 2014; Msaka 2019). In many Bantu languages the primary nominal prefixes for the noun classes with loose semantics (i.e., classes which appear to contain nouns from diverse semantic domains), like class 5/6, and 7/8, have apparently been "recycled" to express evaluative meaning (Déchaine et al. 2014; Di Garbo 2014; Msaka 2019). It is however important to note that even in their recycled use, these evaluative prefixes typically stack on the primary prefixes and obligatorily control agreement, thus behaving like the primary counterparts.

An important empirical question is how to accommodate these productively derivational elements within a noun class or gender system in a way that accounts for their unique morphosyntactic properties. Some researchers treat these prefixes as theoretically identical to other prefixes, i.e., they bear noun class features (see e.g., Mufwene 1980; Myers 1987; Carstens 1991; Bresnan & Mchombo 1995; Maho 1999). Others attribute the multifunctionality to different syntactic positions that the two sets of prefixes occupy (see e.g., Déchaine et al. 2014; Fuchs & van der Wal 2022). We will adopt a similar approach here and leave the issue for future research.

To summarize this section, we have here described the major trends in the Kîîtharaka noun class system. The focus here was the relationship between gender (as defined by singular and plural agreement pairs) and deriflection (as defined by singular and plural noun class prefix pairs). We have also highlighted the fact that these two systems do not perfectly match up: there are nouns in particular agreement classes that do not share a nominal prefix (and vice versa). In the next section, we bring in semantic features, which share this property: there are potential correlations between these features and gender, but there are also clearly exceptions. We then

assess the degree to which nominal prefixes and semantic features *predict* Kîîtharaka gender using the Tolerance Principle as an evaluation metric.

2 Methodology

2.1 The corpus

As noted above, the Tolerance Principle is a theory of productivity in learning, and thus perhaps the most appropriate corpus from which to derive predictions for Kîîtharaka might be a corpus of child-directed speech (CDS) (Yang 2016; 2018). However, it has been shown that in the absence of such a corpus, common nouns can be sampled from an adult corpus (e.g., the most frequent 1000–2000 words) to represent the kinds of nouns children are likely to encounter in the acquisition process (see e.g., Yang 2018; Kodner 2020). Here we use two adult language corpora: a large extract from the Kîîtharaka translation of the bible, and the Summer Institute of Linguistics (SIL) African Wordlist. While frequency data would in theory be available for the bible sub-corpus, this alone may not represent the kind of nouns children come across. The SIL African wordlist sub-corpus therefore supplements this, comprising the most common nouns in an African context.[8] A total of 45,844 word tokens (9,656 word types) was extracted from the Kîîtharaka bible (Bible Translation & Literacy 2019). This text source was chosen because it is the only existing Kîîtharaka corpus. As it was recently translated (published 2019), the bible text can be considered a reasonable source of synchronic language data. The bible text used here includes sections from both the old and new testament to increase type variation across the corpus (see Evans 2007). Chapters that mainly contain a list of proper names (as in Numbers and Chronicles) were excluded. Around 60% of the corpus is from the old testament and the remaining 40% is from the new testament. The second part of our corpus, the SIL African Wordlist, was translated by the first author (see Snider & Roberts 2004). The list contains names of common things like local birds, trees, animals, insects and other phenomena that may have been missing from the bible text.

2.2 Corpus processing and coding

The bible text was uploaded to lancsbox, a corpus software tool developed by Lancaster University (Brezina et al. 2020). We then extracted a word list which enabled us to manually identify nouns (see Ngcobo 2010 for a similar approach). Further processing of the word list was done so that there was only a single lemma form for each noun retained. Nouns were manually extracted from this word list. This resulted in a total of 901 nouns from the bible text. Of the 1,622 translatable words in the SIL Comparative African Word List (between items 1.1 and 11.1),[9] 1,426 noun types

[8] See section 3.2 where we verify that the predictions of the entire corpus also hold for just this corpus.

[9] Verbs were translated as infinitives as this was the only way to ensure noun class 15 was represented. 37 words were not translated as they denoted things that lacked a native equivalent.

were not already present in the bible corpus. Together the total noun corpus therefore consists of 2,327 nouns. Each noun was evaluated against a set of semantic features collected from previous work on Kîîtharaka specifically and Bantu more generally (see, Creider 1975; Denny & Creider 1986; wa Mberia 1993).

