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Maria D. Sera, Kaitlin R. Johnson and Jenny Yichun Kuo

Classifiers augment and maintain shape-based categorization in Mandarin speakers

Abstract: Past evidence suggests that adult Mandarin speakers rely on shape more heavily than English speakers when categorizing solid objects (Kuo and Sera 2009). In this experiment, we began to examine that effect developmentally by investigating the acquisition of the three most common Mandarin Chinese classifiers for solid objects (i.e. ge, zhi and tiao) in relation to development in shape-based categorization by native speakers of Mandarin and English from 3 years of age to adulthood. We found that 3-year-old Mandarin speakers were above chance in their classifier knowledge, but this knowledge continued to develop through 7 years of age. We also found that Mandarin speakers relied more heavily on shape than English speakers, and that shape-based categorization among English speakers tended to decline with age on the trials in which shape choices matched the Mandarin classifiers. The findings suggest that classifiers initially augment Mandarin speakers' attention to the shape of solid objects, and then maintain this early stronger shape bias after they are fully learned. The work highlights how categorization and word learning are graded and intertwined.

Keywords: classifiers, categorization, shape-based categorization, development, Mandarin Chinese, language and cognition

Maria D. Sera: University of Minnesota. E-mail: sera@umn.edu
Kaitlin R. Johnson: University of Minnesota
Jenny Yichun Kuo: National Chiayi University, Taiwan

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1 Introduction

1.1 Preliminaries

Cognitive processes affect and are affected by the acquisition of language. Studies suggest effects of language on color categorization (Davidoff et al. 1999; Özgen 2004); on spatial memory (Levinson 2003; Hermer-Vazquez et al. 1999); on number (Pica et al. 2004; Carey 2009); on categorization of solid objects (Sera et al. 2002; Kuo and Sera 2009), and on non-solids (Lucy 1992; Lucy and Gaskins 2003; Li et al. 2009; Imai et al. 2010). For example, adult speakers of Berinmo and Himba, languages that do not have different words for *blue* and *green*, show worse discrimination between those colors than English speakers (Roberson et al. 2000). Thus, any comprehensive account of cognition and its development should incorporate the role of language.

One difficulty of incorporating language into accounts of cognition, however, is that language itself changes with development, and these changes are thought to reflect underlying cognitive development. There are studies showing differences between children and adults in their knowledge of color terms (Roberson et al. 2004); spatial terms (Martin and Sera 2006); number words (Sarnecka and Carey 2008) and other kinds of lexical items (e.g. Erbaugh 1986; Yamamoto 2005). For example, Roberson et al. (2004) found that acquisition of color terms was slow and showed a great deal of individual variation in children from two cultures between 3 and 6 years of age. Moreover, studies also indicate that language development reflects cognitive development (e.g. Smith 1984; Levine and Carey 1982). For example, Smith (1984) found that children initially respond correctly in a non-linguistic task that measured their concept of *red* before they respond correctly in a linguistic task that tested their knowledge of the corresponding term. More recent studies (e.g. Franklin et al. 2005) similarly suggest that English-speaking children discriminate across different English color categories *before* they fully know English color terms. The studies showing that language affects conceptual development but that conceptual development precedes language development raise the following question: How can language affect conceptual development if the language to be learned depends on learning the concepts first? In the current study, we begin to unravel the reciprocal relations between language and cognition by studying the development of both abilities in one group of children. We focus on the relation between the development of categorization and knowledge of Mandarin classifiers between 3 and 7 years of age because past research suggests that the two abilities undergo substantial developmental change during this period (e.g. Carey 1985; Erbaugh 1986), and that

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knowledge of classifiers may be behind some of those changes (Imai and Gentner 1997; Li et al. 2009). Scholars who have studied classifier acquisition have assumed that the order in which classifiers are learned reflects underlying changes in conceptual development (e.g. Yamamoto 2005). To our knowledge, however, there is no published study in which the two – categorization and classifier acquisition – have been examined in one group of children.

1.2 Categorization of solid objects

Evidence indicating that children do not fully learn classifiers – which divide objects into groups – until late childhood is not surprising given the significant conceptual development that occurs during this time. One of the most important categorical distinctions within solid objects that develops during this period is the differentiation of living from non-living things. For example, classic observations by Piaget attributed "animistic thinking" to children between 2 and 7 years of age who sometimes attribute lifelike qualities to inanimate objects (1929). They might say, for example, that the moon moved across the sky because it was alive. Even though researchers have learned considerably more about the development of children's "vitalistic" concepts since Piaget (Piaget 1929; Inhelder and Piaget 1964), and more recent studies indicate that young children's knowledge about living things is more sophisticated than Piaget believed (e.g. Carey 1985; Gelman 2003; Inagaki and Hatano 2006), there is still considerable conceptual change that occurs during early and middle childhood (see e.g. Keil 1983; Morris et al. 2000). For example, Keil (1983) found that children initially view plants as not alive (like rocks), and that there was an intermediate stage in which they overextend animal properties (e.g. "is awake") to plants. Recent evidence reported by Lindeman and Saher (2007) also indicates that the distinction between living and non-living things is not made uniformly by all adults; they found that adult college students who are superstitious attribute purpose to objects and explain biological processes in terms of organ intentionality (e.g. lungs *want* to breathe) much like children. Changes in the features used to categorize non-living solid objects have also been noted among English speakers. Functional similarity often outweighs shape similarity with increasing knowledge of functional artifacts (Freeman and Sera 1996). Kelemen and Carey (2007) have also shown that children sometimes over-generalize the idea that functional artifacts were made with a purpose in mind to other non-living solid objects. For example, they might say that rocks are "made for" throwing. In short, there is considerable evidence indicating a host of differences between children and adults from Western cultures in their categorization of solid objects.

