Fast-mapping and Reorganization: Development of Verb Meanings as a System

Noburo Saji (nons@sfc.keio.ac.jp)
Graduate school of Media and Governance, Keio University at Shonan-Fujisawa, 5322 Endo, Kanagawa, Japan
Henrik Saalbach(henrik.saalbach@ifv.gess.ethz.ch)
Institute for Behavioral Sciences, Swiss Federal Institute of Technology, Zurich, Switzerland
Mutsumi Imai(imai@sfc.keio.ac.jp)
Faculty of Environment and Information Studies, Keio University at Shonan-Fujisawa, Japan
Yupin Zhang(michelle1368@hotmail.com)
State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China
Hua Shu (ShuhHua@bnu.edu.ch)
State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China
Hiroyuki Okada (hokada@eng.tamagawa.ac.jp)
College of Engineering, Tamagawa University, Machida, Japan

Abstract

This paper explores the process through which children sort out relations among verbs belonging to the same semantic domain. For this purpose, we studied how Chinese 3-, 5-, 7-year-olds and adults apply various carry/hold verbs to videos depicting 13 different carrying/holding actions. Results show that the degree of convergence between children's verb use and that of adults' are very different for different verb. Furthermore, when convergence with adult meaning was adopted as the index of whether "children have acquired the word meaning", the key predictor of "acquisition" was the degree of semantic overlap with verbs belonging to the same semantic domain, while word frequency was the key predictor which contributed the most for verbs that children produced frequently. These results underscore the importance of examining the mechanism of reorganization of word meaning to obtain a full picture of lexical development.

Keywords: Word meaning representation, Lexical development, Semantic reorganization

Introduction

In the past decades, much effort has been devoted to the problem of how young children break the barrier of mapping words onto the world at the initial stages of lexical development. Although the ability to fast-map is an amazing accomplishment and an extremely important first-step for building up the lexicon, what children achieve by fast-mapping is often over-estimated: The success of fast-mapping by no means implies that children have acquired adult-like, full meanings of words. In fact, researchers have documented that children's word meaning representations go through changes. Most well-known changes are those from under-extension, cases in which children construe word meanings too narrowly and use words for very limited referents (e.g., using "dog" only for particular type of dog), and over-extension, cases in which children use words too broadly (e.g., using "dog" for all small four-legged animals). Some researchers have also noted cases where children initially use verbs "correctly" for some time, followed by a period in which children start making errors (Bowerman, 1982).

Thus, for many words, word meaning continues to grow and often goes through a reorganization process after the word is initially mapped to a meaning. For theories of lexical development, understanding how reorganizations of word meanings occur is as important as understanding how fast-mapping takes place. Yet, much of the mechanism of the reorganization process of word meanings has been left unspecified. For example, how does under- or over-extension of a word last?; how long does it take for children's word meaning representation to converge with that of adults?; what causes modification of the meaning of a word, and how does it take place?

An important force behind the reorganization of the meaning of a word is the learning of a new word closely related to the previously learned word (Clark, 1987). For example, children often originally use the word "doggy" too broadly to refer to other small, four-legged animals such as cats, sheep, etc.; when they learn the words for those animals, overextension errors stop. In this light, to understand how reorganization of word meanings takes place, it is important to examine how a change in the word meaning representation of one word affects the word meaning representation of neighboring words in the same semantic domain by looking at children's understanding the meanings of word in the same domain *as a whole*. To our knowledge, there is only one study that systematically examined how meanings of words belonging to the same semantic domain change developmentally. Ameel, Malt & Stroms (in press) studied how children aged 5 to 14 years and adults named various kinds of containers. They documented that the children's patterns of word uses progressed to the adult patterns only gradually through the addition of new words and reorganization of existing categories. Furthermore, these authors identified both over-extension and under-extension across different words in the domain: some words were initially used more broadly by children than by adults, while other words were used more narrowly.

The purpose of the present research was two-fold. First, extending Ameel et al. (in press), we wished to document how young children's meanings of verbs for common actions evolve with development. Specifically, we examined the developmental trajectory of children's lexical knowledge of 13 verbs denoting carrying and holding events

in Chinese as well as their knowledge of the semantic domain as a whole. Second, we wished to identify factors influencing the ease of learning word meanings. Here, our research is unique in that we employed multiple criteria for determining how well children "know" a given verb.

