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Rules vs. Analogy in Mandarin Classifier Selection*

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A long-running debate concerns whether human language is processed solely by analogy to memorized exemplars, as connectionists have claimed, or instead may be processed by symbol-manipulating rules (e.g. Pinker 1999). In this paper we bring this debate to the Mandarin noun classifier system, arguing that the so-called general classifier 個 *ge* is selected by a default rule. Reviewing evidence from a variety of sources, including new corpus analyses, we first argue that the selection of most classifiers is lexically mediated, and then show that *ge* has no lexical semantics. Finally, we show that *ge* is used in a variety of situations that have nothing in common except for the inability to form analogies with examples in memory: when nouns are too dissimilar from lexical exemplars, are derived from other syntactic categories, or cooccur with classifiers too infrequently, and when speakers have memory access problems.

Key words: analogy, rule, classifier, default rule

1. Introduction

Work done over the last decade on the Mandarin noun classifier system has taught us much about the nature of nominal semantics and human categorization. In this paper, however, we are not particularly interested in nominal semantics or human categorization. Instead, we aim to use the Mandarin noun classifier system as a source of data for a different issue, something that might be called the rule/analogy debate. This is the debate between researchers who maintain the classical generativist line that human language is processed by symbol-manipulating rules (e.g. Pinker and Prince 1988, Marcus, Brinkmann, Clahsen, Wiese, and Pinker 1995), and connectionists who claim that human language is processed solely by analogy (e.g. Rumelhart and

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McClelland 1986, Hare, Elman, and Daugherty 1995). Here we use the term 'analogy' in the sense used in historical linguistics, where patterns are generalized to new cases by referring to examples, as for instance when *dive* became irregular (i.e. *dived* became *dove*) by analogy with pairs like *drive-drove*. The connectionists claim that all language processing involves analogy of this sort. Their opponents concede that analogy is involved in irregular inflection, but insist that the most interesting parts of language (e.g. regular inflection) are rule-driven.

For such a deep issue, it is strange that this battle has so far been fought only over inflection (especially past-tense inflection in English). We suggest that the arguments that have been used to support the existence of rules in inflection work equally well to support the existence of rules in the Mandarin classifier system. Specifically, we argue that the classifier 個 *ge* is the unique 'general' classifier, selected by a default rule; the remaining 'specific' classifiers are selected by analogy with exemplars. This is essentially what has been long assumed in different terms (e.g. Li and Thompson 1981), though the assumption has recently come under fire (e.g. Loke 1994, Tyan 1996). Rather than being merely a defense of the status quo, however, this paper brings a new way to understand the claim that *ge* is 'general,' and moreover, we also provide new evidence for it.

We begin the discussion in section 2 by sketching out the highlights of the rule/analogy debate in inflection. In section 3, we highlight in an equally sketchy way some properties of the Mandarin classifier system, defining the basic kinds of classifiers that we will be comparing. In section 4 we describe why we think most classifiers are processed by analogy. The heart of the argument then comes in section 5, in which we show how the behavior of *ge* implies that it must be selected by rule, and not by analogy. New evidence for this claim comes from analyses carried out with the Academia Sinica Balanced Corpus (described in Chen, Huang, Chang, and Hsu 1996, public Web access is at http://www.sinica.edu.tw/ftms-bin/kiwi.sh). The evidence all boils down to one observation: *ge* is used in a variety of situations that have nothing in common except the impossibility for speakers to form analogies with examples in memory. That is, *ge* is truly selected by default. Finally, in section 6 we point the way to future research.

2. Rules and analogy in inflection

Analogy says that *dived* became *dove* because *dive* is similar to *drive*; if words are similar in some ways (e.g. they rhyme), they should be similar in others as well (e.g. their past tense forms should rhyme). Generative linguists, and until recently most cognitive psychologists, have not been too enamored of analogy as an explanation,

however, since there was no clear way to decide when it worked and when it didn't. For example, if *ears hear*, why don't *eyes heye* (Kiparsky 1988)?

Connectionism provides a way of formalizing analogy. It does this by encoding similar forms as overlapping representations in a network. The result is that forms that are 'similar' (i.e. overlap often enough) will tend to behave the same way.

The first connectionist model of linguistic analogy was Rumelhart and McClelland (1986), a simple network that was taught to directly associate English present tense forms with past tense forms. With enough training the network was able to generalize to new forms by implicitly referring to the examples that it had learned. For example, given untrained irregular and regular verbs like *weep* and *drip*, it correctly responded with *wept* and *dripped*. Moreover, the model seemed to treat regular past tense as a special case, overregularizing many irregular verbs, just as children acquiring English do. Rumelhart and McClelland (1986) thus drew the reasonable though dramatic conclusion that human language (at least English tense inflection) did not require rules. There was no regular rule such as 'add *-ed*'; instead, all past tense forms were derived by analogy.

However, subsequent work by the psycholinguist Steven Pinker and colleagues (e.g. Pinker and Prince 1988, Pinker 1991, Prasada and Pinker 1993) found several weaknesses in this model. The most fundamental was that the model was incapable of creating a true default, a category that is defined negatively as the 'elsewhere' case for all 'miscellaneous' items that don't fit into any of the other categories. The Rumelhart and McClelland (1986) model treated the *-ed* class as special only because it was so large; otherwise the *-ed* class was just one similarity-defined class among many.