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In contrast to the wealth of evidence on conceptual development in Western countries, there are just a handful of studies on categorization by Mandarin speakers (Zhang and Schmitt 1998; Saalbach and Imai 2007; Kuo and Sera 2009; Li et al. 2009), and even fewer that have examined the phenomenon in children (Chen 1978; Chiang and Chiu 2006; Li et al. 2009; Imai et al. 2010). Chen (1978) following Nelson (1974) found that between five and eight years of age Mandarin-speaking children's concepts of solid objects increase in both size and hierarchical organization. Chiang and Chiu (2006) offer evidence that Mandarin children have categories organized hierarchically by 10 years of age. To our knowledge, only two published studies have examined the development of shape-based[1] categorization in Mandarin speakers: Li et al. (2009) and Imai et al. (2010). Li et al. (2009) focused on the conceptual distinction between solid objects and substances, and found that Mandarin-speaking children rely on material similarity more than English-speaking children when extending novel words to simple solids. Imai et al. (2010) found more shape-based categorization in Mandarin-speaking 3- and 5-year-olds than in German-speaking children. Neither of these recent studies, however, examined children's developing knowledge of classifiers.

In the current study, we examined reliance on shape versus kind (taxonomic) similarity in Mandarin- and English-speaking children and adults' categorizations of solid objects. Reliance on shape similarity changes with development, at least among English speakers (Smith 1995; Mash 2006; Scherf et al. 2009; Sera and Millett 2011). For example, in a longitudinal study of 15- to 20-month-olds, Smith (1995) showed that reliance on shape in categorization was not observed among the youngest children but gradually increased as children learned nouns that referred to solid objects. Children who knew 50 or fewer nouns were just as likely to categorize solid objects by shape as by color. Only after children learned 80 nouns were they more likely to categorize novel objects by shape. So according to Smith and colleagues (Samuelson and Smith 1999; Colunga and Smith 2005; Yoshida and Smith 2003) shape-based categorization increases among English-speaking children as they learn English nouns. There exist, however, alternative interpretations of the increase in shape-based categorization by young English-speaking children that do not view noun learning as the cause (e.g. Waxman and Gelman 2010). Regardless of the reason for the increase, however, shape-based categorization seems to begin to decrease in English-speaking 4-year-olds who then begin to categorize solid objects based on their function, or as a plant, or

1 By shape-based we mean the number of salient dimensions – one, two or three – following Tai's (1994) analysis of Mandarin classifier use.

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animal (Baldwin 1992; Imai and Gentner 1997). Thus, it appears that shape-based categorization of solid objects may follow an inverted-U-shaped function among English speakers. In this paper, we begin to investigate the development of shape-based categorization by Mandarin speakers as they learn the most commonly used classifiers for solid objects (*ge*, *zhi*, and *tiao*) whose uses are, in part, shape-based.

1.3 Classifiers

Classifiers are words used in a variety of languages such as Mandarin Chinese, Japanese, Vietnamese and Hmong when counting or referring to objects. In some ways, all nouns in classifier languages function like English mass nouns. When making plurals of English mass nouns one has to specify a countable class such as grains, pieces, or bars (e.g. *three grains of rice, three pieces of furniture*). In classifier languages, one must also specify a class for the count nouns (Allen 1977). For example, when saying *one leaf* in Mandarin one would say, *yi pian yezi* (*one-CLASSIFER-leaf*). In this way, speakers of classifier languages group count nouns into additional categories. Because the analogy has been made between English mass nouns and all nouns in classifier languages (The Mass Noun Hypothesis), many studies have examined whether speakers of classifier languages treat the referents of count nouns as English speakers treat the referents of mass nouns (e.g. Lucy 1992; Imai and Gentner 1997; Li et al. 2009). For example, Lucy (1992) reported that adult speakers of Yucatec-Mayan rely more on material similarity (versus shape) when classifying entities than English speakers. More recently, Li et al. (2009) report that Mandarin speakers rely more on material similarity than shape when classifying simple solids and non-rigid objects.

Speakers of classifier languages, however, have not always been found to rely less on shape than English speakers in categorization tasks (e.g. Schmitt and Zhang 1998). In Mandarin Chinese, shape is an important basis for classifier use. For example, the classifier *tiao* is used to refer to long, flexible objects such as snakes and ropes, and the classifier *zhi* is used for long rigid objects (Tai and Wang 1990). Along these lines, Kuo and Sera (2009) found that speakers of Mandarin Chinese rely more heavily on shape than English speakers when categorizing solid objects. For example, when shown a picture of a broom and asked whether a vacuum cleaner or a fork is more similar to the broom, adult speakers of Mandarin Chinese were more likely than English speakers to choose the fork, likely because both are long and share the classifier *zhi*. Consistent with these latter findings, the Li et al. (2009) study did not find that Mandarin speakers rely more on material similarity than shape when extending words to novel complex

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solid objects. Thus, different patterns of classifier-noun combinations may affect categorization in different ways.

