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The role of visual form in lexical access: Evidence from Chinese classifier production

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ABSTRACT

The interface between the conceptual and lexical systems was investigated in a word production setting. We tested the effects of two conceptual dimensions – semantic category and visual shape – on the selection of Chinese nouns and classifiers. Participants named pictures with nouns ("rope") or classifier–noun phrases ("one-*classifier*–rope") in three blocked picture naming experiments. In Experiment 1, we observed larger semantic category interference with phrases than with nouns, suggesting comparable semantic categorical effects on classifier and noun selection. In Experiments 2 and 3, items with similar shapes produced an interference effect when they were named with classifier–noun phrases, but not with bare nouns. This indicates that object shape modulates classifier (but not noun) selection. We conclude that object shape properties can by themselves influence word selection processes just as semantic relationships (captured by semantic category) do. The factors operating during word selection may be more diverse than has been previously thought.

1. Introduction

To convey a message, a speaker must retrieve from memory the words that best express her thoughts. This process occasionally derails, and an unintended word is produced. Errors of healthy or aphasic speakers often involve words related in meaning, most notably members of the same semantic category, despite the speakers' firm knowledge of the message (e.g., Caramazza & Hillis, 1990). These errors are assumed to originate at the interface between conceptual[1] and lexical representations, due to difficulties in selecting the appropriate lexical response. The prevalence of semantic category coordinates in word substitutions has suggested that semantic relatedness, at least the kind captured by category coordinates, plays a central role during word production.

This idea has been intensively examined for over two decades in word production research using chronometric experiments with concrete nouns as stimuli. In the picture–word interference paradigm, participants name pictures while ignoring distractor words. Distractors that are semantic category coordinates of the target delay participants' responses more than unrelated ones (e.g., Lupker, 1979; Rosinski, 1977; Schriefers, Meyer, & Levelt, 1990). In the blocked naming task, participants translate words or name pictures in blocks comprising a few items. Responses are slower in blocks comprising semantic coordinates than in unrelated blocks (e.g., Kroll & Stewart, 1994; Schnur, Schwartz, Brecher, & Hodgson, 2006; for similar findings in other experimental settings see Bloem and La Heij (2003), Howard, Nickels, Coltheart, and

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[1] No attempt was made to distinguish between concepts and semantics; these two terms are used interchangeably.

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Cole-Virtue (2006), Humphreys, Lloyd-Jones, and Fias (1995), Wheeldon and Monsell (1994), etc.; but see Damian and Bowers (2003)). The interpretation of such semantic interference effects has been at the heart of influential models of lexical access (e.g., Levelt, Roelofs, & Meyer, 1999). The most prevalent view is that lexical access in production is sensitive to activation levels of the lexical nodes, which are determined by their semantic distance with the target concept. Semantic category membership is a common way of manipulating semantic distance.

Significantly, however, experimental conditions that involve other types of semantic relationships usually yield no reliable effects, or facilitation rather than interference (e.g., Costa, Mahon, Savova, & Caramazza, 2003; Glaser & Düngelhoff, 1984; see Mahon, Costa, Peterson, Vargas, and Caramazza (2007), for a summary of findings). Examples include "part of" relationships (e.g., engine-car, Costa, Alario, & Caramazza, 2005) and verbal association manipulations in the picture–word paradigm (Alario, Segui, & Ferrand, 2000; La Heij, Dirkx, & Kramer, 1990; Lupker, 1979; in blocked naming, verbal association manipulations pattern with semantic category: see Abdel Rahman and Melinger (2007), and the general discussion below). These findings have suggested that semantic effect is not merely driven by semantic distance, but that semantic relationships captured by category coordinates play a special role in word production (see below for further discussion for processing assumptions).

To understand whether or not word selection is driven solely by category coordination, we focused on a semantic dimension that can be largely orthogonal to semantic category: visual structural similarity – Objects such as *banana* and *bow* have structural similarities despite belonging to different semantic categories. The effect of object shape in noun production has been previously investigated, but strong conclusions have remained elusive.

