Numeral Classifiers in Specific Counting Systems: Cultural Context, Linguistic Principles, and Cognitive Implications

Andrea Bender (bender@psychologie.uni-freiburg.de)
Sieghard Beller (beller@psychologie.uni-freiburg.de)
Department of Psychology, University of Freiburg
D-79085 Freiburg, Germany

Abstract

Specific counting systems are characterized by a combination of two features: They are based on larger counting units (multiplication function) and apply to certain objects only (object specificity). This paper analyzes the constitutive role that numeral classifiers may play for specific counting systems, with instances from Polynesian and Micronesian languages. Despite a considerable divergence in classifiers, objects of reference, and factors chosen, a common principle can be identified that sheds new light on the numerical context of numeral classifiers and on the question of their cognitive status.
Key words: Numeral Classifiers, Numeral Cognition, Counting

Introduction

Classifiers are independent morphemes that group the associated nouns into classes according to some sort of salient characteristics. The most common type of classifiers are numeral classifiers, which are obligatory components of counting constructions in many languages. A close counterpart in English are words like *sheet* in “two sheets of paper”.

Cognitive research on numeral classifiers has predominantly focused on their classifying function, that is on the associated nouns and on the principles that underlie their classification (e.g., Aikhenvald, 2003; Berlin & Romney, 1964; Craig, 1986; Dixon, 1986). Two general hypotheses have been developed, arguing for a categorization based either on perception (e.g., Allan, 1977) or on social function of the respective objects (e.g., Denny, 1976; for a synthesis see Lee, 1987). However, besides their *classifying* function, numeral classifiers also have a *quantifying* function and a numerical context in which they occur. The quantifying function is required by the noun itself: In classifier languages, nouns refer to some kind of mass, and classifiers give a unit to that mass. Classifiers can simply refer to an individual instance of the mass (i.e., unit classifiers), but may also express measures, groups or multiples, parts, and kinds (Denny, 1986). Denny argues that classifiers establish two kinds of quantifications: they define the sort of quanta (e.g., units, parts, multiples, measures or kinds), and they define the class of such quanta to which it is restricted. For instance, a “sheet” defines single pieces as quanta, and two-dimensional things as its class of reference.

A less well established function of numeral classifiers may arise from their usage in actual counting. Focusing on this context will shed more light on a cognitive aspect that has been largely neglected so far.

A fairly well documented case is provided by number systems in Polynesian and Micronesian languages. Belonging to the Oceanic subgroup of the Austronesian language family, dating back some 6 000 years (Tryon, 1995), these languages inherited a decimal number system supplemented by numeral classifiers. Both, the number systems and the sets of numeral classifiers were then adapted and extended according to cultural needs. Most of these languages also developed specific counting systems, which applied a counting unit diverging from 1 and were restricted to specific objects (e.g., Bender & Beller, in press; Clark, 1999; Lemaître, 1985). The two language groups elaborated different components each: Polynesian languages the specific counting systems, Micronesian languages the numeral classifier systems. But etymological and syntactic parallels between several numeral classifiers and numerals used in the specific counting systems suggest that both types of systems are linked.

In order to analyze this link and explicate the cognitive and numerical context of numeral classifiers, we will first characterize the numeration principles of each type of system, before we focus on the role of numeral classifiers for specific counting systems. In conclusion, we will discuss the cultural and cognitive origins of this interaction.

Characteristics of Polynesian and Micronesian Number Systems

Compared to the English number system (e.g., Miller et al., 1995), those in Polynesian and Micronesian languages are fairly regular (Beller & Bender, 2005). They are (basically) decimal, and therefore their higher numerals typically refer to the powers of ten. Most power terms were developed locally, but reached large numbers in both language groups: On average, number systems extended up to 10^5 or 10^6, with a range of 10^3 to 10^{10}. In addition to the variation among power terms, however, even cognate power terms may denote different numbers: Not only may they refer to different power levels, but they may also refer to values that are different from the pure powers of ten (cf. Table 1).

In a certain sense, these high numerals also reveal the characteristics of the respective systems: In Polynesian languages, some of these numerals are part of specific counting systems with apparently “mixed bases”, whereas in Micronesian languages, power terms are typically considered as a particular type of numeral classifiers (Benton, 1968; Harrison & Jackson, 1984), as will be detailed now.

