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Word learning does not end at fast-mapping: Evolution of verb meanings through reorganization of an entire semantic domain

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Abstract

This paper explores the process through which children sort out the relations among verbs belonging to the same semantic domain. Using a set of Chinese verbs denoting a range of action events that are labeled by carrying or holding in English as a test case, we looked at how Chinese-speaking 3-, 5-, and 7-year-olds and adults apply 13 different verbs to a range of carrying/holding events. We asked how children learning Chinese originally divide and label the semantic space in this domain, how they discover the boundaries between different words, and how the meanings of verbs in the domain as a whole evolve toward the representations of adults. We also addressed the question of what factors make verb meaning acquisition easy or hard. Results showed that the pattern of children's verb use is largely different from that of adults and that it takes a long time for children to be able to use all verbs in this domain in the way adults do. We also found that children start to use broad-covering and frequent verbs the earliest, but use of these verbs tends to converge on adult use more slowly because children could not use these verbs as adults did until they had identified boundaries between these verbs and other near-synonyms with more specific meanings. This research highlights the importance of systematic investigation of words that belong to the same domain as a whole, examining how word meanings in a domain develop as parts of a connected system, instead of examining each word on its own: learning the meaning of a verb invites restructuring of the meanings of related, neighboring verbs.

In past decades, researchers have attempted to reveal the mechanism by which children learn words and build up their lexicons. In particular, much effort has been devoted to uncovering how young children map words onto concepts at the initial stages of lexical development. For example, researchers have asked what internal biases or abilities children possess to make the word-world mapping possible and how these biases or abilities emerge. Past research addressing these questions has indeed greatly advanced our understanding of the nature and mechanisms of early lexical development. For example, it is now widely accepted that young children are able to fast-map a novel word to its meaning (e.g., Carey & Bartlett, 1978; Heibeck & Markman, 1987; Golinkoff , Hirsh-Pasek, Bailey, & Winger, 1992; Imai, Gentner & Uchida, 1994; Imai & Haryu, 2001; Haryu & Imai, 1999; Markman, 1989), by adopting multiple resources including linguistic cues such as syntactic form (e.g., Bloom & Keleman, 1995; Gelman & Taylor, 1984; Gleitman, 1990; Fisher, 1996) and extra-linguistic cues such as social pragmatic information (e.g., Baldwin, 1991; Tomasello, 1997).

The ability to fast-map is indeed an amazing accomplishment and an extremely important first-step for building up the lexicon. At the same time, however, what children achieve by fast-mapping is often over-estimated. As has been stressed by some researchers, success at fast-mapping by no means implies that children have acquired the adult-like meaning of a word (e.g., Clark, 1972, 1995, 1997, 2009; Bloom, 2000; Waxman,2002; Bowerman, 2005; Hills, Maouene, Sheya & Smith, 2009; Pinker, 1989; Gropen, Pinker, Hollander & Goldberg, 1991). Development takes place not only in terms of the number of words in the vocabulary, but also in terms of the depth of knowledge about the meanings of each word (e.g., Clark, 2009; Nagy & Anderson, 1984; Bowerman, 1982; Ameel, Malt, & Storms, 2008).

The question raised above of course cannot be addressed without defining what lexical meaning is—a notorious conundrum with which many linguists, philosophers and psychologists have wrestled throughout history. For example, what is the meaning of the word "cat"? This is a word that even 2-year-old children "know," yet it is extremely difficult—or virtually impossible—to provide a definition by which all "cats" are correctly identified and all "non-cat" entities can be successfully excluded from the extension (e.g., Anderson & Nagy, 1991; Fodor, 1981; Jackendoff, 1983 for response to Fodor; Labov, 1973; Putnam, 1975; Wierzbicka, 1990; Wittgenstein, 1953).

It is beyond the scope of the paper to propose a satisfactory theory of word meanings. Here, for the purpose of addressing our research questions, we loosely define "adult-like word meaning" as the representation that allows speakers to apply a word to a range of situations in the same way adult native speakers of the language do. Native speakers of a language 'know' what entities (or what situations) a given word (for all word classes) can or cannot apply to. We assume that this knowledge is partly based on the *sense* of a word, and that this sense contains semantic features (Jackendoff, 1990; Levin, 1993). However, we do not commit ourselves to a view that the sense consists *solely* of a set of minimal propositional semantic features. We assume that *connotation* or any other type of knowledge (which may or may not be propositional) that affects the usage and application of a word in a range of contexts is also part of its meaning (Anderson and Ortony 1975; Anderson, Pichert, Goetz, Schallert, Stevens & Trollip, 1976; Fillmore, 1978; Kemmer & Barlow, 2000; Langacker, 1987; Landauer & Dumais, 1997). For example, "animal", "cat", and "kitty" can all refer to the same object, but adult native speakers would know which word would be most preferred in a given

context. We consider this knowledge to be part of the word meaning [1] but we would not speculate on how (in what form) this "knowledge" is represented.