In the picture–word paradigm, object shape interference has been observed in some studies (e.g., Neumann & Kautz, 1982; discussed in La Heij (1988)) but not in others (Mahon et al., 2007). These inconsistencies may arise because printed (distractor) words do not activate the visual properties of their referents in a systematic manner (as suggested by contrastive results reported in word recognition settings: Dahan & Tanenhaus, 2005; Huettig & Altmann, 2004, 2007; Pecher, Zeelenberg, & Raaijmakers, 1998; Schreuder, Flores D'Arcais, & Glazenborg, 1984); the clarification of this issue may come from convergent evidence across different paradigms (Huettig & Hartsuiker, 2008; Huettig & McQueen, 2007). In contrast, there are clear indications that, under strong time pressure, shape or visual similarity contributes to or modulates semantic category effects in error generation (Lloyd-Jones & Nettlemill, 2007; Vitkovitch, Humphreys, & Lloyd-Jones, 1993; Young, Ellis, Flude, McWeeny, & Hay, 1986; see also La Heij, 1988). However, the interpretation of these findings has highlighted an interaction between visual properties and semantic categorical membership, rather than proposing that visual shape properties alone modulate word selection (although see Humphreys, Riddoch, AND Quinlan (1988), who reported an interaction between the factors shape similarity and lexical frequency). Indeed, the few pure visual shape errors observed in those studies have been attributed to failures of visual structure access. Huettig and Hartsuiker (2008) reported that non-coordinated visually related distractors, found to be active during a naming trial, did not influence the production latencies of the target word. Finally, post hoc tests of a role of visual similarity in the blocked naming paradigm failed to show any effect (Damian, Vigliocco, & Levelt, 2001).

A related reliable finding is that naming a color (e.g., GREEN) is delayed more by color related distractor words ("blood") than by non-color words ("door"; Klein, 1964), suggesting that a visual property (e.g., "redness") of the distractor affects word production. However, such results could be attributed to the strong *blood-red* verbal association and/or the fact that *red* was part of the small response set (e.g., Fox, Shor, & Steinman, 1971; Scheibe, Shaver, & Carrier, 1967; see Macleod (1991)). The effect of *blood* could thus be driven by the categorical relationship between red and green rather than by visual properties alone. Also using the Stroop paradigm, Klopfer (1996) reported that perceptually closer colors (e.g., word "green" in blue ink) interfered more than perceptually more distant colors (word "yellow" in blue ink). Given that in both conditions the word and color name are of the same semantic category, this effect may be attributed to the visual similarity between the color pairs.

Here we provide consistent evidence that the shape of an object to be named is a dimension that can, in and by itself, affect word production processes. This is shown for a grammatical class different from nouns, namely Chinese numeral classifiers.

The use of numeral classifiers is a wide-spread phenomenon in Asia and America (Adams & Conklin, 1973). In Chinese, whenever a noun is determined by a deictic element or a numeral, a classifier must be used (e.g., "one-*CL*–noun"). Children of three or four years old have already acquired the basic classifier–noun phrase syntax, as no omissions of classifiers are observed and the generic classifiers are widely used as syntactic placeholders (Erbaugh, 1986, 2002; Fang, 1985; Tse, Li, & Leung, 2007). Some types of classifiers have their counterparts in Indo-European languages, for example collective classifiers (e.g., /dui4/,[2] pair), measuring classifiers (e.g., /xie1/, some) or uncertain quantity classifier (e.g., /dian3/, "a little"; e.g., Fang, 2001).

Of current interest is a special type of individual classifiers, whose use is mandatory to refer to one unit of a noun entity. In some cases such individual classifiers are assumed to carry lexical semantic properties that are redundant to the meaning of the modified nouns (e.g., one /zhi1/ cat, one cat). In other cases the semantic information is not redundant, and the classifier can differentiate ambiguous meanings of a noun, or modify the style of the speech (one /ben3/ book, one book; one /tao4/ book, one set of books; Lucy, 1992; Zhang, 2007). Linguistic descriptions propose that semantic parameters such as "animacy", "shape", "use", and "humanness" drive classifier usage to various degrees (Shi, 1996; Tai, 1994; Tai & Chao, 1994;

[2] Between the slashes are the phonetic transcripts (Pinyin system) of the Chinese words. The digits refer to the tones of the preceding syllables.

Tai & Wang, 1990). However, such association is very abstract (or opaque) and often unsystematic, as some members of a classifier cohort may not be related to other members (e.g., Allan, 1977). For instance, nouns referring to animals tend to use the classifier /zhi1/ (e.g., cat, mouse, fox, etc.; Exceptions: horse, zebra, etc.); nouns referring to objects with an elongated shape tend to use the classifier /tiao2/ (e.g., river, pants, tail, fish; Exceptions: wire; thread). Often more than one classifier is associated with nouns referring to objects of a given physical shape or from a given category. Both /zhi1/ and /gen1/ are associated with long and thin objects, and which one should be used is usually quite arbitrary. It is not systematic which criterion (e.g., shape or category) prevails, either. The overall result, then, is that there is no transparent or unequivocal mapping between conceptual properties and classifiers. Noun classifier associations thus have to be known by speakers in order to be used appropriately.