The complete set of semantic features is shown in **Table 3** along with the classes for which these features are expected to be potentially relevant. All the nouns in the corpus were coded for all features, and we tested the predicted productivity of each feature for each agreement class.[10] The corpus can be accessed on the Open Science Framework (OSF) using the link: https://rb.gy/ows7r1.

Additionally, morphophonological features—the set of all nominal prefixes in Kîîtharaka, including the null prefix—were also identified and coded for in the same manner as semantic features. The prefixes coded for and their respective expected classes are shown in **Table 4**. As with the semantic features, all nouns were coded for each prefix, and we tested the productivity of each prefix for each agreement class.

In addition to these features, each noun was coded for agreement class and gender based on the observed patterning of singular/plural agreement classes. For example, there are 423 nouns that take *û-* (class 1,3) agreement in the singular. 196 of these take *ba-* (class 2) agreement in the plural, hence are classified as **Gender A**. 208 take *î-* (class 4) agreement hence are coded as **Gender B**. Of the remainder, 11 made no number distinction—coded as transnumeral (TransN) and 1 takes a class 10 prefix and respective agreement, hence placed in Gender D. There were some cases where the same noun lemma occurred with different singular agreement patterns in the corpus (i.e., across different instances in the bible). We dealt with these as follows: in cases where a lemma appeared with two alternative singular agreement prefixes, e.g., *nkoma yathi* (class 9 agreement) and *nkoma athi* (class 1 agreement) "(the) devil went", we coded the noun as in the agreement class matching the nominal class prefix.[11] Cases of alternative plural in class 6 were set as noted above.[12] As far as we can tell, this kind of variation is not predictable from any obvious contextual feature. However, it may be that alternative agreement patterns reflect speaker evaluation—for example whether they want to treat the referent as more human-like, or

[10] The locative feature was not coded for since this class has diachronically diminished in Kîîtharaka and is made up of only two nouns (one each for singular and plural) (see also Fuchs et al. 2018).

[11] There were 5 cases of this kind among all nouns in the bible corpus. As noted in Section 1.2, Kîîtharaka has highly regular singular-plural class mappings. There are some additional cases when plurals can be perceived as collective, which gives rise to a certain amount of variation. For example the class 6 prefix *ma-* may alternate with the regular plural prefix (see, e.g., Contini-Morava 2000: 8,16; for such cases in Kiswahili.)

[12] The *ma-* prefix is probably generally used to express collective plural. But in other Bantu languages, this prefix has also been argued to be a default plural (see, e.g., Bosire 2006; Ström 2012; Fuchs & van der Wal 2022). For the purposes of this paper, we will not treat nouns that can have *ma-* in the plural as separate genders. But this could be re-assessed in future research.

Semantic Feature	Expected Gender	Agreement class pairs
Human	A	1/2
Tree	B	3/4
Dispersive mass	B	3/4
Extended	B	3/4
Spread	B	3/4
Cohesive mass	C	5/6, 14
Augmentative	C	5/6
Plant part	C	5/6
Fruit	C	5/6
Round	C	5/6
Artefact	D	7/8
Pejorative	D	7/8
Plant	D	7/8
Manner	D	7/8
Animal	E	9/10
Loan	E	9/10
Narrow	F	11/10
Wavy	F	11/10
Diminutive	G	12/13
Abstract/Concrete	GAC	14, 14/10, 14/6
Derived	GAC	15
Infinitive	GAC	15

Table 3: Semantic features tested, along with the class(es) expected to have this feature potentially associated with them. Note: The term *Dispersive mass* refers to substances composed of particles that can be dispersed, such as flour and soil. *Extended* describes dimensions that are relatively long. *Spread* is used for things that extend in two dimensions in space, such as a mat. *Cohesive mass* denotes substances that stick together, like liquids. *Plant part* includes parts of a plant other than fruits, such as flowers or leaves. *Artefacts* are small man-made objects that can be held by hand, such as tools. *Pejorative* applies to terms with negative social connotations, for example, "ugly-looking". *Manner* nominals, mainly derived from other nouns to indicate a method or way of doing things e.g., speaking "like people of Tharaka". *Narrow* describes thin and extended-looking things, and *Derived* refers to other derived nominals apart from those denoting manner e.g., infinitives and those derived from other words to form abstract notions, e.g., 'teaching' derived from the word 'teach'. Nouns coded with *Human* feature in the corpus includes those referring to human beings, human professions, other beings like God, spirits and devil (also known as superhumans).