This is not to say that connectionism is inappropriate for irregular inflection. There are good reasons for believing that people do in fact process irregular inflection by analogy. The first argument for this is that they can't be processing it by rule; any general rule you might come up with (such as '*ive* → *ove*' to account for *drive-drove*) will both overgenerate (e.g. *arrive-*arrove*) and undergenerate (e.g. *rise-rose* will be unexplained, though it shows the same *i~o* alternation). More importantly, people tend to extend irregular patterns more readily when there are more exemplars in the lexicon. For instance, Bybee and Moder (1983) found that speakers give the nonsense word *spling* the past tense form *splung* (by analogy with *cling*, *fling*, *sling*, *sting*, *string*, and *wring*) more often than they give *shink* the past tense form *shunk* (which is only similar to *shrink*, *slink* and *stink*). In short, real people, like connectionist models, use irregular inflection by making analogies with exemplars in memory.

By contrast, real people treat regular inflection as a unique default case, as if processed by an exemplar-independent general rule. All of the arguments for this are based on evidence that regular inflection is used precisely when speakers cannot access

examples in memory with which to form analogies. This can happen in a bewildering variety of ways that have nothing in common except that lexical access cannot be involved. Marcus et al. (1995) list twenty-one such ways, including: when forms are too different from exemplars in memory (e.g. unusual sounding words as in *He out-Gorbacheved Gorbachev*); when lexical entries are too weak (e.g. low-frequency words like *chided*, originally *chid*); when forms are being mentioned rather than used (e.g. quotations like *There are two 'man's in the phrase 'man to man'*); when forms are derived from another category (e.g. denominal verbs like *striked* 'went on strike'); and when memory problems make lexical access difficult (e.g. with children or anomic aphasics, both of whom overuse regular inflection). Such evidence has led Pinker and colleagues to support a hybrid model of inflection, whereby only irregular inflection is handled by analogy; regular inflection is handled by rule.

Connectionists have not remained idle in the face of such evidence. Work by MacWhinney and Leinbach (1991), Plunkett and Marchman (1991, 1993) and Hare et al. (1995) all argued that the failure of the McClelland and Rummelhart (1986) model was primarily caused by its overly simple structure. In order to achieve success with English inflection, however, the newer models all have overly complex structures. For example, the Hare et al. (1995) model seems capable of learning defaults even when they do not form the largest class, but it does this by building in the assumption that *-ed* is special, reserving nodes just for this ending that 'inhibit' nodes for the vowel (which should change in irregular verbs but not in regular ones). It appears, then, that connectionism is technically able to simulate default effects, but only by hard-wiring more 'rule-like' structures.

Why is there such a fuss over what seems at first to be a minor technical issue about the mechanics of inflection? The reason is that the debate really concerns what is special about human cognition. Are people (and other animals) merely associationist machines as the behaviorists believed, infinitely moldable by experience? Or do people have built-in mental structures of some sort that give them the ability to jump beyond similarity-driven analogy into the domain of general symbol-manipulating rules? Pinker (1999) provides a book-length meditation on such questions, and his perspective is made clear in the title of one of its chapters: 'A Digital Mind in an Analog World.' As he wrote in an earlier book:

> People think in two modes. They can form fuzzy stereotypes by uninsightfully soaking up correlations among properties.... But people can also create systems of rules... that define categories in terms of the rules that apply to them....(Pinker 1997:127)

As examples of rules in human cognition, he lists not just grammar, but also kinship systems, laws, arithmetic, folk science, and social conventions. This is a rather ambitious vision, but it raises a much less ambitious but still intriguing question. If the rule/analogy dichotomy is found in inflection because this dichotomy is fundamental to the makeup of the human mind, then shouldn't we expect to find it in other aspects of language as well? Could it even be found in a language that is famed for its virtual lack of overt inflection?

3. The Mandarin classifier system

Thus we are led to something that at first seems completely different: the Mandarin noun classifier system. Many languages mark semantically-defined noun classes with special morphemes (see Allan 1977, Aikhenvald 1997). In Mandarin, this involves the requirement that NPs containing numbers or determiners must include a monosyllabic morpheme called a *CLASSIFIER* (or sometimes *MEASURE WORD*). In this section we give a general overview of the Mandarin classifier system, ending with an observation that sets the stage for the rest of the paper.

There are actually several different kinds of morphemes that fall under the umbrella term 'classifier' that vary considerably in their semantic properties. Some kinds of classifiers are typically used with mass nouns, such as standard measures (e.g. 一磅肉 *yi-bang rou* 'a pound of meat,' 一斤肉 *yi-jin rou* 'a catty of meat'), container measures (e.g. 一杯茶 *yi-bei cha* 'a cup of tea', 一碗飯 *yi-wan fan* 'a bowl of rice') and partitive measures (e.g. 一塊蛋糕 *yi-kuai dangao* 'a piece of cake', 一片土司 *yi-pian tusi* 'a slice of toast'). As can be seen by the glosses, English has this sort of thing too; also found both in Mandarin and English are group measures (e.g. 一群狗 *yi-qun gou* 'a pack of dogs', 一雙筷子 *yi-shuang kuaizi* 'a pair of chopsticks'). The syntactic similarity of such cases with the English *of* construction is hinted at by the fact that all of these classifiers allow the appearance of the modifier marker 的 *de*, as in *yi-bang de rou* 'a pound of meat' (Tai 1994, Kuo 1998). In addition to these classifiers, Ahrens and Huang (1996) propose the recognition of kind classifiers and event classifiers, which quantize kinds and events, respectively (e.g. 那種馬 *na-zhong ma* 'that kind of horse'; 這場電影 *zhe-chang dianying* 'this (showing of a) movie').