Past research on classifiers has focused mostly on their influence on the categorization of human concepts (e.g., Tai, 1994; Lee, 1988; Loke, 1994; Saalbach & Imai, 2005; Shi, 1996) and rarely on the production mechanisms of classifiers themselves. Research on language development has investigated the role of semantic features in affecting the production of classifiers in young children (Erbaugh, 1986; Hu, 1993; Loke & Harrison, 1986). Loke and Harrison (1986) observed that Chinese-speaking children acquire shape classifiers earlier than function classifiers, and non-extension round shape classifiers earlier than extended shape classifiers. This is consistent with the order of concepts acquisition in young children (Andersen, 1978). Such results were taken as indications that the same universal natural categorization principles underlie classifier and semantic development (see also Erbaugh, 1986). Evidence about classifier selection in adults comes from individuals with aphasic symptoms (Tzeng, Chen, & Hung, 1991). It was observed that aphasic individuals produced fewer classifiers than did the control group. Such classifier error patterns may either reflect the grammatical impairment in aphasic individuals, or be due to the semantic redundancy of classifiers (Packard, 1993).

The specific mechanisms of classifier selection, and their relationship to noun selection, are still empirically open issues. The experiments reported below investigate how the dimensions along which (some) classifiers are organized may contribute to their selection. Research on noun production has shown that meaning similarity between words – defined as category coordination, or on the basis of a semantic distance measure – plays a prominent role in noun selection. According to one view, semantic coordinate words compete at a lexical level during the selection process (e.g., Costa et al., 2003; Hantsch, Jescheniak, & Schriefers, 2005; Levelt et al., 1999; Roelofs, 1992; Vitkovitch & Tyrrell, 1999); an alternative view is that the conflict between coordinate words arises at a later response buffer (e.g., Mahon et al., 2007; Miozzo & Caramazza, 2003), or earlier during pre-lexical message elaboration (Costa et al., 2005; Dell'Acqua et al. 2007; Kuipers, La Heij, & Costa, 2006). It can be expected that classifiers reliably associated with semantic categories require the same kind of conflict resolution process for their selection. More interesting is the case of classifiers reliably associated with a shape dimension. Shape does not seem play a significant role in (concrete) noun selection. However, given that shape is the critical feature conveyed by these classifiers, shape-based similarity may play the role that semantic coordination (or distance) plays with nouns. In other words, the same mechanisms might operate for both grammatical classes, but the visibility of specific dimensions varies in these two classes. This general hypothesis is tested in the experiments below.

We used the blocked naming paradigm to test the contribution of the dimensions visual shape and category coordination to the production of nouns and classifiers. The same pictures were named with bare nouns (e.g., "rope") or classifier–noun phrases ("one-CL–rope"). Bare noun production was expected to be delayed in category-related blocks. If classifier retrieval follows the same principles as noun retrieval, there should be additional semantic category interference when producing the classifier phrase, compared to bare noun production. More importantly, if classifier access is also influenced by shape, shape-related contexts should induce interference in classifier–noun phrase production only. By contrast, if visual shape similarity is irrelevant for word selection, or if its effects are necessarily mediated by semantic categorical information, then the shape manipulation should never affect performance.

2. Experiment 1: semantic category manipulation in bare noun and classifier production

2.1. Methods

2.1.1. Participants

Forty-eight Mandarin Chinese native speakers, students at Beijing Normal University, participated in exchange of payment. Half of them named pictures with bare nouns and the other half with classifier–noun phrases ("one-classifier–noun").

2.1.2. Materials

We selected 18 pictures (six animals, six vehicles, and six appliances) whose names are commonly associated with a particular classifier. There were three different classifiers within each category, and no shared-classifier across categories. The pictures were grouped into six category coordinate homogeneous triplets (e.g., duck, cow, horse), then repaired into heterogeneous triplets (e.g., duck, train, chandelier). Within any set, each noun was used with a different classifier (see Appendix 1 for a complete list of materials). Three additional unrelated objects from non-experimental categories were selected for practice and warm-up trials.

2.1.3. Design

Every triplet was repeated eight times to form a block. The last six repetitions constituted the experimental trials. Trial order was pseudo-randomized with no identical pictures on consecutive trials. Each participant saw one training block followed by 12 experimental blocks (six related and six unrelated), which were ordered pseudo-randomly.

2.1.4. Procedure

The experiment was controlled by DMDX (Forster & Forster, 2003). Before each block, the three pictures were presented simultaneously on the screen. They were then presented individually for 1200 ms, followed by the target names (bare noun or classifier phrase). Participants had to name the pictures with the designated names; deviant responses were corrected. This was followed by a practice cycle and six experimental cycles with the same structure. Participants saw a fixation point followed by the target picture which they had to name aloud as fast and accurately as possible. The picture disappeared upon vocal response or when a 2000 ms deadline was reached. Naming latencies were measured by the software; errors were recorded by the experimenter.