We thus assume that adult native speakers have shared representations of word meanings that allow them to agree on the word choice in a given situation. This does not entail that adult native speakers have complete or fully-fixed word meaning representations. Native speakers' word use is often creative and non-conventional. Also, there are individual differences in the choice of a word in a given situation, especially when there are several near-synonyms that could all fit there. Word meaning representations should be abstract enough to allow the speaker to adjust word meanings according to the situation, context, and intent. In this sense, our view of word meanings has much in common with that of emergentist framework, which assumes that word meanings arise from habits of usage or applications of words across overlapping situations (e.g. Elman, 2009; McRae, 2004).

Researchers have documented that children's word meanings are not quite the same as adult meanings by showing that their application of words is sometimes quite different from that of adults. For example, children may under-extend words, using them only for limited referents (e.g., using "doggy" only for dogs they know and not for dogs in general). They may also over-extend words, applying them too broadly (e.g., using "doggy" for many other four-legged animals). Schaefer (1979) reported that, in judging whether an event could be described as *cutting*, children gave inappropriate weight to the feature "presence of blades" and used the verb *cut* for an event in which a bottle was in fact *broken* by a blade. 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; Clark, 1973a; Mervis, 1987; Nelson,

1974; Pye, Loeb & Pao, 1996). To the extent that children apply a word to different referents and/or in different situations than adults, we will consider their word meaning representations to be different from those of adults. We will not attempt to determine exactly in what representational format the differences between child meanings and adult meanings arise (e.g., if this difference arises because children have different semantic features from adults) because this issue cannot be reasonably discussed without going into the problem of how word meanings are represented in the mind, especially the issue of whether word meanings are represented as a list of features or whether they must be something beyond feature lists (see Ameel et al., 2008 and Clark, 1973a and 2009, for relevant discussions). However, we will attempt to identify some of the major semantic dimensions that separate adult and children in their use of verbs in the carrying and holding domain (see Analysis 5 in the Result section).

To obtain a decent picture of lexical acquisition, it is as important to understand how reorganizations of word meanings occur as it is to understand how fast-mapping takes place. However, research investigating reorganization of word meanings is only sparsely found in the literature. Some studies have reported on children's errors in production (e.g., Bowerman, 1978, 1982; Clark, 1973a; Mervis, Golinkoff, & Bertrand, 1994), but these focus on the very early stages of lexical development, and do not capture how reorganization process takes place at later stages of lexical development. Furthermore, previous word learning studies mostly dealt with the learning of single words. But to understand the process of lexical acquisition in a larger context, it is critical to understand how children learn words as parts of a connected system. We not only need to uncover how they relate a newly-learned word to other nearby words but also how the structure of the semantic domain as a whole is affected by the new word.

In the next section, we elaborate this point and discuss how this bigger question can be broken down to address more specific issues.

Learning Word Meanings by Learning Other Words: The Role of Lexical Contrast in Word Learning

Traditionally, linguists have argued that every word form in a language expresses a unique meaning (Bolinger, 1977; Lyons, 1963), and that the meaning of any particular word depends on how the word is related to other similar words (Aichison, 1987; de Saussure, 1916/1983; Lyons, 1977; Miller & Johnson-Laird, 1976). This idea of considering the lexicon as consisting of structured subsets is more or less shared among current researchers of lexical semantics (Cruse, 1986; Fillmore, 1982; Fillmore & Atkins 1992; Levin, 1993: Pustejovsky, 1995).

Previous research documenting young children's spontaneous production also suggested that learning a new word plays a key role in reorganizing the meaning of a word in the child's lexicon (Clark, 1982, 1987, 1995, 1997). For example, children might originally overextend the word *doggy* to refer to other small, four-legged mammals such as cats, sheep, etc.; once they learn the conventional terms for those animals, children no longer overextend *doggy* to refer to them. At other times, children learn a new word for an object while still retaining that object as a referent of an word already in their lexicon: for example, the new noun *dachshund* denotes a specific type of *dog*. Likewise, children's understanding of the word "red" may be modified as they learn other color terms such as "pink", "orange", and "scarlet" (cf. Sandohofer & Smith, 1999).

Haryu and Imai (2002) experimentally demonstrated that children readily relate a newly learned word to an existing one, either establishing a contrastive relation or a contrastive hierarchical relation, depending on typicality: When the labeled object is an atypical member of the category denoted by a familiar name, children interpret the new label to refer to a new category that contrasts with the familiar one. As a result, they modify the boundary of the old category by excluding the referent-type that received a new label. When the labeled object was a typical member of the old category, in contrast, children interpreted the new label to be a subordinate within the old category, and accepted the newly labeled object as a referent of both the new and t old labels (see Waxman & Senghas, 1992, for similar results). Thus, previous studies suggest that the learning of a new word indeed invites a reorganization of meaning for existing words in the child's vocabulary. However, these studies have looked only at how one previously-learned word might change with the learning of another new word.