“Mixed Bases” and Specific Counting Systems

In 1906, Best published an article in which he argued that Māori employed binary and (semi-)vigesimal systems of numeration. Generalized for other Polynesian languages, this opinion was widely shared by colleagues in his time (e.g.,

Table 1: Traditional numerals in general counting for the powers of the base in some Polynesian and Micronesian languages (adapted from Bender & Beller, 2006a, 2006b). Numerals diverging in value from a strictly decimal pattern are shaded; prefixes are put in brackets for easier comparison.

Power level	Polynesian languages						Micronesian languages			
	Mangarevan	Hawaiian	NZ-Māori	Tahitian	Tongan	Nukuoro	Kiribati	Pohnpeian	Chuukese	Woleaian
10^1	rogo'uru	'umi	ngahuru	'ahuru	(hongo)fulu	hulu	(te)bwiina	(e)isek	(e)ngoon	(se)ig
10^2	rau	lau	rau	rau	(te)au	lau	(te)bubua	(e)pwiki	(e)pwúkú	(se)biugiuw
10^3	mano	mano	mano	mano	afe	mano	(te)ngaa	kid	(e)ngéréw	(sa)ngeras
10^4	makiu	kini	(tini)	manotini	mano	(se)mada	(te)rebu	nen	(e)kit	(se)n
10^5	makiukiu	lehu		rehu	kilu	(se)guli	(te)kuri	lopw		(se)lob
10^6	makore	nalowale		'iu		(se)loo	(te)ea	rar		(se)piy
10^7	makorekore					(se)ngaa	(te)tano	dep		(se)ngit
10^8	tini					(se)muna	(te)toki	sapw		(sa)ngerai
10^9	maeaea					(se)bugi		lik		
10^{10}						(se)baga				

Large, 1902) and has influenced descriptions of traditional number systems until recently. Indeed, many Polynesian languages do comprise a specific term for 20 (i.e., a reflex of **tekau*), and in some we find numerals for 200, 2 000 and so on. However, a genuine vigesimal system requires not just an emphasis on 20 itself, but its recurrence in *powers*, that is at $20^1 = 20$, $20^2 = 400$, $20^3 = 8\,000$, and so on. None of the Polynesian languages yielded anything close to such a recurrence of powers. What can be found instead are cyclic patterns at $2\cdot10^1 = 20$, $2\cdot10^2 = 200$, and $2\cdot10^3 = 2\,000$. A number system containing such patterns might rather be termed a "mixed-base" 2 and 10 system or a decimal system operating with "pair" as the counting unit.

The principles of a mixed-base system and its usage in Polynesian languages can be briefly illustrated for the case of Māori (for more details see Bender & Beller, 2006a). Traditional Māori basically contained two different counting systems: a single mode and a pair mode. Counting in the single mode applied reflexes of the Proto-Polynesian numerals for 1 to 10 and the power terms *rau* (10^2) and *mano* (10^3). According to Best (1906), *mano* also set the limits for counting, while any amount beyond this was referred to as *tini*. Counting in the dual mode basically applied the same numerals as counting in the single mode. However, these numerals were not used to refer to single items, but to pairs. Counting in the single mode was the general way of counting, while counting in pairs was restricted to a few objects such as fish, fowl and certain root crops. Nevertheless, proceeding in the single mode had to be made explicit, while applying the pair as counting unit went without saying (Best, 1906).

Similar principles of mixed-base systems can be found in several other Polynesian languages. These mixed bases mainly involved one or more of the factors 2, 4, 10, and 20 and were, again, restricted to specific objects (Bender & Beller, 2006a).

Although most of the contemporary Polynesian languages comprise only residuals of numeral classifiers, these residuals play an important role for the specific number systems, as can be illustrated with an example from Tongan. In traditional Tongan, a general system of counting was supported by four distinct systems for specific objects (Bender & Beller, in press). In these systems, the power terms *(hongo)fulu* and *(te)au* are partly replaced by distinct lexemes—*(te)tula*, *(te)kau*, *(te)fua*, and *(te)fuhi*—which reflect Proto-Polynesian classifiers. All terms imply a numerical change, as they multiply the adjoined numeral by 2 or 20. For instance, *(te)kau* refers to 20 pieces of either yams or coconuts, *(te)fuhi* to 200 yams, and *(te)fua* to 200 coconuts:

[1] *niu* *'e* *te-* *kau*
coconut NUMBER PARTICLE 1 score (i.e., 20)
"20 coconuts"

[2] *niu* *'e* *uo-* *fua*
coconut NUMBER PARTICLE 2 10-scores (i.e., 200)
"400 coconuts"

Two aspects are particularly noteworthy here. First, these apparently mixed-base systems are still decimal systems, which only apply counting units diverging from 1. And second, these mixed-base systems accompany regular decimal systems for general counting, while they themselves are restricted to certain objects—a feature also constitutive for numeral classifier systems.