For these and other reasons, there is considerable debate on the validity of the Mass Noun Hypothesis, and on the mechanisms by which classifiers influence the meaning of noun phrases (e.g. Huang and Ahrens 2003; Cheng and Sybesma 2005; Zhang 2011). However, there is no disagreement that classifier languages make more distinctions within count nouns than English. Sera et al. (2010) recently showed that different classifier languages mark different distinctions within living things and functional artifacts. For example, Mandarin and Japanese have a classifier for people, unlike Hmong, which generally uses the same classifier for people as for other solid objects. Artifacts are also flexibly grouped across classifier languages, into shape-based, function-based or more "embodied" based groups. For example, *scissors* and *toothbrush* both take the same classifier in Mandarin (*ba*) because they are both held by the hand. In Japanese, *spoon* takes the classifier associated with long objects (*hon/pon*) and scissors takes a different classifier (*tsu*). Yet there has been little research on the role that these different patterns of classifier use play in the categorization of solid objects. Because Kuo and Sera (2009) linked shape-based differences in categorization to use and accessibility of the Mandarin language, we focus on the acquisition of Mandarin classifiers and their potential impact on Mandarin speakers' classification of solid objects in this paper.

Mandarin classifiers capture intrinsic features of nominal categories but because nouns have many properties, it is generally believed that there is no rigid one-to-one correspondence between classifiers and nouns. Some dictionaries list over 400 Mandarin Chinese classifiers (Huang and Ahrens 2003), however the actual number regularly used seems to be much smaller. In a recent study in which Mandarin classifiers were elicited by the most frequent 135 translations of English nouns for solid objects, Sera et al. (2010) found that the classifiers *ge, zhi,* and *tiao* accounted for 56.5% of classifiers used. Importantly, these three classifiers were elicited by nouns that refer to both living and non-living solid objects, and their uses were, in part, shape-based. By *shape-based*, we mean invoking the salient dimensions of an object, following Tai's (1994) account. By this view, *ge* is generally described as being used with nouns that refer to three-dimensional objects in which the three dimensions (i.e. the object's height, width, and depth) are equivalent, such as spheres and cubes. The idea that *ge*'s uses are shape-based in this sense is supported by studies showing that *ge* is not acceptable when referring to objects that have only one salient dimension (Loke 1994; Tien et al. 2002). It should be noted, however, that because most solid objects in the world are three-dimensional, *ge* is also extended and used as a general classifier with solid objects. Another frequently used classifier was *zhi*. There are two

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Chinese characters that correspond to *zhi*, resulting in two homophonic forms of *zhi*. One form of *zhi* (隻) is used for animals, and the other form (枝) is used for long, rigid, non-living objects. The design of our classifier acquisition task enabled us to assess developing knowledge of each homophone of *zhi*. The third most commonly used classifier was *tiao,* which was used with nominals that refer to both living and non-living objects that are long and flexible, such as snakes, ropes, scarves and fish.

There have been a number of studies on the acquisition of Mandarin classifiers. Many (though not all) of these studies have been based on naturalistic observation of the early speech of Mandarin-speaking children. There is consensus that the meanings of classifiers are acquired between the ages of 3 and 7 years of age, with a greater variety of classifiers being used by children with increasing age (Erbaugh 1986; Chien et al. 2003; Li et al. 2010). The most frequently appearing classifier in spoken Mandarin, *ge,* is used early and apparently as a placeholder by children as young as $2\frac{1}{2}$ years of age (Erbaugh 1986). Early uses of additional classifiers seem to be shape-based (Li et al. 2010). Hu (1993) also found that children's comprehension of shape-based classifiers was more advanced than their production of them. Classifier use for animals and living things also seems to develop. For example, Hu (1993) found that Mandarin-speaking children sometimes extended *zhi* (隻) to humans, unlike adults who only use *zhi* (隻) with non-human animals. Li et al. (2010) found that by 4 years of age the shape-based classifiers are used productively to refer to novel objects. Li et al. (2010) also found that the acquisition of these classifiers was not associated with the acquisition of counting. In short, there are good reasons to suspect that Mandarin classifier acquisition reflects (and affects) development in object categorization. For these reasons, we began to examine directly the relation between classifier and category learning in Mandarin-speaking children in the current study.

2 Method

2.1 Participants

Thirty-two participants in each of five age groups took part. All were native speakers of either Mandarin Chinese or English. There were 16 participants in each language and age group (N = 128). The age groups consisted of 3-year-olds, 5-year-olds, 7-year-olds and adults. The age ranges and average age of each group of children are presented in Table 1. The Mandarin speakers were from Chiayi, Taiwan, and were tested in Mandarin by a native speaker. The English speakers

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Group	English-Speaking		Mandarin-Speaking	
	Range	Average	Range	Average
3-year-olds	3;1–3;11	3;7	3;0–3;11	3;6
5-year-olds	5;0–5;11	5;5	4;10–5;11	5;4
7-year-olds	7;0–7;11	7;4	6;10–7;11	7;6

Table 1: Age range and average age of child participants

were from an urban area of the Midwest in the U.S., and were tested by an adult English speaker.