One of the key questions in the literature regards which factors determine the ease (or difficulty) of learning of words. Some researchers have emphasized conceptual or semantic factors (e.g., Gentner, 1982; Imai, Haryu & Okada, 2005), while others have emphasized frequency in the input (Tardif, 1996, Li et al, 2007). However, what does it mean to say that a child "knows" the meaning of a word? How should "ease of learning" be defined?

Concerning the first issue, researchers have commonly stated that the meaning of a given word is "known" or even "acquired" when a child produced the word correctly in one context. Likewise, when researchers discuss the ease of word learning, they tend to consider early-produced words as easy to learn. However, as discussed above, correct use in limited contexts does not guarantee that a child is able to apply a word in the way adults do in other contexts (cf.Bowerman, 1982;Imai et al., 2005). It is thus theoretically important to clarify whether words entering a child's vocabulary early converge to adult-like meaning representations early as well, and whether the factors influencing early entrance into the vocabulary are the same as the factors influencing early attainment of full, adult-like meaning representation. We thus not only used the time a verb appeared in the vocabulary but also the depth of children's knowledge about the meaning of the verb as indexes of word acquisition.

As the target of investigation, we chose the semantic domain of carrying and holding (C&H) verbs in Chinese. While the English verbs "carry" and "hold" differ with respect to whether or not the person holding the object is moving, the Chinese verbs do not distinguish actions in this respect; instead they distinguish the manner in which an object is being carried or held. There are more than 20 words in this semantic domain in Chinese. (See Table.1 for examples). For example, carrying/holding an object on one's head is denoted by "ding," while holding/carrying an object on one's shoulder is "kang." An advantage of studying verbs in this semantic domain is that actions denoted by these verbs are all perceptually visible and concrete, which allows us to show the actions in videos in order to elicit verbs. Furthermore, because these actions are activities children observe every day, they should be very familiar to them.

Yet, the semantics of this domain is very complex, and learners of Chinese have to learn how the domain is organized and which semantic space each verb is mapped to, figuring out the boundaries of many semantic categories. Thus, it is extremely interesting to examine how children learn to divide the C&H actions they observe everyday into a complex system of lexical categories from early stages of lexical development through adulthood.

Table 1: Stimuli videos.

Verb	Action	Word Frequency[1]
Bao	C&H an obj. in both arms	138
Bei	C&H an obj. on the back	135
Ding	C&H an obj. on the top of head	98
Duan	C&H an obj. by hand, keeping the obj. horizontally	81
jia	C&H an obj. under one arm	58
Ju	C&H an obj. by lifting the obj over the head	97
Kang	C&H an obj. on the shoulder	52
Kua	C&H an obj., hanging it on the shoulder	14
Lin	C&H an obj., dangling it with one hand	27
Na	C&H an obj. with one hand	595
peng	C&H an obj. cautiously in both hands	48
Ti	C&H an obj., dangling it around the arm	446
Tuo	C&H an obj. in the palm(s)	71

Experiment

Overview

We first selected 13 verbs in the domain of C&H actions and prepared two video clips for each verb, one showing a carrying action (the actor is moving with an object) and the other showing a holding action (the actor is holding an object without moving) both in the manner denoted by the verb. Chinese-speaking children of three age groups (3-, 5-, and 7-olds) and three groups of adult Chinese speakers (university undergraduates, mothers of 2-year-olds, and mothers of 5-year-olds) were asked to describe each action in the video. Mothers were included in the study to see whether they would use verbs differently when talking to their children and when talking to adults. In addition, comprehension data were collected from a different group of adult participants. Production data shows how speakers differentially use verbs in the domain. In other words, production data reflects participants' judgment about the most appropriate verb for a given action. Comprehension data, on the other hand, shows us if adults would accept the use of a verb for a given action, even though they would prefer a different verb themselves. This information is also useful for determining the extension of the verb's boundary as well as for knowing the degree of overlap between two neighboring verbs.

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[1] The frequency count for each verb was taken from the corpus of Frequency Dictionary of Modern Chinese (Beijing Language Institute, 1986; 1200000 words). Cases where the character was used as a morpheme of other words were excluded in the frequency count.