Numeral Classifier Systems

Almost all Micronesian languages contain numeral classifiers, but variation is large with regard to the degree of differentiation. It ranges from a binary system in Kosraean to a system of more than one hundred classifiers in Chuukese or Kiribati (Harrison & Jackson, 1984). With regard to their function, these classifiers can be sorted into three categories: repeaters, qualifiers, and quantifiers. The semantic domains

Table 2: Woleaian pattern of qualifier (*-mal*) and power classifiers (*-ig*, *-biugiuw*) in counting animates (adapted from Bender & Beller, 2006b).

Number	Number term (components)	Literal translation
1	se-*mal*	one-animate
2	riuwe-*mal*	two-animate
10	se-*ig*	one-ten
12	se-*ig* me riuwe-*mal*	one-ten and two-animate
20	riuwe-*ig*	two-ten
100	se-*biugiuw*	one-hundred

typically covered by the qualifiers are shape, nature, and generality (Benton, 1968), while the remaining majority of objects are placed into a general or unspecified category. Power terms behave like numeral classifiers: Both are suffixed to numerals from 1 to 9, replacing each other, and both are thereby themselves counted. Some scholars (e.g., Benton, 1968; Harrison & Jackson, 1984) argue therefore that power terms should be considered as classifiers or, more precisely, as quantifiers. In counting, however, the category of power classifiers cuts across the other categories, as from 10 onwards—with just a few exceptions—they replace other classifiers in all compounds referring to power terms or their multiples (for an instance from Woleaian see Table 2).

One of the most extensive systems of numeral classifiers is documented for Chuukese (Benton, 1968). In addition to the four power classifiers, Chuukese also contains 101 "real" classifiers. For our comparison of specific counting and classifier systems, the category of *quantifiers* is of particular interest, as it refers to enumerable or measurable quanta. Besides encompassing classifiers that refer to units of objects, this category also includes classifiers with a fixed numerical value, namely the power classifiers, as well as others that seem to change the numerical value of the adjoined numeral. In Chuukese, quantifiers typically refer to portions of food and to other units of counting and measuring. Most of these counting units are numerically imprecise (e.g., bunch), but five of them also imply a specific value; *yáf*, for instance, refers to bundles of 10 coconuts.

The way in which this classifier is used in specific counting systems can be illustrated with an instance from Woleaian (which is part of the Chuukese dialect chain). Woleaian *yaf* is used for counting globular things such as coconuts, chickens, eggs, stones, coins, and valuable shells, and is translated as a "grouping (of ten)" (Alkire, 1970). While power classifiers typically replace other classifiers when a power or one of its multiples is referred to, the power classifiers for ten may take different forms for certain objects. Woleaian, for instance, encompasses three terms for ten: *ngaul* with the restricted interpretation of "ten groups", *yaf* referring to tens of coconuts, and *ig* for tens of everything else (Harrison & Jackson, 1984). However, they refer to different absolute numbers.

When counting objects other than coconuts, the numerals *ig* for 10, *biugiuw* for 100, *ngeras* for 1 000, and so on are

Table 3: Patterns of classifiers in power terms in Woleaian and Kiribati (adapted from Bender & Beller, 2006b).

Power level	Woleaian		Kiribati	
	others	coconuts	others	coconuts
10^1	(se-)**ig**	(se-)yaf	(te-)**ngaun**	(te-)bwii(na)
10^2	(se-)biugiuw	(se-)ngaul / (se-)**ig**	(te-)bubua	(te-)**ngaun**
10^3	(sa-)ngeras	(sa-)ngeras	(te-)ngaa	(te-)ngaa
…	…	…	…	…

used (see Table 3). Counting coconuts differs from this pattern: Bundles of 10 coconuts are counted with *yaf*; when reaching the absolute number of 100 coconuts, *ngaul* (referring to ten groups of ten) is used instead of the general power classifier *biugiuw*. Often, hundreds of coconuts were even referred to with *ig*, the classifier indicating 10-general. From 1 000 onwards, the number words refer back to the total number of nuts and no longer to their constituent groups of ten. In other words: At least for amounts between 10 and 1 000, coconuts were counted with a specific system in which the classifiers also had a multiplying function.