2.2 Design

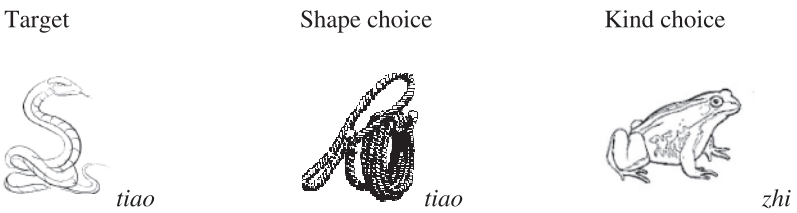
Each Mandarin speaker participated in two tasks, a categorization task and a classifier comprehension task. All of the participants took part in the categorization task first, and the classifier comprehension task second in order to reduce the possibility that participants' performance on the categorization task would be influenced by overt, recent mention of classifiers. English speakers only participated in the categorization task. The trials within each task were presented in four different random orders. So four participants per age and language group received each order.

2.3 Categorization task

The categorization task was a two-alternative, forced-choice task (TAFC). TAFC tasks are commonly used measures of categorization and its development that have generated a wealth of behavioral, neurological and computational evidence (see e.g. Hill 1898; Smith and Ratcliff 2004; Bogacz et al. 2006). Our categorization task consisted of six unique test trials with each trial presented once. For each trial, participants were shown three black and white drawings: a target drawing that depicted a living thing and two test drawings. One of the test drawings was similar to the target in shape but depicted an object that was not alive (a shape choice). A pilot study containing the drawings used conducted with English- and Mandarin-speaking adults established that the shape choices were indeed most similar to the target in physical shape by both language groups. The other test drawing depicted an object that was a living thing but of a different shape than the target (kind choice). An example of one set of drawings appears in

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(a) *Classifier-consistent trial*



(b) *Classifier-inconsistent trial*

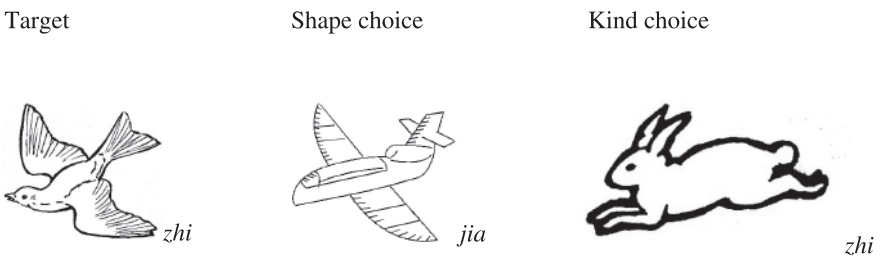


Fig. 1: A sample set of the black and white drawings used in the categorization task, including the Mandarin classifier that is commonly used with each object.

Target	Shape choice	Kind choice
woman	doll	chicken
snake	rope	frog
alligator	pencil	snake
bird	plane	rabbit
man	tree	baby
fish	light bulb	dragon

Table 2: Description of the items used in test trials of the categorization task.

Figure 1. Table 2 describes the items used in all of the trials. For half of the trials, the shape choices took the same classifier as the target. We called these classifier-consistent trials. For the classifier-consistent trial depicted in Figure 1, the rope and the snake which are similar in shape were nouns that elicited *tiao* from Mandarin-speaking adults in the Sera et al. (2010) study, unlike frog which elicited *zhi* (隻). If classifiers are driving the categorization differences previously found between English and Mandarin speakers, we would expect differences on these trials between the two language groups to increase as classifiers are learned.

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For the other half of the trials (the classifier-inconsistent trials), the shape choice elicited a different classifier from adults than the target. Thus, in Figure 1 both the bunny and the bird (two animals) elicited *zhi* (隻) from Mandarin-speaking adults and the airplane which is similar in shape to the bird elicited *jia* by all 10 Mandarin-speaking adults from Beijing tested by Sera et al. (2010). Thus, we could examine whether English and Mandarin speakers were judging similarity by shape and by classifier-item similarity.

The procedure of the task was as follows. All three drawings were presented on one 8 × 11 inch laminated sheet of paper with the target centered at the top, and the shape and kind choices below it. The shape and kind choices appeared an equal number of times on the right as on the left. In order to avoid use of the classifiers under study, we asked all of the participants to make judgments about the "pictures." The exact instructions given to participants were "See this picture (while the experimenter pointed to the target)? Which of these pictures (while pointing to shape and kind choices) is more similar to this one?" The Mandarin instructions, represented here in Pinyin (a Romanized writing system of Mandarin), were: *Na yi zhang han zhe zhang bijiao xiang?*

The first two trials were training trials in which categorization by shape and kind would lead to the same choices. For one of these trials, the target was a deer and the correct choice that matched the target in shape and kind was a sheep; the incorrect choice was a cup. For the second practice trial the target was an apple, and correct choice was an orange, and the incorrect choice was a dog. These trials were intended to make sure that all participants understood the task, and they were given feedback if they chose incorrectly.