The semantics of the above classifiers are quite subtle and complex, and we will have to talk about some of them later, but we will spend most of this paper discussing another sort, the individual classifiers. These are what linguists typically think of when they think of noun classifiers: morphemes that are selected by individual entities on the basis of their inherent semantics. Such classifiers fail the *de* test, suggesting that they are distinct from standard measures, container measures, partitive measures, and group measures; they quantize individual entities, suggesting that they are distinct from event

and kind classifiers as well. In the following table we list the individual classifiers that we have examined the most carefully (they are the most common ones), along with some examples of nouns they cooccur with. We've also given simplified semantic descriptions for the noun classes, but the actual role of semantics in the use of these classifiers is quite complex, as we will shortly illustrate (see also Kuo 1998, Shi 1996, Tai 1994, Tai and Chao 1994, Tai and Wang 1990 and many other sources for fuller discussion).

Table 1.

Classifier	**Examples**	**Semantics**
個 *ge*	人 *ren* 'person'	humans
	國家 *guojia* 'country'	abstractions
	西瓜 *xigua* 'watermelon' 太陽 *taiyang* 'sun'	3D objects
位 *wei*	老師 *laoshi* 'teacher'	humans (respectful)
張 *zhang*	紙 *zhi* 'paper' 桌子 *zhuozi* 'table'	flat, broad objects
條 *tiao*	路 *lu* 'road' 魚 *yu* 'fish'	flexible oblong objects
件 *jian*	事情 *shiqing* 'thing, affair'	abstractions
	衣服 *yifu* 'clothing'	clothes
片 *pian*	葉子 *yezi* 'leaf'	flat objects
隻 *zhi*	狗 *gou* 'dog'	animals
	鞋子 *xiezi* 'shoe'	one of a pair
枝 *zhi*	鋼筆 *gangbi* 'pen'	cylindrical rigid oblong objects
顆 *ke*	牙齒 *yachi* 'tooth'	small objects
粒 *li*	米 *mi* 'rice grain'	very small objects
面 *mian*	牆 *qiang* 'wall'	flat objects
根 *gen*	棍子 *gunzi* 'stick'	rigid oblong objects
把 *ba*	刀子 *daozi* 'knife' 椅子 *yizi* 'chair'	things with handles

One important way in which this table is misleading is that it treats *ge* as just one individual classifier among many. Actually, it has traditionally been held that *ge* is unique among individual classifiers in that it may be substituted for any of the others. For instance, speakers don't have to say 一張桌子 *yi-zhang zhuozi* ('a table'); they can (and many do) say 一個桌子 *yi-ge zhuozi* instead. For this reason, *ge* has been

called the *GENERAL CLASSIFIER*, with all of the other individual classifiers called *SPECIFIC* (or *SPECIAL*) *CLASSIFIERS* (e.g. Li and Thompson 1981).

4. Analogy in the Mandarin classifier system

Now that the basic terminology is clear, we can turn to our main interest: showing that the general classifier *ge* acts like regular inflection (i.e. is processed by rule) while the specific classifiers act like irregular inflection (i.e. are processed by analogy). We start with the specific classifiers, since they have naturally been the focus of much of the classifier literature.

As explained in the previous section, specific classifiers are sensitive to semantic features, but as it turns out, not in a way that can be expressed by general, exceptionless rules (Tai 1994, Tai and Wang 1990, Tai and Chao 1994). For instance, take the semantic characterization of *tiao* in Table 1 above. If we proposed a rule that read 'Use *tiao* for all flexible oblong objects', this rule, like proposed rules for irregular inflection, would work much of the time but would also both overgenerate and undergenerate. Thus it would falsely predict that 一條頭髮 *yi-tiao toufa* 'a hair' is acceptable, and that 一條板凳 *yi-tiao bandeng* 'a bench' and 一條新聞 *yi-tiao xinwen* 'a piece of news' are unacceptable.

Specific classifiers, like irregular inflection, are also influenced by similarity (in this case, semantic similarity) with lexical exemplars. For example, consider paper, beds, tables and sofas; these are all 'flat' in some sense, but clearly some are flatter than others. Ahrens (1994) has shown that this affects the likelihood that speakers will actually use *zhang* with these objects (most likely with paper, least likely with sofas), suggesting that paper is the prototype for the *zhang* class (in the sense of Rosch 1973). Another way to say this is that paper is a privileged exemplar of the *zhang* class; speakers seem to decide whether to use *zhang* with an object on the basis of that object's similarity to paper. In other words, speakers use analogy.

Another property that suggests analogy is the fact that speakers extend the use of classifiers on a case-by-case basis. In the domain of vegetables and fruit, for instance, *tiao* is consistently used for objects that are in fact oblong; one says 一條黃瓜 *yi-tiao huanggua* 'a cucumber' but usually not 一條西瓜 *yi-tiao xigua* 'a watermelon'. As Wiebusch (1995) points out, however, in the domain of clothing *tiao* is extended quite freely; one says 一條褲子 *yi-tiao kuzi* 'a pair of pants' (because pants are in fact long), but also 一條短褲 *yi-tiao duanku* 'a pair of shorts' (which by definition are not). Similarly, when they are oblong, both tables and paper remain flat, but only tables continue to require the use of *zhang*; strips of paper may take *tiao* (Shi 1996). Other objects, such as towels, are both oblong and flat, but the required classifier is *tiao*, not *zhang*. Prototypical fish are oblong, and so they always take *tiao*, never *zhang*, even if

they are as flat as a flounder (Kuo 1998). Distinguishing *tiao* from *gen* and 枝 *zhi*, which also mark oblong objects, can really only be done by citing many examples, and the same is true about distinguishing *zhang* from the other 'flat object' classifiers *pian* and *mian* (Tai and Wang 1990, Tai and Chao 1994).