A similar pattern emerges in Kiribati where, again, coconuts are counted in groups of ten (see Table 3).

The Role of Numeral Classifiers for Specific Counting Systems

Numeral classifier systems and specific counting systems with mixed bases share two important features. First, they treat different types of objects differently when being counted ("object specificity"). And second, at least some of them change—in one way or another—the numerical value of the adjoined numeral with regard to the absolute amount of single items ("multiplying function"). In addition, nearly all specific counting systems apply at least one numeral classifier to define the new counting unit. But despite these similarities, the composition of number words and counting systems varies considerably.

Types of Classifier Usage

In Micronesian languages, general numerals are only used in enumerating a series, that is in abstract or rapid counting. The number words otherwise used are bimorphemic, always consisting of a numerative prefix as the first component and a classifier as the second component (**N-C**). In Polynesian languages, on the other hand, this composition can vary and is accompanied by changes in numerical value and sometimes by changes in meaning.

The common type in Polynesian languages is the **C-N** compound in which the classifier precedes the numeral. Classifiers allowing a C-N compound are often described as having a multiplying effect, as they seem to indicate a counting by groups of ten. However, this effect only occurs for the multiples of ten in an otherwise regular counting pattern. According to Clark (1999), it should therefore be termed "10

Table 4: Types of number compounds in Samoan and Micronesian constructions[a].

Power level	Samoan				Micronesian numerals
	General numerals	Classifier construction			
		Type 1	Type 2	Type 3	
10^0	N	C-N	N-C	N-C_m	N-C
10^1	N-P_1	C-P_1	C-N	(P_1-C_m)	N-P_1
10^2	N-P_2	(?)	C-P_2 (C-N-P_2)	(P_2-C_m)	N-P_2

[a] **Abbreviations:** N = numeral (1-9), P = power term, with subscribed number referring to the power level, C = classifier (other than power term), C_m = multiplying classifier.

deletion” rather than multiplication. In **N-C** compounds, the numeral precedes the classifier. With regard to their formal properties, N-C classifiers can be grouped together with power classifiers like **fulu* (10) or **rau* (100) (Clark, 1999; Harrison & Jackson, 1984). Unlike most of their Micronesian counterparts, however, Polynesian N-C classifiers have a consistent multiplying effect.

Let us exemplify the syntactical and numerical characteristics of Polynesian classifiers with instances from Samoan (for more details see Bender & Beller, 2006b). Samoan contains 15 different classifiers, most of which explicitly distinguish between certain types of food. When counting the respective objects, these classifiers are prefixed or suffixed to the respective numerals according to one of three different types (see Table 4).

Classifiers of type 1 always precede the numeral (C-N) and are counted in a simple way.

Classifiers of type 2 change their syntactical order beyond ten (from N-C to C-N): When suffixed to a numeral from 2 to 9 or when prefixed to 100s, the resulting term refers to the number indicated by the numeral. However, when prefixed to the numerals from 2 to 9, the classifier indicates “tens of …” or 10-deletion. This process is complementary to the one in Micronesian languages, where power classifiers replace other classifiers. From 100 onwards, however, the numerals indicate the proper power level, and therefore these number words can—contrary to the Micronesian ones—involve two classifiers: *'au selau* (100 bunches), for instance, contains both a qualifier (*'au* for coconuts) and a power classifier (*selau* for 100).

Finally, classifiers of type 3 only allow an N-C construction and systematically change the numerical value of the adjoined numeral due to an inherent factor that defines a counting unit different from 1, namely scores (of coconuts), tens (of skipjack), and pairs (of coconuts or young pigs).

Types of Counting Systems

Most classifiers simply *classify* the objects of reference. Quantifiers also introduce a new—though in most cases blurred—counting unit (such as group or bunch). The power classifiers, on the other hand, do not classify, but *multiply.* They indicate a precise value—either the base of the number system or one of its powers—that serves as a factor for the adjoined numeral. As power classifiers replace other classifiers, they typically indicate the new counting unit independently of the object concerned. A few classifiers, however, adopt both a classifying and a multiplying function: They have a precise value and are restricted to certain objects indicating, for instance, “tens of coconuts”.