2.4 Classifier comprehension task

The classifier comprehension task consisted of 18 unique trials, 3 shape and 3 kind trials, for each classifier (*ge*, *zhi*, and *tiao*). The two different types of trials were constructed to assess developing knowledge of the homophones of *zhi* independent of each other. Thus, the trials were designed to examine whether children's initial knowledge of the classifiers involved distinctions within the dimension of shape or distinctions within living things. All shape trials consisted of three line drawings of non-living things (e.g. an apple, a crayon, and a scarf). All kind trials consisted of three drawings that depicted living things (e.g. a girl, a bird, and a snake). A total of nine shape and nine kind trials were presented to each participant, with each different classifier being queried three times. So for example, a child would be presented with drawings depicting a ball, a pencil, and a belt three times. One time the child would be asked to "Give me one *ge*,"

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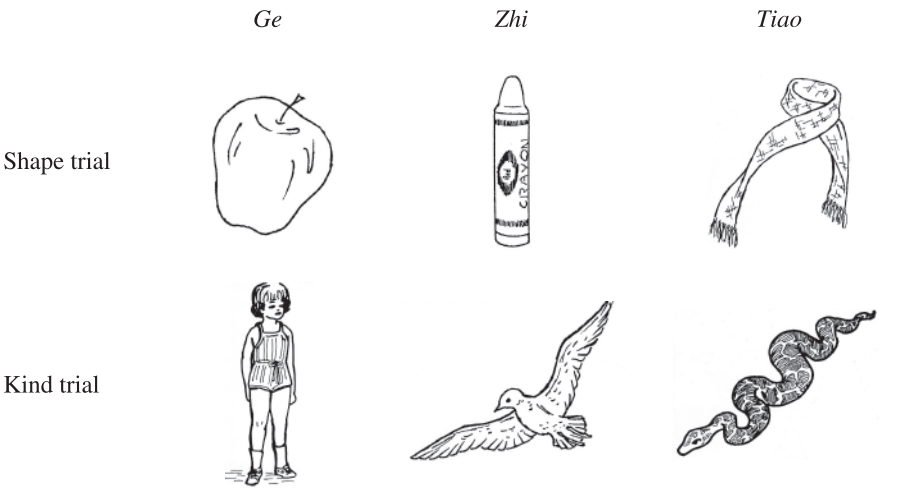


Fig. 2: Sample drawings depicting a shape and a kind trial of the classifier comprehension task.

another time they would be asked to "Give me one *zhi*," and one time they would be asked to "Give me one *tiao*." The pictures depicting each item were slightly different for each query. Figure 2 shows an example of the drawings used for one shape trial and one kind trial. Appendix A describes the items used in the classifier trials.

2.5 Procedure

The procedure for the classifier comprehension task worked as follows. The three drawings for each trial were placed in one small, clear, plastic bag. The experimenter would hand one bag to the participant at a time, and ask the appropriate query (Give me one *ge*/*zhi*/*tiao*). The participant then reached into the plastic bag and placed their answer into a box.

3 Results

3.1 Categorization task

We first calculated the percentage of shape choices by each participant on the classifier consistent and inconsistent trials. Then, we submitted these percentages

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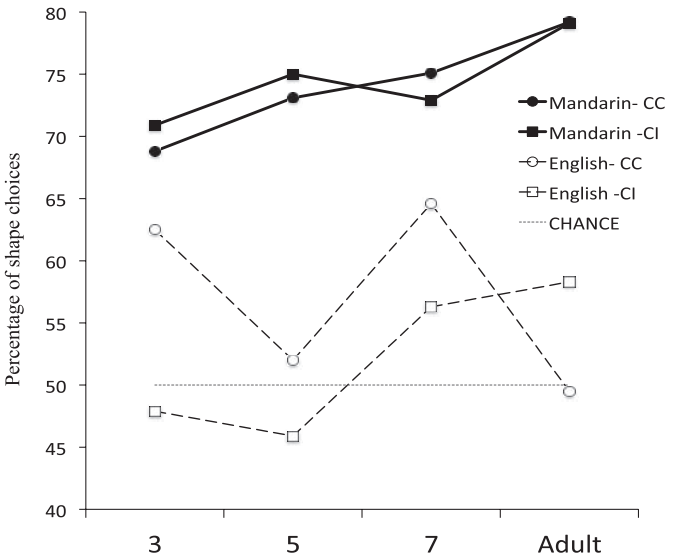


Fig. 3: The percentage of shape choices by Mandarin and English speakers for the classifier consistent (CC) and inconsistent (CI) trials as a function of age.

to a 3-way mixed design ANOVA with Language (English or Mandarin) and Age (3, 5, 7 or adult) as between-subjects factors and Trial Type (classifier consistent or classifier inconsistent) as a within-subjects factor. The analysis yielded a main effect of Language ($F(1,120) = 19.05$, $p < .001$), of moderate size (Cohen's $d = .54$). Figure 3 shows the average percentage of shape choices for each age and language group and trial type. The ANOVA yielded no other significant effects or interactions. The results from t-tests comparing the number of shape choices at each age group for each kind of trial appear in Tables 3 and 4. Tables 3 and 4 also show the effect sizes for each trial type as a function of age (Cohen's d). The pattern of effect sizes suggests that the difference between English and Mandarin