The data were analyzed in 5 respects: (1) how many verb types were produced across 26 videos in each age group (2) to what degree the pattern of children's use of verbs converges with that of adults, and how it develops with age; (3) whether care-takers use verbs differently when talking to young children than when talking to older children or to adults (e.g., over-use of particular verbs and under-use others), and whether young children's over-extension of some verbs reflects the pattern of care-taker's special verb use to young children; (4) what verbs are learned "more easily" than others; and (5) what factors affect the ease of verb learning.

Method

Production Task

Participants. A total of 78 native Mandarin speaking children and adults participated in this study. Production data was collected from 16 3-year olds, 20 5-year olds, 21 7-year olds, and 21 adults. Comprehension data was additionally collected from 21 adults. Children were recruited from several preschools and primary schools in Beijing, China. Adult subjects were undergraduates at Beijing Normal University. Fifteen mothers of 2-year-olds and 15 mothers of 5-year-olds, parents of children enrolled in a preschool affiliated with the Beijing Normal University, also participated.

Stimuli. A set of 26 videos showing C&H actions was prepared. We first selected 13 representative verbs in the domain that Chinese speakers use in everyday situations when referring to C&H activities. Two video clips for each verb were prepared, one showing a carrying action and the other showing a holding action. Each event was video-taped with a female agent carrying and holding a familiar and typical object for the action denoted by the verb.

Procedure. The videos were presented on a computer screen in random order. In the production task for undergraduates, a sentence "She is X-ing the thing ("Ta [she] shenme [what] zhe [-ing] yi ge [a/one] dongxi [thing]?") was presented with each video, and the participant was asked what X would be. The sentence was presented to children orally by a native Chinese speaker and they were asked to name the verb which best referred to the action. Mothers of 2- or 5-year-olds saw the videos together with their children and were asked to describe each video for their child.

Comprehension task

Participants. 27 adult native speakers of Chinese, all undergraduate students at Beijing Normal University who had not been tested in the production participated.

Stimuli and procedure. Because the number of trials would be prohibitively large if we used all 26 videos and also because participants' response was virtually the same across the carrying and the holding videos in the production

task, only the thirteen video clips representing carrying (moving) actions used in the production task were used here. Participants saw an exhaustive combination of all videos and verbs (i.e. each video appeared with each verb) in random order. In each trial, they were asked to judge whether or not the verb could refer to the action shown in the video. Thus there was a total of 169 trials (each of the 13 videos combined with each of the 13 verbs).

Analyses and Results

1. How many verb types did children and adults produced across 26 carrying/holding actions?

The most commonly used measure for vocabulary growth is the number of words children produce. For example, CDI (Communicative Development Inventories) asks care-takers to check which words children produce, without asking whether they always use the word correctly. We thus counted up the number of verb types each individual produced across the 26 videos. Adults on average produced 11.2 different verb types. The mean-produced verb types for children were 7.25, 6.25, and 8.57 for 3-, 5- and 7-year-olds, respectively. The means of verb types were not different among the three child groups, all $ps > .1$, Bonferoni corrected, but it differed significantly between each of the child groups and the adult group, all $ps < .01$.

2. How does children's use of the verbs converge with the adult pattern?

Matrix preparation. Response matrices were created for each age group. For the production task, we tallied the numbers of verbs produced by the participants for each video in each age group. In each matrix, there were 26 rows which corresponded to 26 videos. When the participant produced a verb other than the 13 verbs we targeted, a new column was added, and the number of participants producing that verb was tallied in the cell.

We first checked whether participants in each age group used the same verb for the corresponding pair of carrying (moving) and holding (non-moving) actions. The correlation was high for all age groups (3year-olds: .71; 5-year-olds: .84 ; 7-year-olds: .84; adults: .94), indicating that Chinese speaking children and adults used the same verb for the same manner, regardless of whether the actions were moving or non-moving. We thus aggregated the responses for the moving and non-moving actions of the same manner to simplify further quantitative analyses[2].

For the comprehension task, we used a 13X13 matrix representing the proportion of "Yes" responses for each combination of the 13 videos and 13 verbs. The production data indicate how participants differentially apply verbs to C&H actions. The comprehension data reflect the extension of the boundary of each verb in the domain.

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[2] We also conducted analyses separately for the carrying and holding actions, but the pattern of the results was very similar for all age groups.