As these different types of classifiers are not evenly distributed in the respective languages, they also help to define different types of counting systems:

Classifier Systems. In Micronesian languages, most classifiers simply classify the counted objects. Power classifiers are used to reach larger numbers; most other quantifiers have mainly blurred numerical value. Classifiers adopting both a classifying and a multiplying function occur, but only rarely.

Mixed Systems. In Samoan and Rennellese, which contain the largest set of classifiers in Polynesia, the Micronesian pattern emerges most clearly. Most of the 15 classifiers in Samoan are used only in their classifying function. Nine also have the effect called 10-deletion in which the classifier replaces the power classifier. Only three classifiers in Samoan have a clear multiplying function, and these classifiers are then counted in the same way as power classifiers.

Composite Systems. In Tongan, on the other hand, five classifiers can be identified in addition to the power terms. Although their etymology hints towards the specific objects counted, none of them has a classifying function only. Instead, they are used exclusively in the specific counting systems, where they are suffixed to the numeral in a similar way as the power terms and then counted in the same way. They are employed to define or count new counting units and thereby adopt both the classifying and the multiplying function. For instance, when counting coconuts, *(te)kau* defines a new counting unit at the score, which is then counted (with an N_1-C_{20} construction) until ten such units are reached (cf. instances [1], [2]). The power classifier for ten is replaced then—and counted further—with *(te)fua*, indicating 10 scores of coconuts (i.e., ten score-units are labeled with N-C_{200} instead of N-P_1-C_{20}).

Multiplier Systems. The type of specific counting systems with the least involvement of classifiers can be identified in Eastern Polynesian languages such as Tahitian. Here, we find some of the most abstract specific counting systems. They are still restricted to certain objects, but share reflexes of one classifier only and only in a fossilized form (i.e., **tekau*). This term may originally have functioned as a classifier with a blurred counting unit only (as in Samoan) and then developed into a multiplier.

As these examples show, specific counting systems are composed in both language groups according to the same principle, albeit with significant differences in details.

Composition Principle

The specific counting systems do not merely differ with regard to the involvement of classifiers. Although all of them enabled different modes of counting, each did so in a different way. More precisely, we do not find congruence in *any* of their characteristic components: counting unit, classifier, or object of reference. From our survey of Polynesian and Micronesian languages, we were able to extract counting units defined by one or several of the factors 2, 4, 5, 8, 10, 12, 20, and 22, with the pair being the most popular (Bender & Beller, 2006a). In addition, even though often referring to the same objects, the classifiers that are linked to this multiplication function do differ across languages. And finally, even with regard to the objects counted specifically, no consistent picture emerges, at least not on the level of concrete objects. Coconuts, for instance, are of special concern in most but not all languages.

And yet, on a more abstract level, these systems share two characteristics: All of them are restricted to specific objects that belong to a small category with common features ("object specificity"), and in some cases, the process of counting was enhanced by counting them in larger counting units, thus changing the numerical value of the adjoined numeral ("multiplication function"). How can we reconcile this consistent pattern with the differences in terms of detail?

In Polynesian and Micronesian languages, the most limited number systems generally co-occur with largely reduced classifier categories and/or specific counting systems (Bender & Beller, 2006b; Harrison & Jackson, 1984). Backed by this observation, our analysis encourages us to assume that one of the main reasons for applying specific counting systems was to extend the original number system to large numbers.

The Polynesian and Micronesian instances reviewed in this article show that a number system can be extended in at least two dimensions: Classifiers can be added "in breadth" in order to differentiate ways of counting for different objects; classifiers can also be added at the end of a power series ("in length"), thereby extending the range of counting. A large number of classifiers is the result of the first extension, and high numerals are the result of the second. Combining the two creates a third—and for our purpose the most interesting—variant: If classifiers are incorporated not on the basic, but on a higher level, a new series of counting for the respective objects is instantiated and extended, based on a higher counting unit ("base substitution"). This creates a specific counting system and enables an acceleration of counting.

For the extension of the Micronesian number systems beyond their original numerals of up to 10^3, it was sufficient, as Harrison & Jackson (1984) argue, to have numeral classifiers, particularly quantifiers, as a grammatical category. Power classifiers initiate a mathematical series of increasing powers, but apart from yielding a mathematical interpretation only, they share all properties with quantifiers, particularly in that they themselves are counted. Consequently, other quantifiers can also be incorporated into the power series if the counting unit to which they refer is (re-)defined as a power of the base. By incorporating new classifiers, the system can be extended *ad libitum*.