In the real world, children usually encounter sets of words in specific semantic domains, and so need to delineate the boundaries among multiple words simultaneously. Here, we use the term *semantic domain* to mean *a paradigmatically and syntagmatically structured subset of the lexicon* (Lyons, 1977, p.268; cf. de Saussure, 1986). To be able to use words like the adults in their language community, children need to discover the relations among these words and grasp the boundaries of each one. To understand how reorganization of word meanings takes place, then it is important to understand how the representations of word meanings from the same domain *as a whole* start out, and how they change with development to converge on those of adults.

To our knowledge, only one study has examined empirically how meanings of words in a single semantic domain change developmentally as parts of a connected

system. Ameel et al. (2008) studied how children aged 5 to 14 years and adults named various kinds of containers. They documented how children's pattern of word use evolved gradually with the addition of new words and the subsequent reorganization of existing categories. The authors identified both over-extension and under-extension for different words in the domain: Some were initially used more broadly by children than by adults, while others were used more narrowly. Thus, although some researchers have tended to view the processes of over-extension and under-extension as competing mechanisms (e.g., Clark, 1973a; Dromi, 1987; Mervis, 1987; Nelson, 1974), the Ameel et al.'s findings suggest that over-extension and under-extension may be complementary processes when applied to words in the same semantic domain. If some words are over-extended, neighboring words may be under-extended as a consequence. This illuminates the importance of examining the development of word meanings in a domain as a whole rather than looking at changes in the meaning of one particular word.

As in the case of object names, to acquire the meaning of a verb that allows learners to apply that verb in the same way as adult native speakers, the meaning of the verb must be considered in relation to other verbs in the same domain. Specifically, children must understand what the verb has in common with neighboring verbs, and at the same time, how it differs from its neighbors. For example, for English-speaking children to be able to use the change-of-state verbs such as *break, split, shatter, chip, crack, tear* and *rip* appropriately, it is not sufficient just to know that each verb requires an Agent and a Theme object and contains the semantic feature of "change-of-state". The appropriate usage of each verb also requires knowledge of how the meaning of each verb differs from the meanings of the others within this domain (Majid, 2008; Majid, Bowerman, Staden, & Boster, 2007).

Of course, this does not mean that children cannot *use* these verbs until they have learned all the verbs in the domain and sorted out the differences among them, nor does it mean that the acquisition of adult-like meanings of a given verb require the acquisition of adult-like meanings of *all other verbs* in the semantic domain. (In fact, we later demonstrate that the degree with which the acquisition of the adult-like meaning depends on the acquisition of other related verbs varies across verbs depending on their semantic nature, see analysis 7.) Children learn a partial meaning of these words with fast-mapping, and then gradually refine and reorganize the meanings through restructuring of the semantic domain. But even with only partial meanings, they are able to use words that they know, and their use of a verb is often close enough for adults to understand what is meant by the child. Nonetheless, to the extent that the children's choice of the verb in a given situation is different from that of adults, their representation of that verb still needs to be refined in order to converge on the adult representation for its meaning.

Present Research

In this research, we investigated how children's word meanings develop in the domain of verbs for some common actions. We selected a range of actions which are typically labeled by the verb "to carry" in English. As we have pointed out, the meaning of a word is in part determined by the relation between it and other relevant words in the same semantic domain, and boundaries are likely to differ across languages (Gentner & Bowerman, 2009; Lyons, 1968). Although English tends to have many manner-specific verbs in semantic domains such as "motion" and "speech", it does not distinguish different manners of carrying or holding objects. In contrast, Mandarin

Chinese makes some fine distinctions in terms of the manner in which the object is carried or held. There are roughly 20 verbs that would be translated into English as “to carry,” and each of them refers to the event of a person carrying an object in a distinct manner. For example, carrying/holding an object on one’s head is denoted by “ding”, while carrying/holding an object on one’s shoulder is “kang”. Carrying/holding an object with two arms is denoted by “bao”, but if the object is held with one arm at the side of the body, the action is called “jia”. Several verbs like “na”, “ ti”, and “lin” refer to carrying/holding actions with one hand, and verb choice depends largely on the shape of the hand holding the object. (Note that these verbs are not necessarily all contrastive with clear gaps among them. Instead, as verified by the comprehension data, one part of the semantic space is densely covered by several close synonyms sharing boundaries, while other parts of the space are only sparsely covered with clear gaps with other verbs. See analysis 6 for detail.)

Interestingly, however, Chinese does not distinguish verbs along one semantic dimension critical for English: It does not distinguish whether the event is dynamic (the agent holding the object is moving) or static. In Chinese, if the manner of holding the object is the same, the same verb is applied to events that are referred to distinctly as *carrying* vs. *holding* in English. In short, Chinese children have to learn many different verbs for events which English speakers would refer to simply with “to carry” or “to hold”.