Finally, evidence from language acquisition suggests that specific classifiers are learned on an analogical basis. Erbaugh (1986) reports that children extend their use of specific classifiers from the most prototypical exemplars outwards to the peripheries of the category. Children also make extensions by association; Hu (1993) cites the example of a child who used the clothing classifier *jian* both for clothes and for washing machines (which actually require the 'machine' classifier 台 *tai*).

It appears that to explain such complexities with rules alone, we'd need almost as many rules as there are lexical items. This is precisely the sort of situation that calls for analogy. On top of all this, of course, specific classifiers are sensitive to the lexical semantics of nouns, an area of language where connectionist modeling has had particular success (e.g. Collins and Loftus 1975, McRae, de Sa, and Seidenberg 1997).

However, we should make it clear that the fact that analogy plays a major role in the selection of specific classifiers does not mean that the classifier system is as as arbitrary as irregular inflection. While it may be natural to extend the *drive-drove* pattern to *dive-dove* by analogy, there is no synchronic reason (from the perspective of native speakers) why the *drive-drove* pattern should exist in the first place: it is merely an accident of the history of English. By contrast, there are important cognitive factors in the selection of specific classifiers that go beyond accidents of the history of Mandarin and consequent analogical spread. For example, the 'flat object' classifier *zhang* seems intuitively appropriate for tables even for non-native speakers, although objectively speaking tables are not merely flat. We will allude to such cognitive factors later in section 5.2.

5. The general classifier *ge* as rule

We claim that *ge* is not controlled by analogy. Rather speakers select it by a default rule: if they cannot find an exemplar in memory that goes with a specific classifier, then they will use *ge*. This is a spelling-out in processing terms of what seems to be meant by 'general classifier'.

Although some readers may find this conclusion unsurprising, not everyone believes that *ge* is really a general classifier (e.g. Loke 1994). Zubin and Shimojo (1993) even go so far as to question the very concept of a general classifier cross-linguistically. They suggest that so-called general classifiers can have three distinct functions in a classifier system, thus implying that a language needn't have a unique default rule.

Fortunately, as demonstrated below, Mandarin *ge* serves all three of the functions that Zubin and Shimojo ascribe to general classifiers (although in their paper they imply that *ge* only serves one of them). More important for our purposes, *ge* behaves like a true default in processing, since it is used in a wide variety of situations that have nothing in common except for the inability to make analogies with examples in the lexicon.

5.1 *Ge* and semantic content

If *ge* is a true default, then it should not be allowed to have any special meaning of its own. In this subsection we argue that this is indeed the case, first responding to Loke (1994), and then adding two new arguments from our corpus analysis.

One of Loke's reasons for supposing that *ge* has semantic content is founded on the observation that there are well-defined semantic classes that take only *ge*. These include humans (or more precisely, humans for whom it would be inappropriate to use the polite *wei*, e.g. 小偷 *xiaotou* 'thief', 小孩 *xiaohai* 'child'), solid three-dimensional objects above a certain size (e.g. 西瓜 *xigua* 'watermelon') and abstractions (e.g. 希望 *xiwang* 'wish'). However, these semantic categories for *ge* are so disjoint that they may be more easily defined as representing all nouns that do not require a specific classifier. That is, the reason why *xiaotou*, *xigua*, and *xiwang* all take *ge* is not because thieves are people, watermelons are 3D, and wishes are abstractions, but because none of these are in the categories 'people to be polite to' (requiring *wei*), 'animals' (requiring *zhi*), 'flat objects' (requiring *zhang*), and so forth. The only classifier left over after eliminating all the inappropriate ones is the default classifier *ge*.

This complement function of *ge* is in fact one of the three suggested by Zubin and Shimojo (1993) as being served by a general classifier. The reason the semantic categories ostensibly marked by *ge* are disjoint is because they represent the negative space left by removing the more coherent categories marked by the specific classifiers.

Of course, some specific classifiers also mark quite distinct semantic categories; thus 隻 *zhi* is used both for animals and for one of a pair. When this happens with specific classifiers, however, there are historical reasons, and indeed reasons that are consistent with the idea that specific classifiers are processed by analogy, since historically they have spread from semantic class to semantic class on an exemplar basis or else have involved the orthographic merging of two distinct morphemes. *Zhi*, for instance, was first used for individual birds (the character 隻 *zhi*, showing a bird in a hand, was in opposition to 雙 *shuang* 'pair', showing two birds; see e.g. Wieger 1927). This narrow category was later extended to all animals, but without totally eliminating the original meaning 'one of a pair'. In spoken modern Mandarin it's even

more complex, since 隻 *zhi* is pronounced the same way as 枝 *zhi*, the classifier for short oblong objects, which has a separate etymology. Since *ge* marks disjoint categories, Loke (1994) suggests that it too arose from the merging of originally distinct classifiers, but if so, this happened very early on. According to Wang (1989), *ge* was already used for classes as disjoint as animals, plants, money, and people even before it became the dominant classifier in the Tang dynasty (618-907 CE). The most we could say from such historical considerations is that *ge* came to serve the complement function in modern Chinese because in ancient times it marked too many disjoint semantic categories, and was therefore reinterpreted as a default classifier.