Conclusion

Micronesian and Polynesian languages alike adopted the principle of establishing specific counting systems with numeral classifiers that define a higher counting unit. This indicates that both the principle and its components may have existed in Proto-Oceanic. The way in which these specific counting systems were constructed, however, differed in most of the languages. The classifiers and counting units that they picked for their specific objects of concern seem to be largely arbitrary (although 2 or 5 are very reasonable counting units from a cognitive point of view). The extent to which they applied specific counting systems, however, and the range of objects for which they did so, most likely resulted from cultural adaptations to various requirements or constraints, such as the resources available in the respective environment and salient in the respective culture or the size of the population.

The Cultural Context of Counting

An indigenous interest in large numbers, indicated by large power terms, is also clearly attested ethnographically for precolonial times (e.g., Elbert, 1988). At least in Polynesia, this interest might have been motivated by socio-economic reasons (Beller & Bender, 2005; Bender & Beller, 2006a, in press). In general, both the extent of the number systems and the number of counting modes increase with increased stratification. A concern with collecting and redistributing resources was particularly strong in islands with powerful chiefs or kings, such as Tonga or Tahiti, and obviously less pronounced in societies with less centralized political forces or small communities, such as Māori (e.g., Goldman, 1970; Kirch, 1984). The category of resources frequently redistributed overlaps to a considerable extent with the category of objects specifically counted. It consists of subsistence products that were both culturally significant and abundant, such as fish, coconuts, the most prestigious starch food, and material for fabrics or thatch (Bender & Beller, 2006, in press). At certain occasions, these objects were required in large amounts, for instance, when collecting tributes, when supplying large numbers of people during war, or when accumulating wealth for competitive givings (e.g., Elbert, 1988).

The same might not hold for the smaller island cultures of Micronesia, although even there, high numbers gained importance with specific resources. On Woleai, for instance, the local redistribution of more than 12 000 coconuts during a funeral is documented (Alkire, 1970). Supra-island ties, linking islands like Woleai with Yap, may have required similar amounts for shares and tributes.

The Cognitive Status of Numeral Classifiers

When redistribution was involved, it was *calculation* rather than counting that was required, and when ceremonial purposes or prestige were involved, this had to be done very carefully. Keeping track of the flow of objects was therefore particularly important, but the respective calculations are difficult in the absence of external representations (Nickerson, 1988; Zhang & Norman, 1995). In this context, specific counting systems could have served a second practical reason, namely to reduce the cognitive load of the calculators by extracting a certain factor—actually the same factor inherent in the counting unit. Larger absolute numbers were thus reached faster and with less effort.

Several factors influence the ease, with which number systems are learnt and operated (e.g., Dehaene, 1997; Wiese, 2003). For their representation a one-dimensional system—that is a system with a distinct lexeme for each number—would, in principle, be sufficient. As numbers grow larger, two-dimensional systems with base and power become more advantageous: Cyclic patterns keep the number words compact while dramatically reducing the amount of lexemes needed. For base size, however, Zhang and Norman (1995) identified a cognitive trade-off: While large bases are more efficient for encoding and memorizing big numbers, they also require the memorization of larger addition and multiplication tables when operating with them.

Introducing a larger counting unit increases the dimensionality of the number system and thereby compensates this trade-off: It facilitates encoding and memorizing of larger numbers, and at the same time keeps base size comfortably small for addition and multiplication. In providing these advantages, numeral classifiers supported their users in difficult tasks of mental arithmetic. In a similar way, quantifiers referring to parts could have facilitated division.

In conclusion, our research encourages us to suggest that the indigenous interest in high numbers in Polynesia and Micronesia inspired people to systematically incorporate numeral classifiers into an originally regular decimal system. In doing this, they not only developed innovative ways of counting, but also designed an efficient strategy to cope with the cognitive difficulties of accurately calculating in the absence of a notation system. In turn, these results add a new dimension to the research on the cognitive status of numeral classifiers: not only as a basis for (noun) categorization, but also as a cognitive tool in numerical cognition.

Acknowledgments

We are grateful to Annelie Rothe, Manuela Sibold, and Simone Traber for support with the material, and to Lothar Käser, Sarah Mannion, and Mario Spengler, for discussion and valuable comments on earlier versions of this paper.

References

Aikhenvald, A.Y. (2003). *Classifiers: A typology of noun classification devices*. Oxford: Oxford University Press.