The semantic domain of carrying/holding in Chinese offers an interesting test case for examining the question we address in this research, i.e., how the meanings of verbs in the domain as a whole evolve toward those of adults. One advantage of studying this semantic domain is that actions denoted by the verbs are all perceptually visible and

concrete. This allows us to depict the actions in videos in order to elicit production of the verbs. Second, because the actions in the domain of carrying and holding are activities people do every day, the verbs are produced very frequently in everyday settings: some of the verbs, in particular “na” [carry with one hand], “bei” [carry on back] , and “bao” [carry in two arms], are among the earliest words in Chinese children’s production vocabulary (Hao, Shu, Xing, & Li, 2008; Liu, Shu, & Li, 2007).

The above big question can be broken down into more specific questions: How do children learning Chinese initially divide and label the semantic space in this domain, and how do they discover the boundaries between different words? Does children’s representation of the semantic space as a whole differ from the adult representation, and if it does, how long does it take them to converge on the adult representation, and how is this convergence attained? Which verbs are over-extended or under-extended, and how are the meanings of these verbs modified in the course of development? Addressing these questions using the carrying/holding domain in Chinese may also provide insights for the following key questions about lexical development: What types of words do children learn first, and what properties of words cause early entry into their vocabulary? What properties of words are responsible for over-extension and under-extension?

Table 1. Stimuli videos used in the study.

Verb	Action	Object	Word Frequency[b]
抱(bao4[a])	Carrying/holding an object in both arms	Stuffed animal	138
背(bei4)	Carrying/holding an object on the back	Rucksack	135
顶(ding3)	Carrying/holding an object on the top of head	Wooden bowl	98
端(duan1)	Carrying/holding an object by hand, keeping the obj. horizontally	Glass bowl with water	81
夹(jia1)	Carrying/holding an object under one arm	Square bag	58
举(ju3)	Carrying/holding an object by lifting the obj over the head	Square box	97
扛(kang2)	Carrying/holding an object on the shoulder	Pipe	52
挎(kua4)	Carrying/holding an object, hanging it on the shoulder	Tote bag	14
拎(lin1)	Carrying/holding an object, dangling it with one hand	Plastic bag	27
拿(na2)	Carrying/holding an object with one hand	Plastic bottle	595
捧(peng3)	Carrying/holding an object cautiously in both hands	Bouquet	48
提(ti2)	Carrying/holding an object, dangling it around the arm	Hand bag	446
托(tuo1)	Carrying/holding an object in the palm(s)	Tray	71

Notes: a: The number indicates the tone of the syllable ; b: The frequency counts excludes cases where the character was used as a morpheme within other words. .

What words are "learned early?": Factors influencing early entry into children's vocabulary

Researchers in lexical development have long been interested in identifying which types of words get included in children's early vocabularies. Several factors have been considered important, one of which is frequency in the input. Many researchers have emphasized the importance of frequency here for word learning (e.g., Gopnik, & Choi, 1995; Tardif,1996). However, others have emphasized that concreteness and imageability of the referents influence ease of learning. These factors have proved useful for predicting the ease of learning when a broad range of words (from concrete object names to verbs for non-physical actions) is considered: When the referents are concrete (e.g., concrete object names and concrete action names), the word is learned more easily than when the referents are non-physical and abstract (e.g., abstract nouns, mental verbs); when the referents are imageable, the word should be easier to learn (Ma, Golinkoff, Hirsh-Pasek, McDonough & Tardif, 2009). The verbs used in our study all refer to concrete physical actions that are quite similar to each other, all in the same semantic domain, so concreteness and imageability seem to be unlikely predictors here.

Ameel et al. (2008) offered an alternative account for early and late entry of words into children's vocabulary in light of under- and over-extensions of word meanings. Within a single semantic domain, some words are often applied to a broad range of instances while others cover a much narrower range. Children may start to produce broad-range verbs earlier than narrow-range ones; in some cases, they might over-extend broad-range verbs to the instances to which adults would use a narrow-range verb, simply because broad-range verbs can be applied more widely. As

Ameel et al. proposed, breadth of coverage may be an important factor in accounting for early word entry (see also Gentner & Bowerman, 2009).

Are words learned early always "easy" to learn?

The issue of "words learned early" is deeply relevant to another key question in the literature of lexical development, that is, what types of words children can learn easily, and what types of words they find hard to learn. This question has typically been addressed only in light of how early children *come to know* words (e.g., Childers & Tomasello, 2006; Gentner, 1982; 2006; Gentner & Bowerman, 2009; Tardif, 1996; Maguire et al., 2006). Researchers have largely relied on vocabulary inventory data in determining whether a given word is learned early or late. However, if we define the acquisition of a word meaning as the acquisition of the adult-like meaning, and define ease of acquisition in light of how early and quickly children's word meaning converges to an adult-like understanding of the meaning, it is unclear whether the factors influencing the ease of initial fast-mapping are the same as those influencing the ease of eventual acquisition of adult-like word meanings.