Another sign that *ge* is semantically vacuous comes from its patterning in headless NPs. Usually a head noun is only dropped when it is clear from context (as when a waiter asks 幾位？ *Ji-wei?* 'How many (people)?'), but it may also occur when the speaker does not know what to call the object (Yau 1986). Dropping the head noun is not such a great loss when the classifier itself provides enough semantic information to recover it. If *ge* carries as much semantic information as the specific classifiers, we would expect it to appear in headless NPs as often as they do, but this is not the case. In our corpus study, we found that *ge* appears proportionally less often before punctuation marks (e.g. periods or commas), and thus presumably in headless in NPs overall, than any of the other specific classifiers we examined (with the one curious exception of *gen*, which for some reason never appears before punctuation). The proportions reached significance by chi-squared tests for comparisons with all individual classifiers except for 枝 *zhi* (the number of observations was too low to make the test valid) and *pian*. The fact that *pian* also appears to be semantically vacuous by this test may be explained by its not being a very good individual classifier; as noted above in section 3, it can also be used as a partitive classifier, and thus has less tight semantic restrictions from the noun. This conclusion is bolstered by the finding that the kind classifier *zhong* also appears as rarely before punctuation as does the individual classifier *ge* (as a kind classifier, *zhong* of course has virtually no semantic linkage with the noun at all). These findings are summarized in Table 2.

Table 2.

Classifier	Number of tokens before punctuation	Total[1]	Proportion
個 *ge*	55	2000	0.0275
位 *wei*	90	1104	0.0815*
張 *zhang*	55	425	0.1294*

[1] The public Web interface to the Sinica Corpus only allows access of up to 2000 tokens per item.

條 *tiao*	48	682	0.0704*
件 *jian*	82	621	0.1320*
片 *pian*	17	422	0.0275
隻 *zhi*	29	337	0.0861*
枝 *zhi*	2	37	0.0541
顆 *ke*	14	228	0.0614*
粒 *li*	4	37	0.1081*
面 *mian*	11	73	0.1507*
根 *gen*	0	155	0.0000*
把 *ba*	26	213	0.1221*
種 *zhong*	67	2000	0.0335

*significantly different proportion from *ge*

Nevertheless, we are sure that many readers will be uncomfortable with the strong claim that *ge* has no meaning whatsoever. A common description of *ge* is that while it may be used as a default, it still has a core meaning of 'human' (e.g. Zubin and Shimojo 1993), and we must confess that this is consistent with our own intuitions as well.

Yet what precisely would it mean for *ge* to have a core meaning but also serve as a default? If we hypothesize that words for people take *ge* because *ge* is a default, and someone else hypothesizes that words for people take *ge* because *ge* is a default but also a 'person' classifier, do these two hypotheses make any testably different predictions? Probably not, and indeed, our hypothesis is to be preferred for parsimony reasons.

It won't help to settle the matter to ask people to list nouns that go with *ge*, and then call the most common choice evidence of its core meaning (as is done in Zubin and Shimojo 1993 for Japanese). Surely the most common choice for *ge* will be 人 *ren* ('person') (and pilot studies we have done have indeed found this), but this is probably because *ren* is the highest-frequency noun that collocates with *ge*. The high frequency of *ren* may help explain why some speakers believe that *ge* has the core meaning of 'human', but it doesn't prove that *ge* actually does have this core meaning in the sense of having privileged exemplars.

A better test would be to examine the distribution of the different semantic classes that collocate with *ge* (e.g. humans, abstractions, 3D objects) to determine which has the highest proportion of privileged exemplars. This can be measured by calculating the *MUTUAL INFORMATION* value (MI), whose formula is given in (1). Essentially, the MI describes how common a collocation is when the lexical frequencies of each word have been factored out. If two words x and y are distributed randomly, $MI(x,y) \leq 0$; if they form meaningful collocations, $MI(x,y) >> 0$; and if they are in complementary distribution, $MI(x,y) << 0$ (see Church and Hanks 1990).

(1) Mutual information value (for two words *x* and *y*)

$$MI(x,y) = \log\left(\frac{prob(x,y)}{prob(x)\cdot prob(y)}\right)$$

We used the MI calculations automatically provided by the public Web interface to the Sinica Corpus, given a window size of five words (i.e. all instances where a classifier appeared within five words before a given noun). All examples were screened to make sure that the classifier and noun weren't actually in unrelated clauses. The result was a list for each classifier we examined showing all collocating nouns with positive MI values. To give a flavor of these lists, Table 3 shows some sample items in the *ge* list, including the first and last items.

Table 3.

Rank	Noun	MI with *ge*	Semantic category
1	定點 *dingdian* 'fixed point'	6.645	abstraction
2	梯子 *tizi* 'ladder'	6.576	3D object
12	婆子 *pozi* 'hussy'	6.000	human
34	終了 *zhongliao* 'completion'	5.277	deverbal noun
368	學生 *xuesheng* 'student'	1.099	human

To deal with the issue of *ge*'s core meaning, we compared the number of collocating nouns of different semantic classes with an MI value above vs. below the median. If *ge* has a core meaning of 'human', we expect a greater proportion of 'human' nouns to appear above the median MI value, while the proportions for abstractions and 3D objects should be the same. As shown in Table 4, this is not what we found. None of the proportions reached significance by chi-squared tests, and the only one that came close was for abstractions (p=0.068). Thus contrary to what is standardly thought, nouns for humans do not have any special status in the *ge* category.

Table 4.

humans	abstractions*	deverbal nouns**	3D objects
27:37	121:104	8:15	27:29

*such as 社會 *shehui* ('society') **such as 希望 *xiwang* ('wish')

It's also worth noting that the most common semantic class by far is the set of abstractions. Does this mean that the core meaning of *ge* is actually 'abstraction'? We think not. After all, an abstraction by its very nature is something that has rather vague

semantics. A core meaning of 'abstraction' is tantamount to a core meaning of 'nothing'. Abstractions simply fall into the *ge* category by default because they aren't drawn to any specific classifier.