Morphophonological feature	Expected gender	Agreement class
mû(u)-	A,B	1,3
a-	A	2
mî-	B	4
Î-	C	5
ma-	C	6
k(g)î-	D	7
i-	D	8
n-	E	9/10
∅	E	9/10
rû-	F	11
k(g)a-	G	12
tû-	G	13
û-	GAC	14
k(g)û-	GAC,H	15
ba-	H	16

Table 4: Morphophonological features tested, along with the class(es) expected to have this feature potentially associated with them.

not. We return to this in the Discussion below. There were also cases where the same noun lemma had clearly different meanings across contexts, with each meaning consistently corresponding to a different agreement pattern, e.g., *kîrundu wa Ngai* "the Holy spirit of God" (class 1 agreement) and *kîrundu kîa ûrongo* "the spirit of deceit" (class 7 agreement). These were treated as two distinct lemmas.

2.3 Application of the Tolerance Principle

Each of the semantic and morphophonological features coded for was subjected to a quantitative analysis to establish its productivity using the Tolerance Principle (Yang 2016). As mentioned in section 1, the Tolerance Principle is an evaluation metric that provides a way of making predictions about the likely productivity of linguistic rules in the presence of exceptions. The Tolerance Principle makes predictions about how and when learners of a language should be expected to generalise a potential rule. Here, we will use it not to make predictions about *when* learners will acquire a rule, but as a way of establishing productive rules for gender assignment

that speakers of the language may represent. As we have highlighted in the preceding sections, gender systems in Bantu (and beyond) are often characterised by exceptions, with multiple semantic features associated with one class, and even a single semantic feature that transcends several classes. Likewise, the various nominal prefixes (here treated as morphophonological cues to gender assignment) will also be evaluated.

In our case, the relevant variables include the number of nouns, N, with a certain semantic/morphophonological feature across the entire corpus, and the number of exceptions, e, which do *not* take the particular agreement class or gender for which we are evaluating productivity. Together, these give us the tolerance threshold, θN, for the potential rule, which we evaluate against the exceptions. For example, if there are N nouns with the *Narrow* feature in the corpus, and we want to evaluate whether the rule *Narrow* → *gender B* is productive, the exceptions will be the number of nouns with this feature that take some other agreement pattern, i.e., belong to another gender. **Table 5** shows how this potential rule (among others) fares when evaluated under the Tolerance Principle. There are a total of 115 nouns with this semantic feature in the corpus. Out of these, only 32 are gender B (agreement class 3/4) and 83 are exceptional (i.e., are in other agreement classes). The tolerance threshold θN in this case is 24, and therefore the rule is not predicted to be productive. Similarly, **Table 5** shows that this same semantic feature is not predicted to be productive for any other gender either.

Gender	Agreement class pairs	Narrow	N	e	θN	Productive
A	1/2	0	115	–	24	No
B	**3/4**	**32**	**115**	**83**	24	**No**
C	5/6	2	115	113	24	No
D	7/8	5	115	110	24	No
E	9/10	6	115	109	24	No
F	11/10	65	115	50	24	No
G	12/13	4	115	111	24	No
H	16/15	0	115	–	24	No
GAC	14,15	0	115	–	24	No
Grand Total	115					

Table 5: Evaluation of the productivity of the semantic feature “Narrow” using the Tolerance Principle. Bolding highlights the potential rule, *Narrow* → *gender B*, discussed in the text. None of these hypothetical rules are predicted to be productive.

3 Results and discussion

3.1 Results

Table 6 summarizes the results of our analysis of semantic features using the Tolerance Principle. Here we show only the evaluation of features with respect to the gender they were predicted to be relevant for. As expected, all other evaluated rules were predicted to be unproductive based on our analysis. Our results reveal that six of the semantic features tested are predicted to be productive as cues for gender determination in Kîîtharaka: *Tree*, *Augmentative*, *Pejorative*, *Diminutive*, *Manner* and *Infinitive*. All three of the evaluative features are predicted to be productive based on the subset of nouns that occur only in these classes (i.e., for which this is the primary gender) *and* for nouns that have the relevant class as an alternative (i.e., for this is a derived meaning, or secondary gender).[13] We show analyses separating these two types of nouns in **Table 7**.[14]