Little research has addressed the "ease of learning" question in light of the second criterion. Are the factors affecting ease of learning the same under these two different criteria? In addition to the factors noted earlier, another semantic property that may also affect ease of learning that should be considered, especially for the second criterion is the degree of boundary overlap with other words. If a word has many neighbors sharing its boundaries, it may take more time for children to acquire an adult-like representation, since the extraction of the right meaning for a specific verb requires sorting out the relations between neighboring words. In any case, our attempt to evaluate which factors are responsible for greater "ease of word meaning acquisition"

quantitatively, with two distinctly specified criteria, should provide the field with some useful insights into the process of word meaning acquisition.

Another aspect of the input: Do mothers adjust their verb use to accommodate children's difficulties with verb learning?

We noted above that the frequency of a word in the input they receive may account for the early entry of certain words into children's vocabulary. In addition, mothers may unconsciously think that using many words with similar meanings is too demanding for children, and so restrict their own usage in the semantic domain to fewer words when talking to young children (see Snow & Ferguson, 1977; Galloway & Richards, 1994), even though they would use more specific words when talking to older children or adults. If so, mothers would be responsible for children's over-extensions rather than this resulting from inherent semantic properties of the word, because they themselves would over-extend certain words (but see Newport, Gleitman & Gleitman, 1977, who argue that adults do not adjust complexity in light of children's output). We test this in our experiment by asking mothers of 2-year-olds and 5-year-olds to describe the carrying and holding videos that we use for testing both children and adults (undergraduates).

Do children rely on different semantic features than adults in their verb meaning representation?

To learn word meanings, children have to detect which semantic features are critical for dividing a given semantic space. Children could organize the semantic space around different semantic features than adults (Ameel et al., 2008; Bowerman, 2005; MacWhinney, 1987; Schaefer, 1979).

The critical semantic feature distinguishing among carrying/holding verbs in

Chinese is the manner with which the actor supports or holds each object. For example, different verbs are used for carrying events where the object held is supported on the head, the back, or the shoulder. When the object is held in the hand, different verbs are used depending on the configuration of the hand and arm. Although certain objects typically appear with each verb (e.g., bowls with “ding” [carry on head], trays with “tuo” [carry on palm], children with “bao” [carry in two arms]), the verbs can be used with other objects as long as the object can be held in the manner required. However, young children may not yet be aware that manner is more important than other elements in the events, such as the objects. This possibility is consistent with the results of previous research showing that children at first have difficulty separating the core component of a verb meaning from the object in the scene (e.g., Forbes & Farrar, 1995; Imai et al, 2005, 2006, 2008; Kersten, & Smith, 2002; Maguire et al., 2002). Our data allow us to examine this possibility quantitatively. As we describe in the Analysis and Results section, we capture the semantic dimensions Chinese-speaking adults and children at different ages rely on as criteria in their verb use, and how the weights for these dimensions shift with age. If children rely on the types of objects being held more heavily than on the manner of holding, we would expect to see a developmental shift of weights from *object type* to *manner* in children’s uses of these verbs.

Experiment

As described in the overview above, we investigated how Chinese-speaking children represent the meanings of verbs belonging to the semantic domain of carrying and holding.

We first selected 13 representative verbs in the domain that are commonly used in everyday contexts and hence should be familiar to young children (see Table 1). We prepared two video clips for each verb, one showing a carrying action with the actor moving with an object, and the other showing a holding action with the actor holding an object while standing still (see below for justification for this). We asked three groups of Chinese-speaking children aged 3-, 5-, 7 and one group of adults (undergraduates) to describe each action. In addition, we asked two groups of mothers (mothers of 2-year-olds and of 5-year-olds) to describe the videos to their children.

Production data can show us how speakers apply verbs differentially from this semantic domain. In other words, the data reflect participants' judgments about the most appropriate verb for a given action. However, it is also useful to know whether speakers accept uses of different verbs for a given action, even though they may prefer to use a different verb themselves. This information is useful for determining native speaker intuition about the range of use (i.e., the breadth of the verb meaning) for each verb, as well as for knowing the degree of boundary-overlap between pairs of neighboring verbs—both properties of words that may influence ease of learning. We therefore conducted a comprehension task with adults, where we paired the 13 verbs with each of the 13 carrying videos, for 169 verb-action pairs. For each pair, participants were asked to judge whether the verb was appropriate for the action depicted.

Method

The production task was conducted with children in three age groups and with three groups of adults. The comprehension task was conducted with adults only.

Production Task

Participants. A total of 108 native Mandarin-Chinese speaking children and adults participated. The production data were collected from 16 3-year-olds, 20 5-year olds, 21 7-year olds, and 21 university undergraduates, 15 mothers of 2-year-olds, and 15 mothers of 5-year-olds. Children were recruited from several preschools and primary schools in the Beijing Metropolitan area. They were tested individually by a female native speaker of Mandarin Chinese in a quiet room in their school. They received a small gift (stickers or pencils) for participation. Adult participants were undergraduates at Beijing Normal University, tested individually in a university laboratory. The mothers of 2-year-olds and of 5-year-olds were parents of children enrolled in a preschool affiliated with Beijing Normal University, and were recruited through the preschool. They were tested individually in the presence of their children in a quiet room at the preschool and received a small gift after participation in the experiment. （If the mother was tested, the child was not tested in the same session.)