5.2 *Ge* and semantic similarity

Processing by analogy requires that an item be similar to exemplars in memory; the more similar it is, the more likely it will be treated the same way. The studies on inflection suggest that regular inflection is immune to such similarity effects. In particular, regular inflection is used more often precisely when there are no phonologically similar forms in memory to analogize to. We suggest that classifiers behave the same way: the less semantically similar a noun is to other nouns in memory, the more likely speakers will be to choose the default classifier *ge*.

This claim collapses the two remaining functions proposed by Zubin and Shimojo (1993) for general classifiers. In the unspecified referent function, a general classifier is used for nouns with extremely vague semantics. *Ge* has this function, too; 這個 *zhe-ge* 'this-*GE*' and 那個 *na-ge* 'that-GE' are the standard terms for 'this' and 'that' in headless NPs when the speaker doesn't want to or cannot be more specific. In other words, when speakers are faced with an object which has no inherent semantic features, such an object is of course not similar to any real example in memory, forcing speakers to fall back on the default *ge*.

The third proposed function of general classifiers is called the default function (though Zubin and Shimojo use 'default' in a different sense than is used in this paper). This means that the general classifier can replace (almost) any specific classifier (in certain situations). This is the only function they ascribe to Mandarin *ge*, by the way, since it has long been observed that speakers replace specific classifiers with *ge* far more often than you'd expect from grammar books and written styles (e.g. Erbaugh 1986, Loke 1996).

Of course, some substitutions are more common than others. As noted above, Ahrens (1994) found that speakers are more likely to replace a specific classifier with *ge* for less prototypical members. The same pattern was found by Tyan (1996) in a judgment task; speakers' judgments of the acceptability of *ge* for a given noun were inversely correlated with the acceptability of a specific classifier for that noun (e.g. *ge* N was judged better when *zhang* N was judged worse). This is precisely the behavior expected of a default, in our sense (although Zubin and Shimojo might consider this more of an example of the complement function): *ge* is used when a specific classifier isn't.

A related observation is that of Loke (1994), who notes that while *ge* does not replace shape-based classifiers like *zhang* very often, it is quite common to use *ge* instead of function-based classifiers (e.g. the 'vehicle' classifier 輛 *liang*). To Loke this implies that *ge* has semantic content, suggesting that *ge* cannot be substituted for shape-based classifiers since *ge* itself marks shape (namely, solid roundish objects above a certain size).

An alternative analysis is simply that function-based classifiers, for whatever reason, are just not as robust as shape-based classifiers. They certainly aren't as common, and research on language development has found that there is a strong preference to use shape rather than other characteristics to classify objects (Pinker 1989). Hence an object that can be classified by shape, such as a saliently flat thing, will have many similar exemplars in memory to analogize to, making the selection of *zhang* very likely. The same is expected of objects that can be classified as animals, 隻 *zhi* also being a very common classifier, and animacy also being a very salient semantic property in word learning (Pinker 1989). Thus objects, like vehicles, that cannot be classified by shape or as animate, will have fewer analogous exemplars in memory, and the exemplars that are present may not seem very similar (if shape and animacy are innately more salient than function). The result is that function-based classifiers are more likely to be replaced by the default *ge*. In other words, the different neutralization patterns of shape-based and function-based classifiers tells us more about the processing of those specific classifiers than it does about the processing of *ge*.

Recognizing the fact that some specific classifiers are more 'robust' than others helps us understand another phenomenon, namely 'neutralization' to classifiers other than *ge*. Some researchers have used this fact to conclude that *ge* is not the only default; other classifiers can serve as defaults within particular semantic classes. For example, Tyan (1996) observed that judgments for shape-based classifiers were also inversely correlated with those for *li* and *ke* in the category of small objects. Similarly, within the category of animals, some researchers (e.g. Hu 1993, Ahrens 1994) note that the 'default' appears to be 隻 *zhi*, not *ge*, so that when adults or children fail to use the specific 'horse' classifier 匹 *pi* (e.g. 一匹馬 *yi-pi ma* 'a horse'), they say *yi-zhi ma* instead, never *yi-ge ma*. Ahrens (1994:228) even claims that *zhi* (for her, including both 隻 and 枝) is 'on its way to becoming a neutral classifier' in Mandarin. If such conclusions are right, we cannot say that *ge* is produced by a unique lexicon-independent, semantics-independent default rule.

Some minor quibbles can be made; we will comment further on Ahrens (1994) below in 5.4.3, and we could note that the experiment in Tyan (1996) involved judgments, not classifier selection in production, which is our primary focus. However, a general response is more appropriate: such cases of 'neutralization' to specific classifiers really only show that classifier selection by analogy can override the *ge* rule

if there are sufficiently good examples in memory to form analogies with.

This is well illustrated the classifier 隻 *zhi*, which has several properties that make it a good candidate for analogical extension. First, it is among the most common classifiers. Second, it is semantically quite consistent; the vast majority of instances involve collocations with animals. Finally, as observed above, the semantic category 'animal' is extremely salient in human cognition.

Children acquiring English past tense inflection also overuse patterns other than the default *-ed*. For instance, children may say *brung* rather than *brought* as the past tense of *bring*. This doesn't mean that English has an additional default past-tense rule, but only that *sting-stung*, *ring-rung*, and so on, allow for particularly robust analogies that can override the default rule. The same sort of phenomenon appears to be found in the Mandarin classifier system.

5.3 *Ge* and atypical nouns

One interesting form of the argument that *ge* is used for nouns without analogous exemplars concerns cases where *ge* is used for nouns that aren't even really nouns.

First, our corpus study confirmed that *ge* is freely used with deverbal nouns, whether derived from active transitive verbs like 體驗 *tiyan* ('learn through experience'), stative intransitive verbs like 自由 *ziyou* ('be free'), or any other kind. This differs markedly from the specific classifier *pian* which also can take deverbal nouns, but when it does, they are all of one type, namely stative intransitives like 空白 *kongbai* 'be blank'. The specific classifier *jian*, which also may be used with abstract nouns, cooccurs with deverbal nouns in a significantly smaller proportion of its noun collocations than does *ge*.