Alkire, W. (1970). Systems of measurement on Woleai Atoll, Caroline Islands. *Anthropos, 65*, 1-73.

Allan, K. (1977). Classifiers. *Language, 53 (2),* 284-310.

Beller, S. & Bender, A. (2005). The cognitive advantages of counting specifically: An analysis of Polynesian number systems. In B.G. Bara, L. Barsalou, & M. Bucciarelli (Eds.), *Proceedings of the 27th Annual Conference of the Cognitive Science Society*. Mahwah: Erlbaum.

Bender, A. & Beller, S. (2006a). “Fanciful” or genuine? Bases and high numerals in Polynesian number systems. *Journal of the Polynesian Society, 115,* 7-46.

Bender, A. & Beller, S. (2006b). Numeral classifiers and counting systems in Polynesian and Micronesian languages: Common roots and cultural adaptations. *Oceanic Linguistics, 45 (2),* 380-403.

Bender, A. & Beller, S. (in press). Counting in Tongan: The traditional number systems and their cognitive implications. *Journal of Cognition and Culture, 7 (3/4)*.

Benton, R.A. (1968). Numeral and attributive classifiers in Trukese. *Oceanic Linguistics, VII (2),* 104-146.

Berlin, B. & Romney, A.K. (1964). Descriptive semantics of Tzeltal numeral classifiers. *American Anthropologist, 66 (3),* 79-98.

Best, E. (1906). Maori numeration: Some account of the single, binary, and semi-vigesimal systems of numeration formerly employed by the Maori. *Transactions and Proceedings of the New Zealand Institute, 39*, 150-180.

Clark, R. (1999). Proto-Polynesian numerals. In E. Zeitoun & P. J-k. Li (Eds.), *Selected papers from the Eighth International Conference on Austronesian Linguistics*. Taipei: Academia Sinica.

Craig, C. (Ed.) (1986). *Noun classes and categorization.* Amsterdam: John Benjamins.

Dehaene, S. (1997). *The number sense: How the mind creates mathematics*. Oxford: Oxford University Press.

Denny, J.P. (1976). What are noun classifiers good for? In *Proceedings of the 12th Regional Meeting of the Chicago Linguistic Society*. Chicago Linguistic Society.

Denny, J.P. (1986). The semantic role of noun classifiers. In C. Craig (Ed.), *Noun classes and categorization.* Amsterdam, Philadelphia: John Benjamins.

Dixon, R.M.W. (1986). Noun classes and noun classification in typological perspective. In C. Craig (Ed.), *Noun classes and categorization.* Amsterdam: John Benjamins.

Elbert, S.H. (1988). *Echo of a Culture: A Grammar of Rennell and Bellona*. Honolulu: University of Hawai'i Press.

Goldman, I. (1970). *Ancient Polynesian society.* Chicago: University of Chicago Press.

Harrison, S. & Jackson, F.H. (1984). Higher numerals in several Micronesian languages. In B.W. Bender (Ed.), *Studies in Micronesian Linguistics*. Pacific Linguistics, C-80.

Kirch, P.V. (1984). *The evolution of the Polynesian chiefdoms*. Cambridge: Cambridge University Press.

Large, J.J. (1902). The vigesimal system of enumeration. *Journal of the Polynesian Society, 11,* 260-261.

Lee, M. (1987). The cognitive basis of classifier systems. In J. Aske et al. (Eds.), *Berkeley Linguistics Society, Proceedings of the Thirteenth Annual Meeting*. Berkeley: Berkeley Linguistics Society.

Lemaître, Y. (1985). Les systèmes de numération en Polynésie orientale. *Journal de la Société des Océanistes, 80,* 3-13.

Miller, K., Smith, C.M., Zhu, J. & Zhang, H. (1995). Preschool origins of cross-national differences in mathematical competence: The role of number-naming systems. *Psychological Science, 6*, 56-60.

Nickerson, R.S. (1988). Counting, computing, and the representation of numbers. *Human Factors, 30*, 181-199.

Tryon, D.T. (Ed.) (1995). *Comparative Austronesian dictionary: An introduction to Austronesian studies; 4 vols*. Berlin, New York: Mouton de Gruyter.

Wiese, H. (2003). *Numbers, language, and the human mind*. Cambridge: Cambridge University Press.

Zhang, J. & Norman, D.A. (1995). A representational analysis of numeration systems. *Cognition, 57*, 271-295.