The feature *Manner* appears unproductive for Gender D (class 7/8)—of 10 nouns, only 1 belongs to this gender. However, there is some regularity observed in that all of the 9 exceptions are transnumerals by virtue of being singulare tantum. Following the mechanism we established in Section 2.1 to account for the non-declensional paradigm, these kinds of nouns are not categorized as Gender D but are cases of GAC. *Manner* is therefore a productive cue to GAC in the same way as the evaluative features described above. This includes names of languages, e.g., *Kĩî-ibirania* "Hebrew language" which serves as a nominal denoting the manner of "speaking like a Hebrew" and other phrases denoting behavioural attributes e.g., *kĩî-muntû* "like a human". Finally, and most notably, the feature *Human*—perhaps the semantic feature most often claimed to be relevant for Bantu—is not predicted to be productive. This is because, despite all nouns in Gender A being *Human*, the number of human nouns in other genders is above the productivity threshold defined according to the Tolerance Principle. However, the Tolerance Principle allows recursive application with feature conjunction. Intuitively, this can result in the feature being productive, though not in isolation. We return to this in the Discussion below.

[13] In other words, if an entity is big, bad-looking or small it will belong to gender C, D and G, respectively. However, for these three genders (C, D and G), there are nouns that can be thought of as inherently bearing these evaluative features, while other nouns are derived: they are typically in other genders, but occur in these when they are evaluated as such by the speaker in the context. For both sets of nouns, the relevant semantic feature is productive.

[14] An anonymous reviewer suggests that we could explore whether our predictions would remain if we used smaller corpus samples, following (e.g., Kodner 2020). However, we do not believe that a lexicon size-frequency relationship exists for Kîîtharaka nouns comparable to what is witnessed in the English past tense inflection. In the case of English, past-tense inflection presents a unique challenge due to the presence of high frequency irregulars, many of which form a significant portion of learners' early lexicons. This phenomenon limits generalizations in a sparse lexicon, requiring learners to memorize a larger set of nouns until they have learnt more words. As we have shown in section 1.2, nominal classification in Kîîtharaka largely comprises a regular formal paradigm. Additionally, Yang (2016; 2018) notes that the Tolerance Principle may not work very well with small lexicon sizes. (Un)productivity based on few values of N may be more of a sampling issue than the (in)ability to apply a rule.

Semantic feature	Expected class	Gender	*N*	*n*	*e*	*θN*	Productive
Human	1/2	A	252	196	56	46	No*
Tree	3/4	B	16	15	1	6	Yes
Dispersive mass	3/4	B	64	10	54	15	No
Extended	3/4	B	161	80	81	32	No
Spread	3/4	B	52	3	49	13	No
Cohesive mass	5/6	C	58	3	55	14	No
Augmentative	5/6	C	32	25	8	9	Yes
Plant part	5/6	C	47	5	42	12	No
Fruit	5/6	C	17	8	9	6	No
Round	5/6	C	44	12	32	12	No
Artefact	7/8	D	136	35	101	28	No
Plants	7/8	D	33	13	20	9	No
Pejorative	7/8	D	24	20	4	8	Yes
Manner	7/8	D	10	1	9	4	No*
Animal	9/10	E	155	89	66	31	No
Loan	9/10	E	151	68	83	28	No
Narrow	11/10	F	115	64	51	24	No
Wavy	11/10	F	54	26	28	14	No
Diminutive	12/13	G	76	74	2	18	Yes
Abstract	14	GAC	1006	821	185	146	No
Cohesive mass	14	GAC	58	34	24	14	No
Derived	15	GAC	1082	778	304	155	No
Infinitive	15	GAC	671	671	0	103	Yes

Table 6: Predicted productivity of semantic features as cues to Kîîtharaka gender assignment based on the Tolerance Principle. Here we show only the results of particular features with their expected classes. *N* is the total number of nouns with the relevant feature, *n* is the number of rule-compliant nouns, *e* is the number of exceptions, and θN is the threshold defined by the Tolerance Principle. Here we flag the predicted probability of the feature *Human* and *Manner* with an asterisk since we will analyze them further below.

Turning to morphophonological features, i.e., nominal prefixes, in contrast to the semantic features tested here, almost all of the morphophonological features tested are predicted to be productive. This is illustrated in **Table 8**, which shows the evaluations of each nominal prefix with

Rule type	Feature	Gender	*N*	*n*	*e*	*θN*	Productive
Inherent	Augmentative	C	26	20	6	8	Yes
	Pejorative	D	9	8	1	4	Yes
	Diminutive	G	15	15	0	6	Yes
Derivational	Augmentative	C	9	7	2	4	Yes
	Pejorative	D	15	13	2	6	Yes
	Diminutive	G	61	59	2	15	Yes

Table 7: Productivity of evaluative classes based on inherent and derivational features. Note: *N* is the number of inherently/derivational nouns with the target feature, *n* is the number of these nouns in the respective genders and *e* the number of the nouns with this feature but in other genders.

respect to the expected gender. Only the prefix *mû(u)-* is unproductive, because it is associated (nearly equally) with two genders—A and B. The same applies to the class 10 prefix *n-* which is associated with two genders— E (class 9/10) and F (class 11/10). The prefixes *û-* and *k(g)û-* are productive for GAC, while for *ba-* there is only one noun bearing the prefix and since no computation is needed for this one observation, the Tolerance Principle by design does not yield any tolerance threshold.