2.2. Results and discussion

The following responses were excluded from RT analyses: (a) production of erroneous classifier or noun; (b) RTs below 200 ms; (c) voice-key failures; (d) outliers (RTs 3 standard deviations away from a participant's mean). The first two types were considered errors. Error rates were deemed too small to be informative (below 2.2% in all experiments). Here we excluded 174 data points (3.4%, including 0.6% errors) in the noun task, and 276 (5.3%, including 2.2% errors) in the phrase task. A summary of the data is presented in Table 1.

Two ANOVAs were computed with participants and items as random factors. Fixed effects were set type (homogeneous vs. heterogeneous; within participants and items) and utterance (bare noun vs. phrase; between participants and within items). Following conventional practice, we report results for F1 and F2 analysis, but we only discuss the results of F1 tests (according to Raaijmakers, Schrijnemakers, and Gremmen (1999), our design may result in biased F2 statistics). There were significant main effects of set type ($F_1(1, 46) = 47.7$, $p < 0.001$; $F_2(1,17) = 35.1$, $p < 0.001$) and utterance ($F_1(1, 46) = 4.16$, $p < 0.05$; $F_2(1,17) = 39.6$, $p < 0.001$). Naming latencies were longer in the related than in the unrelated condition, both with bare nouns (two-tailed pair-wise Student t-tests; $t_1(23) = 4.90$, $p < 0.001$; $t_2(17) = 5.83$, $p < 0.001$) and with phrases ($t_1(23) = 5.15$, $p < 0.001$; $t_2(17) = 5.09$, $p < 0.001$). A significant interaction ($F_1(1,46) = 4.08$, $p < 0.05$; $F_2(1,17) = 7.37$, $p < 0.05$) suggested that the effect of set type was larger with phrases than with bare nouns. The interaction (i.e. larger effect with classifiers) was further tested by scaling the interference effect in the two tasks. We computed the proportion of the homogeneous–heterogeneous difference against the sum of these conditions for each subject and item. The difference between the relative interference effect indexes in bare noun (mean = 0.022) and NP (mean = 0.035) naming, estimated with one-tailed Student t-tests, was significant ($t_1(46) = 1.79$; $p = 0.04$; $t_2(17) = 2.35$; $p = 0.02$); this shows that the difference in the effect magnitude is disproportionate to the overall RT differences in these two naming conditions.

Noun production is sensitive to semantic category context. The greater interference effect in phrase production suggests additional interference for classifiers. The results of the two following experiments substantiate this interpretation.

3. Experiment 2: shape similarity manipulation in bare noun and classifier production I

3.1. Methods

3.1.1. Participants

There were 48 new participants from the same pool as Experiment 1.

3.1.2. Materials

Twenty-four pictures of common objects (12 flat and 12 long) were selected (see Appendix 2). Three different classifiers were associated to the items in either shape type. The items were grouped in eight homogeneous triplets, four long and four flat (e.g., banana, lipstick, alligator, which are all longish and categorically distinct). The triplets were then rearranged into eight heterogeneous sets in an odd-one-out fashion. That is, due to item selection limitation, two out of the three items in each heterogeneous set were of the same shape type. Eleven independent participants rated the visual similarity of paired objects between one (totally different) and seven (extremely similar). The average ratings for pairs from heterogeneous triplets were significantly lower than those from homogenous triplets (2.3 vs. 3.4; $t(10) = 7.23$, $p < 0.001$). All other methodological aspects were identical to those of Experiment 1.

3.2. Results and discussion

The data were processed as above. We excluded 175 data points (2.5%, including 0.4% errors) in the noun task and 275 (4.0%, including 1.6% errors) in the phrase task.

In the latencies, there were significant main effects of set type ($F_1(1,46) = 9.45$, $p < 0.005$; $F_2(1,23) = 6.92$, $p < 0.05$) and utterance ($F_1(1,46) = 6.65$, $p < 0.05$; $F_2(1,23) = 113$, $p < 0.001$). The interaction approached significance ($F_1(1,46) = 2.11$, $p = 0.15$; $F_2(1,23) = 10.36$, $p < 0.005$). Pair-wise comparisons revealed no difference between homogeneous and heterogeneous sets with bare nouns ($t_1(23) = 1.40$, $p = 0.18$; $t_2(23) = 1.31$, $p = 0.20$). The difference was significant with phrases ($t_1(23) = 2.78$, $p < 0.05$; $t_2(23) = 3.47$, $p < 0.005$).

These results suggest that object shape affects classifier production, but not noun production.