Results. In order to see the degree of convergence between children's pattern of verb use and that of adults (undergraduates), the production matrices from each age group was compared to the adult's matrix. Following the algorithm proposed by Ameel et al. (in press), we calculated correlations for all pairs of the videos within each age group (i.e. the number of verbs produced for each video), which resulted in matrices of 78 correlation values (for each age group). Using the first-order correlation matrices, we further calculated the correlation between each child group and the adult group. This second-order correlation should indicate the degree of convergence between the two (each child group and the adult group). Figure 1 shows the correlation among the age groups. The correlation between 3-year-olds and adults was as low as .29. Convergence with the adult pattern increases linearly from 3 to 7 years (5year-olds: .46 ; 7-year-olds: .59). However, even 7-year olds are not quite adult-like in their use of the verbs in this domain.
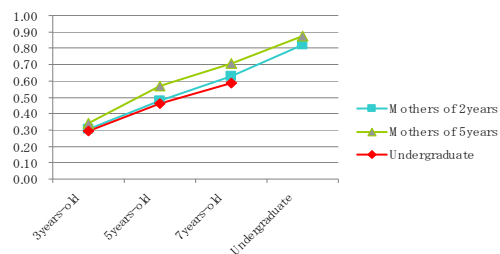

Figure 1: Correlation between children and adults

3. Did care-takers use carrying/holding verbs differently when talking to young children and when talking to adults?

Why was young children's pattern of verb use so different from the adult pattern? Perhaps care-takes intuitively think that using so many different verbs is cognitively too demanding for young children, and hence use only a small number of verbs broadly. In other words, children's pattern of verb use may directly reflect care-takers' pattern of verb use. This possibility, however, was not supported: use of the verbs by the mothers of 2-year-olds was no different from the mothers of 5-year-olds (r=.87), nor was it different from the undergraduates (r=.82)

4. How do verbs differ in the degree to which children's meanings converge with adults'?

We next turn to the question of how verbs within the semantic domain differ from each other with respect to ease of acquisition. In Analysis 2, we examined the degree of convergence of the *pattern* of verb use in the whole domain. However, it is likely that the degree of convergence with the adult pattern differs across verbs and these cross-verb differences may provide insights into the question of what factors affect the acquisition of verb meaning. For this purpose, we adopted Entropy (*H*) as a quantitative index of how broadly a given verb refers to events. The notion of

Entropy is often used as an index for the degree of dispersion of the response for categorical variables. If responses are concentrated around one or small number of categories, then the Entropy value is low, and if responses are widely dispersed across different categories, Entropy is high [3]. Figure2 shows the Entropy value for the eight verbs which were produced by at least 10 individuals in each age group [4].

Entropy values were lower in adults' production than in children's production for all of the eight verbs except for "ding", for which the values for the child groups were as low as that for the adult group. The fact that Entropy values were lower in adults than in children suggests that the range of actions each verb applied to was more restricted for adults, while children tended to apply each verb to a much broader range of actions. However, the Entropy values differed substantially across different verbs within each age group. For example, the Entropy values for "na" ('to carry or hold in one hand') were much higher in the three child groups than in the adult group. This is because children applied "na" much broadly, using the word for actions that the adults would use different, more specific verbs. In contrast, the Entropy value for the "ding" ('to carry/hold on the top head') video was near 0 for all age groups, suggesting that even children of the youngest group only used this verb for the two videos shot for the "ding" action.

Taken together, the results of the analysis using Entropy suggest that young children tended to apply one verb for various actions, while adults tended to use a specific verb for a specific event with a high level of agreement. On the whole, children between 3- and 7-year-old of age were still in the process of sorting out how the semantic domain was divided and how each semantic category is mapped to each verb. In so doing, the timing of convergence to adult-like use does not occur evenly across the different verbs. Some verbs (e.g., "ding") converged to the adult pattern almost from the beginning. In contrast, the range of application of "na" gradually narrowed with development, as children learned more specific verbs and sorted out the boundary between "na" and other more specific verbs before eventually using "na" as adults do.