3.2 Discussion

Gender assignment systems are one of the most well-studied features of Bantu languages, but there is longstanding debate as to whether these systems are based on semantics, morphophonology, or both.[15] We have argued that part of the reason this debate rages on is that previous work has largely shied away from quantifying the robustness of the features proposed to underlie gender assignment (though cf. Ngcobo 2010; Msaka 2019). Importantly, no previous work on gender assignment in Bantu has engaged with theories of productivity. In this study, we aimed to illustrate how a quantitative approach, couched within a theory of productivity, makes it possible to go beyond intuitions and to deal with exceptional cases in a principled way. We took gender assignment in Kîîtharaka as our test case. Although there are many theories of morphological productivity, here we used the Tolerance Principle (Yang 2016).

Our results suggest that for Kîîtharaka, only a few semantic features are predicted to productively cue agreement class, namely, *Augmentative* (gender C), *Pejorative* (gender D),

[15] As a reviewer points out, the term 'based on' may imply a diachronic rather than a synchronic phenomenon. Of course, in this paper, we are focused on the latter. However, as Bauer (2001) notes the two are not entirely dissociable: the synchronic status of the elements in the lexicon is a result of diachronic events. In other words, once a word derived by a rule enters the lexicon, it becomes a product of a diachronic process. Whether the rule that derived it remains productive is a further question.

Morphophonological feature	Expected class	Gender	*N*	*n*	*e*	*θN*	Productive
mû(u)-	1	A	397	161	236	66	No*
a-	2	A	188	188	0	36	Yes
mû(u)-	3	B	397	208	189	66	No*
mî-	4	B	208	208	0	39	Yes
î-	5	C	187	153	34	36	Yes
ma-	6	C	145	143	2	29	Yes
k(g)î-	7	D	269	237	32	48	Yes
i-	8	D	240	237	3	44	Yes
n-	9	E	300	292	8	53	Yes
∅	9	E	148	69	81	30	No
n-	10	E	499	377	120	80	No
n-	10	F	497	107	390	80	No
rû-	11	F	122	108	14	25	Yes
k(g)a-	12	G	83	77	6	19	Yes
tû-	12	G	77	77	0	19	Yes
û-	14	GAC	106	103	3	23	Yes
k(g)û-	15	GAC	677	674	3	103	Yes
ba-	16	H	1	1	0	—	—

Table 8: Predicted productivity of morphophonological features, here nominal prefixes, as cues to Kîîtharaka gender assignment based on the Tolerance Principle. Here we show only the results of particular features with their expected genders. *N* is the total number of nouns with the relevant feature, *n* is the number of rule-compliant nouns, *e* is the number of exceptions, and θN is the threshold defined by the Tolerance Principle. Note that the prefix *mû(u)-* is tested for association with two genders. We flag the predicted productivity for this prefix as we will discuss it below. For the prefix *ba-*, the threshold for productivity does not hold when the value of *N* is 1.

Diminutive (gender G), *Tree*, and *Infinitive* (GAC, class 15). On the other hand, morphophonological features—the nominal prefixes—are widely predicted to productively cue gender in Kîîtharaka. In other words, Kîîtharaka speakers are mostly predicted to be able to productively determine the gender of a novel noun (here taken as the agreement pattern it shows) on the basis of a nominal prefix alone. The only apparent exception to this was the prefixes *mû(u)-* (which is shared by gender A and B) and *n-* (which appears with plural agreement classes of gender E and F).