Stimuli. The stimuli consisted of a set of 26 videos showing carrying/holding actions. We first selected 13 representative verbs in the domain that Chinese speakers use in everyday situations when referring to carrying/holding activities. The description of each verb is given in Table 1, together with the frequency of the word in the corpus for the Frequency Dictionary of Modern Chinese (Beijing Language Institute, 1986; 1,200,000 words[2]).

We prepared two video clips for each verb, one with a carrying action (with the actor moving) and the other showing a holding action (with the actor standing still). We included both the carrying and holding actions because we wished to see how consistently children and adults used the same verb across the two situations. Each

event was video-taped with a female agent carrying/holding a familiar, typical object for the action denoted by the verb. The same object was used in both the carrying and the holding videos denoted for each verb.

Procedure. The videos were presented on a computer screen in a random order. We used a slightly different procedure for the undergraduates and for the mothers and their young children, as described below[3].

Child participants. Each video was presented on a computer screen for the 3 to 7-year-old children, with the question asked orally by a native Chinese speaker. They were asked: "Ta [she] shenme [what] zhe [-ing] yi [one] ge [classifier] dongxi [thing]?" ("What is she doing (to) a thing?") The children's responses were recorded and transcribed later.

Undergraduate participants. The videos were presented on a computer screen, and a sentence "She is [Blank]-ing (to) a thing?" ("Ta" [she] BLANK "zhe" [-ing] "yi" [a/one] "ge" [classifier] "dongxi" [thing]?) was shown below the video. The undergraduate participants read the sentence as it appeared on the screen and typed the verb that fits best to fill the blank position in the sentence into a response window presented at the right side of the video. They were instructed to go through the experiment at their own pace. The order of the stimuli was randomized across participants.

Mother-child participants. The mothers of 2-year-olds and 5-year-olds saw the videos together with their children. The method of presenting the visual stimuli was the same as that for the undergraduate participants. However, instead of being asked to type the verb in the sentence, they were asked to describe the action to their children orally. The mothers' responses were recorded and transcribed.

Comprehension Task

Participants. Twenty seven adult native speakers of Chinese, all undergraduate students at Beijing Normal University, participated. They had not participated in the production task. They were paid 20 RMB for participation.

Stimuli and procedure. In each comprehension trial, participants saw a combination of the verb and a video, and were asked to judge whether or not the verb could refer to the action. For this task, we only used the "carrying action" videos, with a total of 169 trials (each of the 13 videos combined with each of the 13 verbs).

Analyses and Results

Overview of the Analyses

The production data were analyzed in light of the following points: (1) how many verb types children and adults produced across the 26 videos in each age group; (2) whether the pattern of verb use was consistent across holding events (with the actor was standing still) and carrying events (with the actor moving); (3) how closely the pattern of children's uses of verbs agrees with that of adults, and how it changes with age; (4) whether caretakers used the verbs differently when talking to their children than when talking to adults; (5) what features children relied on to distinguish the events named by the verbs and whether these features are different from the features adults use; (6) which verbs are learned "more easily" than others; and (7) what factors affect ease of learning.

The data from the comprehension task were analyzed to determine the breadth of meaning of each verb and its degree of overlap with neighboring verbs. These findings were used for Analysis (7).

Matrix Preparation

For the analyses, we first constructed response matrices using the data from the production and comprehension tasks. The production data indicate how participants differentially applied verbs to carrying/holding actions. The comprehension data show the extent of the boundary of each verb in the domain.

Matrix preparation for the production data. For the production task, we created matrices for each group (3- to 7-year-old children, undergraduates, and mothers of 2-year-olds, and mothers of 5-year-olds) separately for the two event types (carrying and holding). This resulted in 12 matrices (6 groups x 2 event types). In each production matrix, we tallied the number of verbs produced for each video. In each matrix, there were 13 rows representing the 13 videos. The columns represented the verbs the children had produced. The number of the participants producing that verb was tallied in the cell (see Table 2 for an example of the matrix for 3-year-olds).

Comprehension data. The matrix for the comprehension data consisted of 13 rows representing the 13 videos and 13 columns representing the 13 verbs. Each cell of this matrix represents the proportion of "Yes" responses for each combination of the 13 videos and 13 verbs.

Table2. Sample of a production matrix (part of the 3-years-olds' matrix).