Second, *ge* is the only classifier used with mentioned language, where linguistic units are treated as objects of discussion rather than referential symbols. (For example, this sentence treats 'This sentence is being treated as an NP' as an NP to illustrate this phenomenon in English.) When such ad hoc NPs receive a classifier in the corpus, this classifier is always *ge*. An example is given below.

(2) 你對我好，我也對你好，這個「好」就變得具有生命力。
Ni dui wo hao, wo ye dui ni hao, zhege 'hao' jiu biande ju you shengmingli.
"You're good to me, I'm good to you, this-GE 'good' comes to have vitality".

Finally, *ge* and only *ge* can be used to 'classify' linguistic constituents that are not even nouns at all. Thus speakers can use *ge* with adverbial resultative complements, as in 吃了個飽 *chi-le ge bao* 'ate until stuffed', or entire idioms, as in 問了個水落石出 *wen-le ge shuiluoshichu* 'asked until everything was clear' (Wu and Li 1997). Admittedly the use of *ge* in such contexts is somewhat anomalous, since it tends not to

be preceded by a numeral or determiner, giving a strange flavor to some constructions that include a numeral (e.g. 吃了一個飽 *chi-le yi-ge bao*). Other times, however, including the numeral doesn't seem to affect acceptability (e.g. 問了一個水落石出 *wen-le yi-ge shuiluoshichu*). Interestingly, children may use *ge* for non-nominal constituents more frequently than adults (e.g. Hu 1993:107 gives the example 一個不認識 *yi-ge bu renshi* 'one unrecognized'). These phenomena are clearly worthy of further investigation.

5.4 *Ge* and lexical access problems

The above arguments illustrate the default use of *ge* with forms when there are no good exemplars to form analogies; *ge* is also used as a default when such exemplars exist, but speakers have difficulty accessing them for various reasons.

5.4.1 *Ge* and collocation frequency

One way that lexical access can fail, thus triggering the use of *ge* with a noun, is if the collocation frequency of the noun with some competing specific classifier is too low. That is, speakers' selection of a specific classifier with a noun will depend partly on how often they have encountered that classifier-noun combination before: the rarer it is, the more likely they will be to neutralize to *ge*. As shown in Table 5, *ge* has the lowest mean MI for classifier-noun collocations of all the individual classifiers we examined (classifier frequencies are from CKIP 1994).

Table 5.

Classifier	Mean MI	Classifier frequency
個 *ge*	3.53	0.28447
位 *wei*	4.34	0.10062
件 *jian*	5.69	0.03676
條 *tiao*	5.86	0.03639
隻 *zhi*	6.11	0.01072
片 *pian*	6.32	0.02324
張 *zhang*	6.56	0.11932
顆 *ke*	7.13	0.00170
把 *ba*	7.33	0.05952
根 *gen*	7.85	0.00849
面 *mian*	8.11	0.02526
粒 *li*	8.38	0.00252
枝 *zhi*	9.42	0.00472

This suggests to us another parallel between *ge* and regular inflection. Regular verbs are, on average, less frequent than irregular verbs; in fact, the top 13 most frequent English verbs are all irregular (Pinker 1991). This is the case because over generations, speakers have forgotten the correct past tense forms for low-frequency irregular forms, and are thus forced to use regular inflection as a default; low-frequency irregular verbs thus become regular over time. The same may be true for classifiers in Mandarin. Collocations between a specific classifier and a noun that have too low an MI make it difficult for speakers to remember what specific classifier it was that went with that noun, thus forcing them to fall back on *ge* as a default choice. Over time this would cause *ge* to have a low mean MI value. Another way to say this is that *ge* has a high type/token ratio: many types (nouns) collocate with it, but each type only collocates a few times. This is also another sign of its being semantically vacuous (see Zubin and Shimojo 1993 for a similar argument for Japanese).

The impact of this discovery must be tempered by an obvious criticism, however. The calculation of MI involves dividing by the frequency of each collocating word, and in this case, one of these is the classifier. Thus increased classifier frequency may cause decreased MI, and *ge* is by far the most frequent classifier. This criticism is strengthened by the fact that over all of the specific classifiers studied, MI is strongly negatively correlated with classifier frequency (Spearman's r=-0.66, $t(12)$=-9.65, p<0.001). A scatterplot makes it clear that *ge* is a perfectly ordinary classifier in this pattern. In particular, the mean MI for *ge* is only slightly lower than that for *wei*, which is the classifier with the next lowest mean MI value. Nevertheless, the proportion of *ge*-noun collocations with MI over 5 is significantly lower than for any other classifier, including *wei*.

Of course, there is a valid reason why corpus linguists prefer MI to raw collocation frequency; highly frequent words tend to collocate more frequently by chance alone, and the only way to deal with this is to divide by the frequency of each word. Hence if MI is negatively correlated with classifier frequency, this is a meaningful finding, not an artifact of the calculation, although it's not yet clear quite what it means.

5.4.2 The acquisition of the classifier system

It is perhaps not surprising to find that nonnative adult learners of Mandarin overuse *ge* (Polio 1994), since most are explicitly taught that *ge* is the general classifier (Loke 1994). However, the same phenomenon occurs with children acquiring Mandarin as a first language (Hu 1993, Miao and Zhu 1992, Erbaugh 1986). The most natural explanation for this is that children (and perhaps also L2 learners) have trouble remembering what the 'correct' specific classifiers are supposed to be. Hence they are using *ge* as a default in our sense.