In fact, across both parts of our analysis, it is notable that agreement classes 1 and 3 were not predictable from any of the features tested. Perhaps most surprisingly, the feature *Human*, a target feature for classes 1 and 2 (Gender A), was not predicted to be productive. Human/animacy has been claimed to play a key role in motivating assignment of nouns (to gender A) across the Bantu language family (see e.g., Wald 1975; Contini-Morava 2008; Ngcobo 2010; Crisma et al. 2011: and many others). Likewise, if singular prefixes alone marked agreement class or gender, it would be impossible to predict whether a *mû(u)*-prefixed noun is in gender A (class 1/2) or gender B (class 3/4). Assuming an explicit theory of productivity forces us to specify what it means for a particular feature to be productive. In this case, that theory requires that nouns with the relevant feature (or features) not be assigned to other classes beyond a certain threshold—clearly the case for humanness and *mû(u)-* in Kîîtharaka.

However, while it is possible that these features simply are not productive in Kîîtharaka, it is worth considering some other possibilities. First, it could be that our corpus, which is partially extracted from the bible, contains a higher number of certain kinds of nouns than one would find in other texts, or in spontaneous speech (e.g., spirits, God and other super-humans, all assigned the feature *Human* in our analysis). Indeed some of these nouns are exceptions in our corpus (i.e., they are not in gender A). For instance, *kîroria* "prophet", though *Human*, is in agreement class 7/8 (gender D). An over-representation of such nouns could lead to an increase in the number of exceptions relative to cases that follow the rule, potentially incorrectly predicting the +*Human* feature to be unproductive for gender A. However, it is not clear how likely this actually is. In fact, a large portion of our corpus—1,426 nouns, more than half of the total—comes from the translated SIL Comparative African Wordlist rather than the Bible text. This is potentially a more balanced representation of commonly used nouns across African languages. Thus, we re-ran our Tolerance Principle analysis with just the subset of nouns from the SIL wordlist. The results were qualitatively similar—e.g., the *Human* feature was still not productive (see the SIL list only section of the corpus analyses—URL provided in Section 2.2).

A second possibility is that both the semantic feature *Human*, and the morphophonological feature *mû(u)- do* productively cue genders A and B, but they require recursive application of the Tolerance Principle. In other words, these features would be productive when re-evaluated based on a subset of the lexicon. In the analysis described above, we treated each semantic and morphophonological feature as individual and independent of any other features. However, both semantics and morphophonology may be used jointly to determine certain aspects of gender assignment. The Kîîtharaka corpus data indeed shows that all human nouns with the prefix *mû(u)-* are in gender A. Similarly, all non-human nouns with prefix *mû(u)-* are in gender B. If we treat *Human* as a binary feature (a possibility for gender features according to Lumsden 1992; Rooryck 1994: and others), the lexicon can be divided into [+*Human*] nouns and [–*Human*] nouns. The remaining features, like the morphophonological feature *mû(u)-*, can then be re-evaluated on each

subset. In its original conception, the Tolerance Principle was indeed designed to be applied in such a recursive way. This was motivated by the *Maximise Productivity* principle, which asserts that learners are actively searching for productive rules (see Yang 2016; 2018). Learners could thus evaluate rules that apply to both the full lexicon, but also those that may apply to only a subset of the lexicon. Recursive application is predicted to affect the time-course of acquisition, but not the eventual productivity of the resulting rule. While recursive rule application also makes the space of possible rules to be tested much bigger, using these particular features immediately jumps out from our data. To explore this, we retested the productivity of the prefix *mû(u)-* and found that the rule [*mû(u)-*] → *gender A* was productive for the subset of the lexicon with the feature [+*Human*] ($N = 166$, $n = 161$, $e = 5$, $\theta N = 32$), and the rule [*mû(u)-*] → *gender B* was also productive for the subset of the lexicon with the feature [–*Human*] ($N = 231, n = 207, e = 24$, $\theta N = 42$). Notably, in the same vein, the semantic rule [+*Human*] → *gender A* can also be reapplied to a subset of the corpus including nouns with the prefix *mû(u)-*. For this subset, the rule [+*Human*] → *gender A* is productive ($N = 165$, $n = 161$, $e = 4$, $\theta N = 32$). In other words, recursive application of rules targeting genders A and B with features *mû(u)-* and +*Human* give us additional evidence for productivity.

Finally, it is potentially worth looking more closely at the exceptions to the semantic rule [+*Human*] → *gender A*. In the entire corpus, there are 252 human nouns of which 196 nouns are in gender A. The remaining 56 human nouns are distributed across gender C ($N = 2$), gender D ($N = 21$), and gender E ($N = 21$) and a few in genders B and G. While this rule would not be productive with this number of exceptions, the exceptional nouns largely comprise humans with special attributes. For instance, there are those with supernatural abilities e.g., *kîroria* and *ngai* (gender D) “a lesser god”. There are also those with properties or behaviours that are deemed socially undesirable, e.g., *îrwaya* “prostitute” or *kîonje* “a cripple” (Gender C). Some of these nouns also convey pejorative meanings. For example, the noun *kîrundu* can mean “spirit of God” (gender A), “demon/evil spirit” (gender D) or “spirit of the dead” (gender D).[16] These exceptional nouns are given in **Table 9**.