4. Experiment 3: shape similarity manipulation in bare noun and classifier production II

A new group of participants named a set of 24 items comprising 75% new materials (depictability and classifier constraints forced the inclusion of six items from Experiment 2; these were rearranged in new triplets; see Appendix 3). Visual similarity ratings collected with 11 naive participants following the procedure above showed comparable patterns ($M_{\text{unrelated}} = 2.2$; $M_{\text{related}} = 3.2$; $t(10) = 6.33$, $p < 0.001$).

Table 1
Results of Experiments 1–3: Mean Reaction Times (RT), error percentages (Error), and RT differences between the related and unrelated conditions (Effect).

	Utterance type (*Examples from Related blocks*)	Relatedness				Effect
		Related		Unrelated		
		RT (ms)	Error (%)	RT (ms)	Error (%)	
Experiment 1	Bare noun (*duck, cow, horse*)	675	0.7	646	0.4	29**
	Classifier–noun phrase (*a/zhi1/duck, a/tou2/cow, a/pi3/horse*)	751	3.3	700	1.1	51**
Experiment 2	Bare noun (*banana, alligator, lipstick*)	635	0.6	628	0.1	7
	Classifier–noun phrase (*a/gen1/banana, a/tiao2/alligator, a/zhi1/lipstick*)	708	2.2	689	1.2	19*
Experiment 3	Bare noun	607	0.6	608	0.2	−1
	Classifier–noun phrase	619	2.5	602	1.5	17**

* Indicates that the RT difference was significant ($p < .05$) in both subject and item analyses.
** Indicates that the effect was highly significant ($p < .01$) in both subject and item analyses.

5. Results and discussion

We excluded 167 data points (2.4%, including 0.4% errors) in the noun task, and 256 (3.7%, including 2.0% errors) in the phrase task. There was a trend of the set type effect ($F_1(1,46) = 2.78$, $p = 0.103$; $F_2(1,23) = 5.47$, $p < 0.05$), and no main effect of utterance ($F_1(1,46) = 0.015$, $p = 0.904$; $F_2(1,23) = 0.281$, $p = 0.601$). Critically, the interaction was significant ($F_1(1,46) = 4.10$, $p < 0.05$; $F_2(1,23) = 17.9$, $p < 0.001$). Pair-wise comparisons revealed no difference between homogeneous and heterogeneous sets with bare noun naming ($t_1(23) = 0.24$, $p = 0.81$; $t_2(23) = 0.45$, $p = 0.66$). The difference was significant with phrases ($t_1(23) = 2.82$, $p < 0.01$; $t_2(23) = 3.70$, $p < 0.005$). These results confirm the effect of object shape on classifier production.

6. General discussion

Semantic category coordinate interference increased when classifier–noun phrase and bare noun production were compared. This was taken to reflect slower classifier production processes, suggesting that classifier and noun selection undergo similar semantic category constraints.

There was a reliable interference effect between items with similar shapes when they were named with classifier–noun phrases, but not with bare nouns. The absence of shape effect in the bare noun condition replicates previous findings with picture–word interference and visual-world paradigms (Huettig & Hartsuiker, 2008; Mahon et al., 2007; but see Klopfer (1996)).[3] It also suggests that our critical finding – the shape interference in phrase production – does not arise from increased difficulty in picture recognition *per se*. We consider two accounts for this effect.

The task demand of producing a classifier may promote a finer tuning of the visual (attention) system to shape dimensions such as the flatness or length of an object. Such task-specific tuning may focus participants' attention more on the visual factors, inducing greater difficulty during picture recognition in the homogeneous condition. Importantly, in this account, the mechanism that promotes pre-lexical interference is driven by linguistic information.

Alternatively, interference may stem from an increased difficulty in selecting the target classifier representation at the lexical or response levels. Given that shape is one dimension along which classifier–noun is associated, in the homogeneous condition classifiers consistent with the target object shape are more strongly activated and lead to interference in comparison to the heterogeneous condition. As mentioned in the Introduction, verbal association produces interference patterns similar to those of semantic category in the blocked naming task (Abdel Rahman & Melinger, 2007). Such effect was attributed to flexibility in how different facets of object meaning are activated in different contexts. The phenomenon reported here seems to be different in nature. Despite facets of visual shape being activated to enable classifier selection, these did not promote interference among nouns. The condition for observing interference could lie in the long term mapping between the meaning to be expressed and the representations of the words. For nouns and some classifiers, such meaning relies mostly on category membership (Experiment 1); for other classifiers, but not for nouns, the core meaning to be expressed lies in the visual shape of the object (Experiments 2 and 3). In line with this interpretation, a facet of meaning characterizing actions or events (namely, their thematic structure) has been shown to drive interference effects during verb production in the picture–word task (Tabossi, Collina, & Sanz, 2002).