Age	Mean difference	Significance (2-tailed)	Cohen's d
3-yr-olds	6.3	$t(30) = .68$, $p = .50$	.246
5-yr-olds	21.0	$t(30) = 2.28$, $p = .03$	.830
7-yr-olds	10.4	$t(30) = 1.03$, $p = .32$	.376
Adults	29.4	$t(30) = 3.22$, $p = .003$	1.169

Table 3: The results from t-tests and calculation of effect sizes (Cohen's d) on the differences in shape choices for Mandarin and English speakers on the classifier consistent trials.

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Age	Mean difference	Significance (2-tailed)	Cohen's d
3-yr-olds	22.1	t (30) = 2.29, p = .03	.804
5-yr-olds	30.0	t (30) = 2.61, p = .014	.981
7-yr-olds	16.6	t (30) = 1.37, p = .182	.498
Adults	20.8	t (30) = 1.64, p = .111	.598

Table 4: The results from t-tests and calculation of effect sizes (Cohen's d) on the differences in shape choices for Mandarin and English speakers on the classifier inconsistent trials.

speakers increases with age on the classifier consistent trials. On these trials, we found no reliable difference between the English- and Mandarin-speaking 3-year-olds, but a reliable and very large difference (Cohen's d = 1.17) between the adults. Thus, the difference between the language groups increases with age on the classifier-consistent trials. The difference on the classifier-inconsistent trials was reliable only between the 3- and 5-year-olds, and the magnitude of the effect size decreased with increasing age (see Tables 3 and 4). Thus, the difference between the language groups decreased with age on the classifier-inconsistent trials. Further analyses (see Table 5) comparing the shape choices to chance (50%) indicated that the Mandarin-speakers' choices were greater than would be expected

(a) Classifier consistent trials

Age	Mandarin speakers		English speakers	
	t (15)	*p (2-tailed) =*	t (15)	*p (2-tailed) =*
3-yr-olds	2.91	.011	1.85	.084
5-yr-olds	4.22	.001	.268	.793
7-yr-olds	3.87	.002	1.89	.079
Adults	4.88	.000	−.009	.993

(b) Classifier-inconsistent trials

Age	Mandarin speakers		English speakers	
	t (15)	*p (2-tailed) =*	t (15)	*p (2-tailed) =*
3-yr-olds	2.84	.013	−.302	.767
5-yr-olds	3.49	.003	−.418	.637
7-yr-olds	2.48	.025	.797	.438
Adults	3.22	.006	.993	.365

Table 5: Shape choices vs. chance in the categorization task by English and Mandarin speakers on classifier-consistent and classifier-inconsistent trials as a function of age.

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by chance at every age group for both trial types. We found a trend for only two groups of English speakers to make more shape choices than would be expected by chance – 3- and 7-year-olds – and only on the classifier-consistent trials ($p < .09$, two-tailed t-tests; see Table 3). Thus, it appears that the difference between English and Mandarin speakers on the classifier-consistent trials is due to English speakers' shape choices *decreasing* with age.

The results from the categorization task replicate those of Kuo and Sera (2009) showing that Mandarin speakers rely more on shape to categorize solid objects than English speakers. Furthermore, they indicate that the differences are present as early as 3 years of age, and that they are in part due to less reliance on shape with increasing age by English speakers. The next set of analyses address how developing knowledge of classifiers co-varies with heavier reliance on shape within the Mandarin speakers.

3.2 Classifier learning

In order to examine the development of classifier understanding, we calculated the percentage of correct responses for each trial for each classifier by each age group of the Mandarin speakers. Table 6 shows the means. These percentages were submitted to an Age (3, 5, 7, or adult) × Classifier (*ge*, *zhi*, or *tiao*) × Contrast (shape or kind) ANOVA again with Age as a between-subjects factor, and Classi-

Classifier	3-yr-olds	5-yr-olds	7-yr-olds	Adults
		Shape trials		
ge	43.6	56.2[a]	79.2[c]	100.0[c]
zhi	60.4[b]	87.5[c]	100.0[c]	100.0[c]
tiao	43.6	81.2[c]	90.2[c]	100.0[c]
All shape trials	49.2[b]	75.0[c]	89.8[c]	100.0[c]
		Kind trials		
ge	31.2	58.4[a]	81.2[c]	91.6[c]
zhi	41.6	54.1[a]	93.8[c]	83.3[c]
tiao	50.1[a]	85.4[c]	95.8[c]	97.9[c]
All kind trials	41.0	66.0[c]	90.3[c]	91.0[c]
All trials	45.1[b]	70.5[c]	90.1[c]	95.5[c]