These examples reveal the possibility that at least some human nouns are not in gender A in order to convey a specific, mostly negative meaning. This accords with our general finding that the semantic features predicted to be productive in Kîîtharaka are mostly evaluative in nature: *Augmentative*, *Pejorative*, and *Diminutive*. And indeed, it has been argued that evaluation plays a key role in nominal classification in other Bantu languages (Castagneto 2017; Msaka 2019). If these nouns are considered not to have the feature *Human*, i.e., if they are treated as having a

[16] As noted in section 2.1, nouns that vary in their singular agreement consistently based on their meaning were treated as different types (i.e., each meaning belongs to a different class). Both spirit of the dead and demon/evil spirit appear in the SIL wordlist as different types. Similarly, the noun *kîûyûûyû* appeared twice, representing “a grand child” (gender A) and “ancestor” (gender D).

Noun	Gloss	Class	Unique feature
îrwaya	prostitute	5	pejorative
îrimorimo	giant	5	superhuman
kîrîndî	a large group of people	7	human collectivity
kîrundu	a demon/spirit of the dead	7	superhuman
kiuno	a fetus	7	pejorative
kîroria	a prophet	7	super human
kîonje	a cripple	7	pejorative
kîîmbere	a firstborn	7	human collectivity
kîa	a fool	7	pejorative
nkoma	a devil/ghost	9	superhuman
ngai	a lesser god/idol	9	superhuman
nthuke	generation	9	human collectivity
nkombo	a slave	9	pejorative
ntigwa	widow	9	pejorative
nthaka	(circumcised) a young man/son	9	(special) human
nthaata	a barren person	9	pejorative
nkea	a poor person	9	pejorative

Table 9: Examples of human (and superhuman) nouns outside of class 1, illustrating that some exceptional nouns have a pejorative meaning.

distinct feature that combines *Human* and *Pejorative*, this could impact how Kîîtharaka speakers represent these nouns and the classes they belong to. For example, re-evaluating productivity after removing nouns coded as *Pejorative* renders the rule [*Human*]→ *gender A* productive ($N = 235$, $n = 196$, $e = 39$, $\theta N = 43$). This is another example of the recursive application of the Tolerance Principle, this time by re-evaluating a semantic feature ([Human]) on a subset of nouns without a particular evaluative meaning ([Pejorative]).[17]

Regardless of exactly how learners come to form this generalisation, our guess is that the feature [+*Human*] can be used productively by Kîîtharaka speakers to predict the gender of

[17] While recursive application is included in the original formulation of the Tolerance Principle, as noted above, it is also worth noting that this introduces some potential questions about how to limit this powerful mechanism. For example, many intuitively unproductive rules could in principle be predicted to be productive on sufficiently small subsets of nouns. This could be dealt with by arguing that productivity must be supported by a sufficient number of examples (e.g., see Ellis 2006; Bauer 2005; Yang 2018; Plag 2018: for relevant comments). Nevertheless, this points to the need for behavioral data to support claims about predictive productivity, as we discuss just below.

novel nouns. This feature, and related features referencing animacy (or agency) have, in addition to evaluative features, been argued to be relevant in many Bantu languages (see e.g., Ström 2012: 274–281; Di Garbo 2014: 42,148,176; Güldemann 2023). The remaining inherent feature which was found to be productive is *Tree*. This is somewhat surprising, and is supported by a relatively small set of nouns. Of course, the Tolerance Principle is a measure of *predicted* rule productivity. The next logical step is to look for evidence of whether the predictions from the present analysis are borne out for speakers of Kîîtharaka. For example, psycholinguistic experiments could test whether Kîîtharaka speakers—either adults or children— use the features that are predicted to be productive based on this analysis, and fail to use those predicted to be unproductive when assigning novel nouns to classes. As noted above, here we have used a corpus of nouns that may not precisely reflect the kinds of nouns young children encounter (though the SIL database may be a reasonable approximation). For this, additional data on child-directed speech in Kîîtharaka would be needed. In addition, while we have proposed at least one case where semantics and morphology likely work together, the question of whether speakers privilege one type of cue over the other (e.g., Karmiloff-Smith 1981; Pérez-Pereira 1991; Gagliardi & Lidz 2014; Lawyer et al. 2024), as well as the time course of acquisition in Kîîtharaka remains open. We leave these issues for future work.