Note that visual semantics have been described either as relatively independent from other types of semantic knowledge (e.g., Humphreys & Forde, 2001; Warrington & Shallice, 1984; Yoon, Heinke, & Humphreys, 2002), or as an integral part of the same semantic system as other conceptual properties (e.g., Caramazza, Hillis, Rapp, & Romani, 1990; Tyler & Moss, 2001). The results we report do not allow adjudicating between these two classic hypotheses. What the current results make clear, however, is that the interface between the message to be expressed and the lexical system relies on a dimension beyond semantic categories. In other words, verbal response selection can be directly modulated by visual shape information alone, just as it is known to be modulated by information captured by

[3] The current result seems to diverge from a study using a categorization task and a similar design (Lotto, Job, & Rumiati, 1999). Where these authors strove to maximize visual similarity (e.g., apple–tomato vs. apple–celery), we merely selected items associated with similar shape classifiers (e.g., snake-pants). The latter may be less confusable at the visual perceptual level.

semantic category. This further allows the speculation that word selection processes rely on a variety of semantic and/or perceptual dimensions that remain to be described.

Finally, the fact that both nouns and classifiers are modulated by similar semantic category relationships also deserves some attention and could be informative on the longstanding debate regarding the selection of open- and closed-class words. However, as described in the Introduction, there still are discussions about the grammatical status of classifiers, and the theoretical considerations made here may or may not be generalized to the closed-class family.

To conclude, we have shown that the factors operating during word selection include the shape dimension, and thus may be more diverse than has been previously thought. The relevance of various semantic dimensions in word production may result from the semantic characteristics and/or grammatical classes of the language under consideration.

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Appendix A. Appendix

See Appendices 1–3.

Appendix 1
Materials used in Experiment 1.

Category	Related			Unrelated		
	(one CL) Object	*Pronunciation*	English	(one CL) Object	*Pronunciation*	English
Animal	(一只)鸭子	*(/yi4zhi1/)/ya1zi/*	Duck	(一只)鸭子	*(/yi4zhi1/)/ya1zi/*	Duck
	(一头)牛	*(/yi4tou2/)/niu2/*	Cow	(一列)火车	*(/yi2lie4/)/huo3che1/*	Train
	(一匹)马	*(/yi4pi3/)/ma3/*	Horse	(一盏) 日光灯	*(/yi4zhan3/)* */ri4guang1deng1/*	Chandelier
	(一只)青蛙	*(/yi4zhi1/)/qing1wa1/*	Frog	(一只)青蛙	*(/yi4zhi1/)/qing1wa1/*	Frog
	(一头)大象	*(/yi4tou2/)/da4xiang4/*	Elephant	(一列)地铁	*(/yi2lie4/)/di4tie3/*	Subway
	(一匹)狼	*(/yi4pi3/)/lang2/*	Wolf	(一盏)电灯	*(/yi4zhan3/)/dian4deng1/*	Light
Vehicle	(一辆)客车	*(/yi2liang4/)/ke4che1/*	Carriage	(一头)牛	*(/yi4tou2/)/niu2/*	Cow
	(一列)火车	*(/yi2lie4/)/huo3che1/*	Train	(一艘)军舰	*(/yi4sou1/)/jun1jian4/*	Warship
	(一艘)军舰	*(/yi4sou1/)/jun1jian4/*	Warship	(一部)电话	*(/yi2bu4/)/dian4hua4/*	Telephone
	(一辆)卡车	*(/yi2liang4/)/ka3che1/*	Truck	(一匹)狼	*(/yi4pi3/)/lang2/*	Wolf
	(一列)地铁	*(/yi2lie4/)/di4tie3/*	Subway	(一艘)飞船	*(/yi4sou1/)/fei1chuan2/*	Airship
	(一艘)飞船	*(/yi4sou1/)/fei1chuan2/*	Airship	(一台)空调	*(/yi4tai2/)/kong1tiao2/*	Air condition
Electrical appliance	(一台)风扇	*(/yi4tai2/)/feng1shan4/*	Fan	(一匹)马	*(/yi4pi3/)/ma3/*	Horse
	(一盏) 日光灯	*(/yi4zhan3/)* */ri4guang1deng1/*	Chandelier	(一辆)客车	*(/yi2liang4/)/ke4che1/*	Carriage
	(一部)电话	*(/yi2bu4/)/dian4hua4/*	Telephone	(一台)风扇	*(/yi4tai2/)/feng1shan4/*	Fan
	(一台)空调	*(/yi4tai2/)/kong1tiao2/*	Air condition	(一头)大象	*(/yi4tou2/)/da4xiang4/*	Elephant
	(一盏)电灯	*(/yi4zhan3/)/dian4deng1/*	Light	(一辆)卡车	*(/yi2liang4/)/ka3che1/*	Truck
	(一部)手机	*(/yi2bu4/)/shou3ji1/*	Cell phone	(一部)手机	*(/yi2bu4/)/shou3ji1/*	Cell phone

Note: The digits in the phonetic transcript denote the tone of the preceding syllable. There is a tone sandhi situation for "–" (one) such that its tone varies according to the tone of the following syllable.