	Bao(verb)	Bei(verb)	Ding(verb)	Duan(verb)	…
Bao(video)	15	0	0	0	…
Bei(video)	0	20	0	0	…
Ding(video)	0	0	19	0	…
Duan(video)	1	0	0	11	…
…	…	…	…	…	…

Validity Check for the Stimuli

Before reporting the results of each analysis, we first examined whether adult Chinese speakers would agree that the carrying and holding videos prepared for each of the 13 target verbs were good actions for the verb. The comprehension data showed high acceptability by adult participants for each of the 13 verbs for the dynamic (carrying) videos we had created (M=.94, SD=.06). This establishes that adult Chinese speakers agreed that the videos created could be actions of the target verbs. Furthermore, the production matrix by the adults showed that adults produced the verb intended most of the time, with the most common responses concentrated along the diagonal of the matrix. Adult speakers, then, judged that the best verb for each of the 26 video was in fact the verb we had originally intended for the relevant video.

Analysis1: How Many Verb Types Did Children and Adults Produce across 26 Carrying/Holding Actions?

Traditionally, the most commonly used measure for vocabulary growth is the number of word types children produce or understand, as in the MacArthur Communicative Development Inventories (CDI). We counted the number of verb types each individual produced across the 26 carrying/holding videos, which were ideally denoted by the 13 target verb types. The adults (the undergraduates) on average produced 11.2 verb types. Children produced a smaller number of verb types (7.25, 6.25 and 8.57 for 3-, 5- and 7-year-olds, respectively). The mean number of verb types did not differ with age, all ps>.1, Bonferroni corrected, but each of the three child groups differed from the adult group, all ps<.01.

The results suggest that adult native speakers of Chinese mostly used different verbs for each of the 13 carrying/holding actions. The 3- to 7-year-old children used

fewer verbs than adults, but the number of verb types produced by the 3-, 5-, and 7-year-olds was approximately the same. This result is explored further in Analysis 3 to see if there is any developmental evolution in children's word meanings with age.

Analysis 2: Do Children and Adults Use the Same Verb Consistently across the Holding and Carrying Distinction?

Next, we examined whether the adult and child speakers of Chinese used the same verb consistently for the two videos representing the carrying and holding events where the manner of holding the object was held constant. If children understand that the actor's motion was not critical (unlike in English), the agreement between the two same-manner videos should be high. For this purpose, we followed the correlation analysis proposed by Ameel et al. (2008), which allowed us to examine the degree to which the pattern of word uses agrees for the carrying and the holding events with the same manner, by calculating the correlation between them. First, we calculated Pearson's correlation values for all pairs of the row vector within the matrix for each age group (where each component of the vector represents the frequency of each verb produced for each of the 13 videos). This resulted in matrices with 78 correlation values, for each carrying and holding matrix. Each correlation value in each matrix reflected the similarity of two actions as indicated by naming patterns for the action. Next, using these first-order correlation matrices, we further calculated second-order correlation values between the first-order correlation matrices for the carrying actions and for the holding actions within the four age groups. We obtained four correlation values representing similarity between the naming pattern for the carrying actions and for the holding actions separately for each age group (see Ameel et al., 2008, for the logic of this algorithm). These second-order correlations were high for all four groups,

although the agreement increases with age: 3year-olds — .71; 5-year-olds — .85; 7-year-olds — .84; adults — .94. This pattern suggests that from early on, Chinese children understand that the distinction between “carrying” and “holding” (i.e., whether the event involves movement of the actor) is not relevant, and they applied the same verb consistently for both moving and non-moving actions performed in the same manner on the same object. However, there is also a developmental trend such that verb use becomes increasingly stable across these events.

Analysis3: How Does Children’s Use of the Verbs Converge with the Adult Pattern?

In Analysis 1, we found that the number of verb types children produce was not different from age 3 to age 7. Did this mean that 3-year-olds and 7-year-olds used these verbs in the same way? Even if the number of verb types children produce spontaneously does not differ among the three age groups, how they use the verbs could still differ. To investigate this, we compared the pattern of children’s verb use with that of adults, again following the algorithm used by Ameel et al. (2008). Here, we calculated the correlation between each age group and the undergraduate group, using the “carry” production matrix [4].

Figure 1 shows the correlation among the age groups. The correlation between 3-year-olds and adults was as low as .17. The degree of convergence with adult verb use increases linearly from age 3 to 7 years (5-year-olds — .43, 7-year-olds — .58). Even though the 3-, 5-, and 7-year-olds did not differ in the number of verbs they produced, they did differ in how they applied the verbs. With age, children gradually converge on the adult pattern of use. However, the degree of convergence is not very high even for the 7-year-olds (r =.58), considering the high correlations (0.84 in average, see Analysis 4) among the 3 adult groups (undergraduates, mothers of

2-year-olds, and mothers of 5-year-olds). The results suggest that children take a long time to learn how to use these words in the same way as adults.