[a] $p < .05$; [b] $p < .01$; [c] $p < .001$

Table 6: Performance on classifiers relative to chance

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fier and Contrast as repeated measures. This analysis yielded a main effect of age ($F(3,60) = 52.5$, $p < .001$) showing reliable differences between 3- and 5-year-olds, and between 5- and 7-year olds, but no reliable differences between the 7-year-olds and the adults (Tukey's HSD, $p < .001$ for all reliable differences and $p > .22$ for all non-reliable differences). We also found main effects of Contrast ($F(1,60) = 6.8$, $p <= .001$) and Classifier ($F(2,60) = 14.6$, $p < .001$), and a two-way interaction between Contrast and Classifier ($F(2,75) = 12.6$, $p <= .001$). The main effect of Contrast indicated that performance was overall better on the shape trials than on the kind trials (78.5% versus 72.1%), and the main effect of Classifier indicated that performance on *ge* was worse than on *zhi* and *tiao* (67.7% versus 77.6% and 80.5% respectively). However, the interaction between contrast and classifier indicated that the shape advantage was primarily due to better performance on the shape trials of *zhi* (see Figure 4b). Comparisons to chance showed that the 3-year-olds' responses were only reliably better than chance on the shape trials of *zhi* ($t(15) = 4.4$, $p < .001$) and the kind trials of *tiao* ($t(15) = 2.5$, $p < .05$). The responses of all other age groups were well-above chance on all trial types. Table 4 shows the results from t-tests that examine whether performance is better than would be expected by chance for each trial as a function of each age.

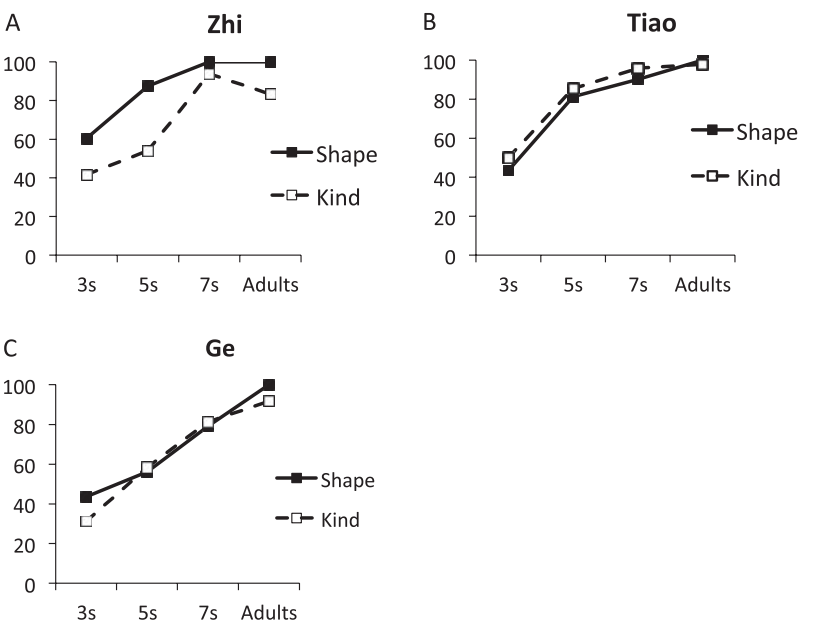


Fig. 4: Percentage correct on the shape and kind trials for each classifier (ge, zhi, and tiao).

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3.3 Classifier knowledge and shape-based categorization

If knowledge of classifiers promotes categorization by shape, we should find that the probability of categorizing by shape increases as knowledge of classifiers improves. We thus examined the probability of categorizing by shape (70% of the time or more; chance = 50%) by Mandarin speakers who had at least partial knowledge of classifiers (performed at 50% or higher; chance = 33%) and those that did not know classifiers (whose performance was chance-like or worse, 33% or lower). Table 7 contains the numbers and probabilities for each age group. Because speakers of English, who never learn classifiers, also sometimes classify by shape, we also included the probability that they categorize by shape at each age level in Table 7. Overall, we found that the probability of classifying by shape given that one knows classifiers was higher than the probability of classifying by shape given that one does not know classifiers (.65 vs .33 within speakers of Mandarin; and .65 vs .27 for Mandarin versus English speakers). We conducted a Chi Square test comparing the number of 3- and 5-year-old Mandarin-speaking children who classified by shape and either had some or no knowledge of classifiers. We only compared the distribution of 3- and 5-year-olds with the Chi Square test because there were no 7-year-olds or adults who did not know classifiers. We were also not able to examine the distribution of 3- and 5-year-olds separately because of the small number of children in some cells. The test yielded a reliable difference, $\chi^2_{(3)} = 8.25$, $p = .041$. These results suggest that knowledge of classifiers contributes to the tendency of Mandarin speaking-children to categorize by shape.