Overall, the way children acquire the Mandarin classifier system is quite consistent with our claims: children do overuse *ge* (since they have memory access problems), and they do extend the use of specific classifiers from prototypes to peripheral exemplars (since they acquire specific classifiers by analogy). Still, there is a curious fact that needs some comment. Children acquiring the English past tense show a U-shaped pattern in development (e.g. Marcus, Pinker, Ullman, Hollander, Rosen, and Xu 1992): at first all irregulars are correct as they are simply parroted back, then errors increase as they are overregularized, and finally accuracy improves again as exceptions to the regular rule are learned. By contrast, according to Erbaugh (1986), the stage where children overuse *ge* is not preceded by a stage where they use individual classifiers correctly. Thus classifier development in Mandarin seems to follow more of an S-shaped curve, where at first accuracy is low because children use only *ge*, and then gradually improves as they learn the specific classifiers. This is a bit mysterious. If examples of specific classifiers are in children's memory, why aren't they simply repeated back verbatim at the earliest stage?

One answer is that child-directed speech may contain such an overwhelming majority of *ge* tokens that children don't even notice at first that specific classifiers exist (Erbaugh 1986 notes that the adults in her study tended to use specific classifiers extremely rarely). To test this hypothesis, we are currently looking (with Jane Tsay) at the early acquisition of classifiers in Taiwanese, where *e*, the cognate of *ge*, also seems to behave as a default but is not used by adults in as high a proportion as *ge* is in Mandarin. As expected, here we do find a U-shaped learning curve, with initial correct production of specific classifiers before the age of twenty-six months followed by an extended period where the default classifier is overused.

5.4.3 Classifiers and aphasia

Lexical access difficulties also plague the sufferers of Broca's and Wernicke's aphasia, and as discovered by Tzeng, Chen and Hung (1991), they also neutralize to *ge* more often than normals. This finding is consistent with our claim that *ge* is chosen by default when memory-access problems prevent accessing the exemplars that guide the selection of specific classifiers.

However, the details are a bit more complex. First, the Wernicke's aphasics in this study, but not the Broca's, also overused *zhi*. For example, instead of replacing *liang* with *ge* for cars, as normals often do, some Wernicke's patients used *zhi*. Tzeng et al. (1991) interpret this as the crossing of semantic classes, suggesting that Wernicke's aphasia disturbs normal semantic processing. In a reanalysis of their data, Ahrens (1994) concludes instead that the Wernicke's aphasics in this study were code-switching from Mandarin to Taiwanese, where the cognate of *zhi* is claimed to be used as a default.

On the face of it, the view of Ahrens (1994) is more in line with the central claims of this paper, since both types of aphasic patients end up overusing defaults. Unfortunately, it isn't necessary to suppose that the Wernicke's patients were code-switching into Taiwanese to explain their overuse of *zhi*. First, the most common classifier in Taiwanese is not the cognate of *zhi* but rather the cognate of *ge*, just as in Mandarin (in fact, the cognates of 枝 *zhi* and 隻 *zhi*, which Ahrens lumps together because they rhyme in Mandarin, don't sound a bit alike in Taiwanese). More interestingly, Hu (1993) found that children acquiring Mandarin also overuse *zhi*, and the subjects in her study were the children of Mainland Chinese parents, not bilingual Taiwanese-Mandarin speakers. In Hu's study, as in Tzeng et al.'s (1991) original analysis of the Wernicke aphasics, the overused classifier pronounced *zhi* is 隻 *zhi*, the classifier for animals.

Nevertheless, the overuse of *zhi* by children or aphasics does not prove that it is also some sort of default. For the reasons discussed in 4.2 above, *zhi* is a prime candidate for analogical overextension. We therefore concur with the conclusion of Tzeng et al. (1991), interpreting their results as meaning that aphasics overuse the default *ge* rule due to memory access problems, while Wernicke's aphasics have additional problems with lexical semantics that cause them to overextend exemplar-rich specific classifiers.

This discussion of aphasia raises a more general issue. Supporters of the hybrid model of inflection have also made much of aphasia evidence (e.g. Pinker 1991). Since we support a hybrid model of classifier production, are we claiming that the brain processes inflection and classifiers in precisely the same way?

The answer to this must be no. The fact that the Broca's aphasics studied by Tzeng et al. (1991) overused 'the *ge* rule' conflicts with the claim made by Pinker (1991) that Broca's aphasics lose the ability to process all grammatical rules. Broca's area may be used in the processing of inflection (see also Jaeger et al. 1996), but as Tzeng et al. (1991) themselves conclude, it is unclear what its role is in the processing of classifiers. The difference in the acquisition patterns of inflection (U-shaped) and in classifiers (S-shaped) also hint at as yet unknown processing differences. Such observations are not fatal to our assertion that *ge* is treated as a default, but they also should serve as a check on more ambitious speculations that all aspects of human language obey rules of the same sort.

6. Concluding remarks

Given the direction of the arguments in this paper, we hope our readers agree with us about what the next steps should be. First, versions of the experimental studies on

inflection need to be carried out on Mandarin classifiers, in particular the ones relating to similarity and other lexical effects (Pinker 1991, Prasada and Pinker 1993, Marcus et al. 1995). Second, a connectionist model of the Mandarin classifier system should be attempted, to confirm that the specific classifiers can in fact be processed by analogy but that *ge* cannot. We are carrying out both of these steps right now. We expect that the results will confirm the basic conclusions of this paper, although surely they will also reveal many new complexities of the Mandarin classifier system as well. We may even end up increasing our understanding of nominal semantics and human categorization after all.

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