Based on the above observations, it appears that two inherent properties of words may be important factors in the "ease" of word leaning, especially when we consider the degree of convergence between child use and adult use as the index for the "ease" of acquisition. One is whether a given word has overlapping boundaries with other neighboring words. For example, "ding" is easy to distinguish from other carry events, because no other Chinese verb of this domain refers to an action in which the head supports the object. In contrast, the boundary of "na" overlaps with several other verbs that also refer to actions

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[3] $P(H) = -\sum_{A \in \Omega} P(A) \log p(A)$

[4] The remaining verbs were not included in the analysis because the Entropy measure is not reliable when the frequency is too low.

with one hand, though the manner in which the hand holds the object is different (e.g., "ti", "tuo", "lin"). As a consequence, children may frequently overextend "na" to actions for which adults would use the corresponding manner-specific verbs. A second inherent property of the word may be the range of instances adults accepted as referents. For example, although adult Chinese speakers tended to use the verb "na" only for what we assumed to be the "na" actions, the comprehension data indicated that adults would accept actions denoted by other hand-holding actions such as "ti" and "ling" as referents of "na". The reverse direction was not observed: adults did not accept "ti" or "ling" for the "na" actions nearly as willingly, suggesting that "na" has broader range of applicability than other, more specific verbs in the domain. In the next analysis, we examined if these observations could be quantitatively supported.
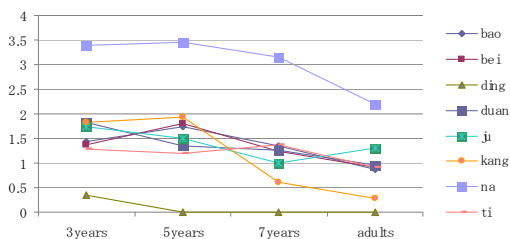

Figure2: Entropy values

5. What factor(s) best explain the ease of learning verbs ?

Measures representing "ease of learning". In our final analysis, we used regression analyses to test whether the two semantic properties of the verbs—the degree of boundary overlap with neighboring words and the range of applicability— affect how "easily" children learn verbs. To quantify these values, we used adult comprehension data, as we wanted to focus on which verbs could be potentially applied to a given action rather what the speakers would consider as the "best" verb. To represent the degree of boundary overlap, we calculated the Entropy value for *each action*. If various verbs are accepted for a given action by adults, it means in addition to the verb originally taken to represent the action, other verbs are also allowed to name the action. Hence, the verb is assumed to have high degree of boundary overlap with other verbs. On the other hand, if only one verb is accepted for the action across different participants, the verb has a low degree of boundary overlap with other verbs. To quantitatively represent the second predictor, the verb coverage, the Entropy value was obtained for *each verb*. Here, if the given verb was accepted for many different actions, i.e., the verb covers a wide range of action instances, the Entropy for the verb is high. In addition to that, it has been noted that word frequency is an important predictor for how early a word enters children's vocabulary (e.g., Li et al, 2007). However, it is not known how word frequency is related to full, adult-like acquisition of word meanings. We thus included the frequency of the

verb as a predictor in the regression model (See Table 1 for the frequency count examined and footnote 2 for the source of the count).

As the index of "ease of learning," we used two different measures. The first measure was how frequently children used each verb, assuming that the verbs children used most frequently were the verbs children feel most familiar with and feel comfortable in using. The second measure was the degree of convergence with the adults' use for each verb, assuming that verbs children used like adults were learned more easily than those for which the children's pattern of use diverged from that of adults. Six regression models were thus carried out: three models (one for each children's age group) using produced frequency as the dependent measure and three models using the degree of convergence as the dependent measure.

Results of the model using Produced frequency as the dependent measure.

The model fit with the three variables was significant for all three ages, (3 years: R^2 =.83, F (3,9) = 14.9; 5 years: R^2 =.82, F (3,9) = 14.1; 7 years: R^2 =.86, F (3,9) = 18.4, all ps<.001). The word frequency (in the adult corpus) made the strongest contribution among the three for all three age groups (3 years: β = .70, 5 years: β = .63, 7-years: β = .58, all ps < .005), suggesting that the verbs young child tend to use frequently are the ones they hear most frequently. The β-values for verb coverage as well as for boundary overlap in 5-years' and 7-years' models were also significant (Verb Coverage: 5 years: β =.40, p < .05 ; 7 years: β = .46, p < .05; Boundary Overlap: 5-years: β = -.46, p < .05, 7-years: β = -.54, p < .005) but not in 3-year-olds' model..

Results of the model using the degree of convergence to the adults' use as the dependent variable.