Appendix 2
Materials used in Experiment 2.

Shape	Related			Unrelated		
	(one CL) Object	*Pronunciation*	English	(one CL) Object	*Pronunciation*	English
Long	(一根)香蕉	*(/yi4gen1/)/xiang1jiao1/*	Banana	(一条)鳄鱼	*(/yi4tiao2/)/e4yu2/*	Alligator
	(一条)鳄鱼	*(/yi4tiao2/)/e4yu2/*	Alligator	(一张)烙饼	*(/yi4zhang1/)/lao4bing3/*	Paste
	(一支)口红	*(/yi4zhi1/)/kou3hong2/*	Lipstick	(一面)镜子	*(/yi2mian4/)/jing4zi/*	Mirror
	(一根) 钓鱼竿	*(/yi4gen1/)* */diao4yu2gan1/*	Fishing pole	(一根) 钓鱼竿	*(/yi4gen1/)* */diao4yu2gan1/*	Fishing pole

Appendix 2 (*continued*)

Shape	Related			Unrelated		
	(one CL) Object	*Pronunciation*	English	(one CL) Object	*Pronunciation*	English
	(一条)彩虹	*(/yi4tiao2/)/cai3hong2/*	Rainbow	(一张)贺卡	*(/yi4zhang1/) /he4ka3/*	Card
	(一支)箭	*(/yi4zhi1/)/jian4/*	Arrow	(一片)叶子	*(/yi2pian4/)/ye4zi/*	Leaf
	(一根)羽毛	*(/yi4gen1/)/yu3mao2/*	Feather	(一条)短裤	*(/yi4tiao2/)/duan3ku4/*	Pants
	(一条)短裤	*(/yi4tiao2/)/duan3ku4/*	Pants	(一支)铅笔	*(/yi4zhi1/)/qian1bi3/*	Pencil
	(一支)铅笔	*(/yi4zhi1/)/qian1bi3/*	Pencil	(一片)雪花	*(/yi2pian4/)/xue3hua1/*	Snowflake
	(一根)长笛	*(/yi4gen1/)/chagn2di2/*	Flute	(一根)长笛	*(/yi4gen1/)/chagn2di2/*	Flute
	(一条)毛巾	*(/yi4tiao2/)/mao2jin1/*	Towel	(一张)脸	*(/yi4zhang1/)/lian3/*	Face
	(一支)枪	*(/yi4zhi1/)/qiang1/*	Gun	(一面)墙	*(/yi2mian4/)/qiang2/*	Wall
Flat	(一张)烙饼	*(/yi4zhang1/)/lao4bing3/*	Paste	(一根)香蕉	*(/yi4gen1/)/xiang1jiao1/*	Banana
	(一面)镜子	*(/yi2mian4/)/jing4zi/*	Mirror	(一支)口红	*(/yi4zhi1/)/kou3hong2/*	Lipstick
	(一片)瓦	*(/yi2pian4/)/wa3/*	Tile	(一片)瓦	*(/yi2pian4/)/wa3/*	Tile
	(一张)贺卡	*(/yi4zhang1/) /he4ka3/*	Card	(一条)彩虹	*(/yi4tiao2/)/cai3hong2/*	Rainbow
	(一面)锣	*(/yi2mian4/)/luo2/*	Gong	(一支)箭	*(/yi4zhi1/)/jian4/*	Arrow
	(一片)叶子	*(/yi2pian4/)/ye4zi/*	Leaf	(一面)锣	*(/yi2mian4/)/luo2/*	Gong
	(一张)地图	*(/yi4zhang1/)/di4tu2/*	Map	(一根)羽毛	*(/yi4gen1/)/yu3mao2/*	Feather
	(一面)旗子	*(/yi2mian4/)/qi2zi/*	Flag	(一张)地图	*(/yi4zhang1/)/di4tu2/*	Map
	(一片)雪花	*(/yi2pian4/)/xue3hua1/*	Snowflake	(一面)旗子	*(/yi2mian4/)/qi2zi/*	Flag
	(一张)脸	*(/yi4zhang1/)/lian3/*	Face	(一片)雪花	*(/yi2pian4/)/xue3hua1/*	Snowflake
	(一面)墙	*(/yi2mian4/)/qiang2/*	Wall	(一条)毛巾	*(/yi4tiao2/)/mao2jin1/*	Towel
	(一片)花瓣	*(/yi2pian4/)/hua1ban4/*	Petal	(一支)枪	*(/yi4zhi1/)/qiang1/*	Gun

Appendix 3
Materials used in Experiment 3.