It is also worth noting that the approach we have taken here is to treat meaning and form class markers (prefixes) as potential cues to agreement class, rather than the other way around. In some sense, this gives a special status to noun internal cues (Gagliardi & Lidz 2014), and at the same time assumes both noun form and meaning have equal status in the minds of speakers. However, acquisition data suggests that children learning at least some languages exhibit knowledge of nominal prefixes much earlier than semantic cues (e.g., Demuth 2003: and the references therein) and show sensitivity to the noun form earlier than to noun external syntactic alternations like agreeing determiners or adjectives (see e.g., Karmiloff-Smith 1981). However, this is likely to change at a later acquisition stage. Studies on the acquisition of Romance languages show that from age 10, children begin to make use of both semantic and syntactic distributional cues to determine gender (see, e.g., Karmiloff-Smith 1981; Pérez-Pereira 1991). Both child learners and adult users of a language could, therefore, make use of their knowledge of deriflection to predict agreement, *and* vice versa. In other words, it could be that gender in fact provides a cue to deriflection. This is argued to be the case in Icelandic, for example, where knowledge of nominal inflection class provides a productive cue to gender in some cases, but in others it is gender that provides the only productive cue to inflection class (Björnsdóttir 2021; 2023). In Kîîtharaka, for the most part, the mapping between deriflection and gender is one-to-one, and the gender of most nouns can be determined from their deriflection class. But this is not always the case. For example, as shown in **Figure 1**, when a noun lacks overt form class features—i.e., does not have a nominal prefix—it is not clear whether the noun is in gender A or gender E. In this case, learners

may derive productive generalisations based on alternative cues, like the semantics of a noun or the agreement pattern it takes, and use these when encountering novel nouns.

At a more general level, while determining the psychological reality of specific cues and how they interact in child learners and adult users of Kîîtharaka are important questions for future research, our findings here highlight that robust predictions can be made about gender assignment in Bantu languages using a data-driven approach combined with an explicit theory of productivity. The same approach can in principle be applied to other Bantu languages. The results may align with ours—which suggest that morphophonological features are generally productive but many semantic features are not—or they may suggest differences across Bantu languages. Either way, the approach has the potential to lead to better understanding of how gender assignment works in this family of languages.

4 Conclusion

Gender and noun class systems are found pervasively in the languages of the world. They are often complex systems, in which a variety of cues can determine how nouns are categorized and what agreement patterns they take. Bantu noun class systems present a particularly well-studied case. A common feature of traditional accounts of gender assignment in Bantu is the characterization of the systems on the basis of semantics. Often, numerous abstract and subjective semantic features are considered to motivate the classes nouns belong to. At the same time, the ubiquitous nominal prefixes found in Bantu also present an obvious morphophonological cue to nominal classes. Here we introduced the noun class system of Kîîtharaka, describing general patterns and exceptions, and highlighting the utility of two distinct notions—gender (based on agreement classes) and deriflection (based on nominal prefixes). We then used a data-driven approach to evaluate the predicted productivity of both semantic and morphophonological features as cues to *gender* in Kîîtharaka. To do this, we created a new corpus of feature-tagged Kîîtharaka nouns and used a well-known theory of productivity, the Tolerance Principle, to test a large set of potential rules, based on semantics and morphophonology. The results show that while morphophonology is predicted to be highly productive, semantic features do not appear to be at the core of the classification system; only five (mainly evaluative) features were predicted to be productive in our analysis. One additional feature, *Human* is predicted to be productive under recursive application of the Tolerance Principle. These results suggest that morphophonology, not semantics, provides the strongest cue for nominal agreement patterns in Kîîtharaka. We hope to have illustrated that this approach can help more robustly characterise noun class systems in the modern Bantu languages, and make testable predictions about speakers' knowledge of these systems. In future work, we aim to test these predictions for Kîîtharaka.

Supplementary files

A. Number of nouns by assignment rules and gender. DOI: https://doi.org/10.16995/glossa.11755.s1

B. Classification of nouns by assignment rules and gender. DOI: https://doi.org/10.16995/glossa.11755.s2

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Competing interests

The authors have no competing interests to declare.

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