The model fit was not quite as good as for the production frequency models (3-years: R^2 = .60, F (3,9) = 4.5 , p < .05; 5-years: R^2 = .51, F (3,9) = 3.1, *ns*; 7-years: R^2 = .41, F (3,9) = 2.1 , *ns*)   The β-value for the degree of boundary overlap was significant for all ages (3 years: β = -.63 , 5 years: β = -.75, 7 years: β = -.69 , all ps < .05). The negative direction of the β-values indicates that the higher the degree of boundary overlap was, the lower the degree of convergence in children's use of verbs with that of adults. The β -value for verb coverage was non-significant throughout the three age groups. Interestingly, β values of corpus frequency decreased with age (3-year-olds: β = .48, p = .07; 5-year-olds: β =.08, *ns*; 7-year-olds: β = -.03, *ns*), suggesting that the role of the frequency of the verb in adult usage (in the corpus) decreases with development.

Discussion

In the semantic domain of Chinese carry-and-hold verbs, the semantic space is carved up very finely with respect to the manner in which an object is held. Some verbs cover a

broad space, while others cover only a narrow space, and there are overlapping boundaries between some verbs.Our research provides insights into how children learn to divide the domain into lexical categories and map each verb onto appropriate semantic space. The number of verbs 3-olds produced across 13 actions corresponding to 13 verbs was no different from that produced by 5- or 7-year-olds. However, the degree of convergence with the adults' pattern increased linearly with development. This suggests that at 3-years of age, children already "know" quite a few verbs in this domain, but their understanding of the meanings of these verbs is very rough. They have the word forms in memory, but they only have coarse representations of their meanings, and there is a long way to go to attain adult-like representation of these verbs.

We tested the possibility that care-takers may give simplified input to young children, overusing some broad verbs in situations where adults talking to adults would use other, more specific verbs. However, it was not the case. The pattern of verb use by mothers of 2-year-olds when talking to their children was virtually the same as that by mothers of 5-year-olds or by undergraduates. Thus, the tendency to overextend broad-coverage verbs such as "na" or "bao" can't be due to simplified input by care-takers.

We then examined the pattern of use separately for each verb to see which verbs children and adults use more broadly and which verbs narrowly, and for which verbs children's use converges with that of adults most closely, using the Entropy value as a quantitative index. Entropy values for all but one verb decreased with development, reflecting the fact that adults used verbs differentially for each action, while children used most verbs much more widely than adults did. This tendency was seen most strongly with "na," which showed highest Entropy in adults. In contrast, Entropy values for the child groups were just as low as for adults in the use of "ding," the verb denoting carrying-or-holding an object on the head.

We suspected that two factors inherent to verbs—verb coverage and boundary overlap—may affect the "ease" of learning, especially when we define "ease" as the degree of convergence with adults' use of the verb together with word frequency. It turned out that in all three child groups, the factor that significantly contributed to the degree of convergence was boundary overlap. Thus having a boundary that is not overlapping with other verbs in the domain contributes to the "ease" of learning most strongly. However, when we examined the role of the three factors using the frequency of verb use, word frequency was the strongest predictor.

Our results provide important insights for theories of lexical development. Most importantly, they caution us against casual use of the common expression "word meaning acquisition" or "children *know* words", with simple reliance on the CDI or corpus data in limited contexts as the index for "word acquisition." When researchers state "the child knows a word," it should be made explicit what *level* of knowledge is being discussed. Initial mapping between a word and its meaning is certainly one level of knowing, but full acquisition of word meanings require sorting out boundaries between neighboring words and understanding relations among words, which takes a long time and a lot of experience (see also Ameel et al. in press).

The finding that corpus input, verb coverage, and boundary overlap contributed differently in predicting the ease of learning when different criteria for "ease" were used should also caution researchers against the casual discussion of factors affecting the "ease" of learning without specifying the criteria for determining the "ease." Most interestingly, when production frequency was used as the measure, corpus frequency was the strongest contributor, but when "ease" was defined as the degree of convergence with adults' use, it no longer mattered. In fact, our results showed that "na," which enters Chinese children's vocabulary very early and is produced most frequently, converged with the adults' pattern least closely. It could be that adult-like representation is acquired latest for a broadly overused (hence most frequently used) word, presumably because the full representation is attained only after the child has learned more specific, appropriate words in the neighborhood, and sorted out the boundaries with those words.

All in all, this research underscores the importance of systematic investigation of words belonging to the same domain as a whole, examining how word meanings in the domain develop within a connected system rather than examining each word separately, to capture lexical development in its full scope.

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