Shape	Related			Unrelated		
	(one CL) Object	*Pronunciation*	English	(one CL) Object	*Pronunciation*	English
Long	(一根)骨头	*(/yi4gen1/)/gu3tou2/*	Bone	(一根)骨头	*(/yi4gen1/)/gu3tou2/*	Bone
	(一条)链子	*(/yi4tiao2/)/lian4zi/*	Chain	(一片)药	*(/yi2pian4/)/yao4/*	Pill
	(一支)笔	*(/yi4zhi1/)/bi3/*	Pen	(一支)笔	*(/yi4zhi1/)/bi3/*	Pen
	(一根)拐杖	*(/yi4gen1/)/guai3zhang4/*	Cane	(一根)拐杖	*(/yi4gen1/)/guai3zhang4/*	Cane
	(一条)领带	*(/yi4tiao2/)/ling3dai4/*	Tie	(一条)领带	*(/yi4tiao2/)/ling3dai4/*	Tie
	(一支)枪	***(/yi4zhi1/)/qiang1/***	**Gun**	(一张)光盘	*(/yi4zhang1/)/guang1pan2/*	Cd
	(一根)柱子	*(/yi4gen1/)/zhu4zi/*	Pillar	(一根)柱子	*(/yi4gen1/)/zhu4zi/*	Pillar
	(一条)围巾	*(/yi4tiao2/)/wei2jin1/*	Scarf	(一片)云	*(/yi2pian4/)/yun2/*	Cloud
	(一支)牙刷	*(/yi4zhi1/)/ya2shua1/*	Toothbrush	(一支)牙刷	*(/yi4zhi1/)/ya2shua1/*	Toothbrush
	(一根)火柴	*(/yi4gen1/)/huo3chai2/*	Match	(一根)火柴	*(/yi4gen1/)/huo3chai2/*	Match
	(一条)路	*(/yi4tiao2/)/lu4/*	Road	(一条)路	*(/yi4tiao2/)/lu4/*	Road
	(一支)牙膏	*(/yi4zhi1/)/ya2gao1/*	Toothpaste	(一张)桌子	*(/yi4zhang1/)/zhuo1zi/*	Table
Flat	**(一面)墙**	***(/yi2mian4/)/qiang2/***	**Wall**	(一张)床	*(/yi4zhang1/)/chuang2/*	Bed
	(一片)药	*(/yi2pian4/)/yao4/*	Pill	(一条)链子	*(/yi4tiao2/)/lian4zi/*	Chain
	(一张)床	*(/yi4zhang1/)/chuang2/*	Bed	**(一面)墙**	***(/yi2mian4/)/qiang2/***	**Wall**
	(一面)鼓	*(/yi2mian4/)/gu3/*	Drum	(一面)鼓	*(/yi2mian4/)/gu3/*	Drum
	(一片)叶子	***(/yi2pian4/)/ye4zi/***	**Leaf**	**(一片)叶子**	***(/yi2pian4/)/ye4zi/***	**Leaf**
	(一张)光盘	*(/yi4zhang1/)/guang1pan2/*	Cd	**(一支)枪**	***(/yi4zhi1/)/qiang1/***	**Gun**
	(一面)旗子	***(/yi2mian4/)/qi2zi/***	**Flag**	**(一面)旗子**	***(/yi2mian4/)/qi2zi/***	**Flag**
	(一片)云	*(/yi2pian4/)/yun2/*	Cloud	(一条)围巾	*(/yi4tiao2/)/wei2jin1/*	Scarf
	(一张)报纸	*(/yi4zhang1/)/bao4zhi3/*	Newspaper	(一张)报纸	*(/yi4zhang1/)/bao4zhi3/*	Newspaper
	(一面)镜子	***(/yi2mian4/)/jing4zi/***	**Mirror**	(一支)牙膏	*(/yi4zhi1/)/ya2gao1/*	Toothpaste
	(一片)雪花	***(/yi2pian4/)/xue3hua1/***	**Snowflake**	**(一面)镜子**	***(/yi2mian4/)/jing4zi/***	**Mirror**
	(一张)桌子	*(/yi4zhang1/)/zhuo1zi/*	Table	**(一片)雪花**	***(/yi2pian4/)/xue3hua1/***	**Snowflake**

Note: The items that were used in Experiment 2 are presented in bold.

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