4 Discussion

The goal of this study was to examine the acquisition of classifiers in relation to the development of shape-based categorization in Mandarin speakers. Among speakers of English, shape-based categorization appears to develop according to an inverted U-shaped curve, increasing in early childhood, and then beginning to decrease around 4 years of age (Baldwin 1992). To our knowledge, this is the first study examining the development of shape- versus living-thing based categorization in speakers of Mandarin Chinese. We compared categorization by shape in English and Mandarin speakers because the most commonly used Mandarin classifiers with solid objects – *ge, zhi,* and *tiao* – are used with nouns that refer to both living and non-living things, and are sometimes shape-based. Thus, it is possible that knowledge of these classifiers leads to a greater reliance on shape by Mandarin speakers. Indeed, past findings suggest such differences between

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Age	Mandarin speakers						English speakers		
	Know classifiers			Do not know classifiers			Categorize by shape	Do not categorize by shape	Probability of categorizing by shape
	Categorize by Shape	Do not categorize by shape	Probability of categorizing by shape	Categorize by shape	Do not categorize by shape	Probability of categorizing by shape			
3-yr-olds	4	4	.50	3	5	.37	3	13	.19
5-yr-olds	10	5	.67	0	1	.00	3	13	.19
7-yr-olds	11	5	.69	0	0	–	7	9	.43
Adults	11	5	.69	0	0	–	4	12	.25
Totals	36	19	**.65**	3	6	**.33**	17	47	**.27**

Table 7: The probabilities of Mandarin speakers classifying by shape given that they either (1) have at least partial knowledge of classifiers or (2) do not know classifiers, and the probability of English speakers classifying by shape.

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English- and Mandarin-speaking adults (Zhang and Schmitt 1998; Kuo and Sera 2009). The results from the current study begin to reveal how those differences might develop.

Our results suggest a two-step process through which classifiers may influence categorization in Mandarin speakers. In the first step, and before classifiers are fully learned, classifiers seem to magnify attention to shape. This effect is suggested by the higher amount of shape-based categorization by the Mandarin speakers whose knowledge of classifiers is reliably better than chance but worse than the classifier knowledge of 7-year-olds and adults. The argument that this early stronger shape bias is due to knowledge of classifiers (as opposed to some other difference between the two groups) is supported by our finding within Mandarin speaking 3- and 5-year-olds that better knowledge of classifiers is linked with more shape-based categorization. In this first step, the magnification is across-the-board and is seen even on trials in which Mandarin-speaking adults typically use a different classifier for the shape choice than the target. The reason for this across-the-board effect is not clear. Perhaps most of the first nouns that Mandarin-speaking children learn co-vary with shape classifiers (versus other classifiers), and children may overgeneralize the classifiers that co-vary with these nouns to similarly-shaped objects. For example, young children who know *bird* and its corresponding classifier (*zhi*) might use *zhi* for the airplane as well as the bird of our classifier inconsistent trial in Figure 1. Future work that examines more closely which Mandarin nouns are learned first, and the classifiers that co-occur with those nouns should shed light on this possibility.

In any case, our results also suggest a second way that classifiers may influence categorization. This second step occurs later, after classifiers are fully learned, and involves maintaining greater attention to shape among adults. The evidence for this process comes from the pattern of choices on the classifier-consistent versus inconsistent trials. The effect sizes suggest that the largest difference between the adults is on the classifier-consistent trials, and the comparisons to chance on these trials suggest that some of the English-speaking children's shape choices tend to be higher than would be expected by chance, unlike the adults' choices. Thus, on the classifier-consistent trials, the shape choices between the Mandarin and English speakers become increasingly more different with development, and this increasing difference seems to be due to the English speakers' shape choices *decreasing* with age. Admittedly, the evidence for this finding should be confirmed in future work with a larger set of objects and in different tasks. Nonetheless, these findings suggest that the differences between English and Mandarin speakers increase with age, and may be due to English speakers' reliance on other properties of objects with development.

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One aspect of our findings that warrants caution is the relatively high number of shape choices that we found for all groups. This could be due to the particular items that were studied. Indeed several findings suggest that the degree to which Mandarin speakers rely on shape versus other properties varies with respect to the kind of object that is being examined (Kuo and Sera 2009; Tsai 2008; Li et al. 2009). However, a more likely reason is that we could not describe the items in the pictures without using a classifier. By specifically querying them about the similarity of the "pictures," we might have drawn participants to the pictures and their physical characteristics, leading all of the participants to rely more heavily on shape than they would otherwise. We should also point out that these results do not necessarily imply that speakers of Mandarin do not rely on internal biological characteristics when classifying living things, nor that their reliance on shape overwhelms their attention to other characteristics of all objects. Clearly, whether there are deeper differences between speakers of Mandarin and English in their concepts of living things is a question for future work.

In sum, as a first step towards untangling the relations between categorization and classifier learning in Mandarin speakers we have shown that there are differences in shape-based categorization early in development between English and Mandarin speakers, that knowledge of classifiers seems to contribute to that difference, and that the size of the difference may vary with development. Future work that examines the nouns that are initially learned by Mandarin-speaking children, and whether the classifiers that co-vary with those first-learned nouns are overgeneralized, will shed additional light on how learning words and categories are graded and intertwined. Examining how learning classifiers and categories affect each other in development is a rich domain in which to study the reciprocal relations between language and cognition.

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Appendix A

Description of the items used for the shape and kind classifier trials used in the classifier comprehension task.

Training trials	**bicycle** **spoon**	**cat** **boat**	**truck** **baby**
Shape Trials	ball apple plate	pencil crayon pen	belt scarf pants
Kind Trials	woman girl man	elephant bird bunny	fish snake dragon

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