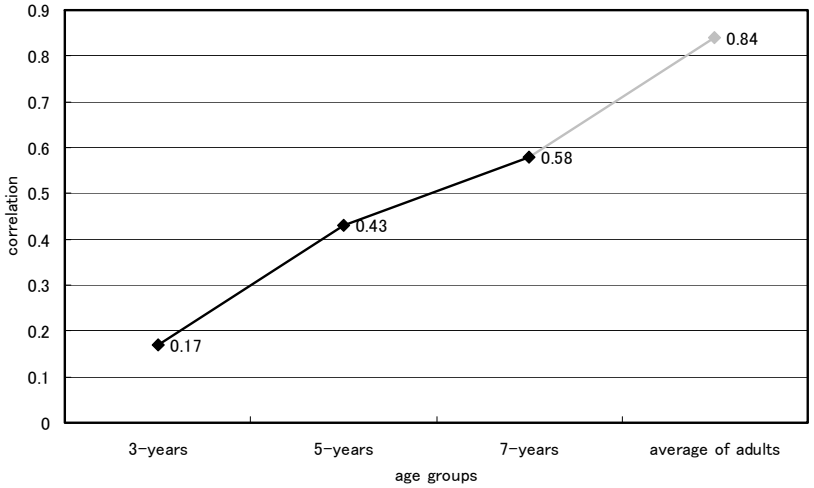


Figure1. Correlation between each of the three child groups and the adult group.
Note: The value for the adult group (.84) represents the average of correlation values between the undergraduate group and the two groups of mothers.

Analysis 4: Did Mothers Adjust Verb Use for Their Children?

The results of Analysis 3 showed that the convergence between 3-year-olds' pattern of verb use and the pattern of adult use starts out very low. As we noted earlier, however, it may be caretakers' verb use that is responsible for children's verb use: If adults think that using many words with similar meanings is too demanding for children, mothers of young children might use only the most common words in the domain when talking to young children. To examine this possibility, we compared the children's pattern of verb use with that of the mothers of 2-year-olds and 5-year-olds.

We correlated the matrices for the mothers with the matrix for the undergraduates, using in the same method as in Analysis 3. The results showed that the

pattern of verb use by the two groups of mothers was extremely similar to that of the undergraduates (r =. 81 and .83, respectively). In contrast, the correlation between 3-year-olds and the mothers of 2-year-olds was .41, and the correlation between 5-year-olds and the mothers of 5-year-olds was .56, respectively. These results suggest that the large difference in the patterns of verb use for adults and children cannot be attributed to the input from caretakers; instead, it must be attributed to internal factors at work in the children.

What are these "internal factors"? Why was the children's pattern of verb use so different from that of adults? We take this up in the next Analysis.

Analysis 5: What Features Do Children Rely on to Distinguish Different Events?

Analysis 3 showed that Chinese children's verb use in the domain of "carrying" is very different from that of adults, and this difference should be attributed to factors internal to children rather than to caretakers' input. To learn word meanings, children have to detect which specific semantic features are critical for dividing up a given semantic domain. Children could first organize the semantic domain around features different from those used by adults (e.g., Schaefer, 1979, MacWhinney, 1987, Bowerman, 2005).

The critical semantic feature for differentiating carrying/holding verbs in Chinese is the manner in which the actor supports the object, e.g., on the head, on the back, or on the shoulder. When the object is held in the hand, different verbs are applied depending on the shape of the hand and the arm. Although certain objects typically appear with specific verbs (e.g., bowls with "ding" [carry on head], trays with "tuo" [carry on palm], children and backpacks with "bao" [carry in two arms]), the verbs can be used for other objects as long as the object can be held in the manner

required by the verb. However, young children may not yet be aware that manner is more important than other features involved in the events, such as the objects [5].

In the present research, we examined this possibility by employing INDSCAL (INDividual SCALing MDS), a version of the MDS (Multi Dimensional Scaling) technique developed for evaluating individual/group differences in a multi-dimensional space common across groups (Carroll and Chan, 1970). While MDS can provide a visual representation of patterns of similarity or distance by detecting underlying dimensions from all of the input groups, INDSCAL allows us to capture the weights each input group assigned to the dimensions detected from all input groups. In the current study, INDSCAL shows how each of the four age groups weighted each dimension in the Common Space.

The four correlation matrices from the different age groups calculated in Analysis 2 were fed into INDSCAL as the input data. INDSCAL provided two kinds of output: First, it identified the dimensions underlying the verb production patterns, along which all the age groups categorized the videos (Common Space). Second, it identified the weights each group placed on each of the common dimensions when they named an event (Individual Space).

The matrices were analyzed using the INDSCAL procedure available in SAS (SAS Institute Inc., 2006). We employed solutions with three dimensions, as the stress value dropped significantly from the two dimension solutions (.22) to the three dimension solution (.14), and the stress value of .14 can be considered to be fairly good. Figures 2A and 2B show the Common Space, where the location of each event point was calculated using the data from all four age groups. Each point thus represents 13 videos of carrying, and distances between the points reflect the similarity

among the videos based on the naming pattern produced (Figure 2A for Dimension 1 x Dimension 2, Figure 2B for Dimension 1 x Dimension 3). In the Common Space, if participants tended to apply the same verb to any two given videos, the distance between the two videos is small, and each of the dimensions extracted reflects a criterion by which the naming of the videos is distinguished. The Individual Space shows how the different age groups weighted the semantic features represented by each dimension (Figures 3A and 3B).

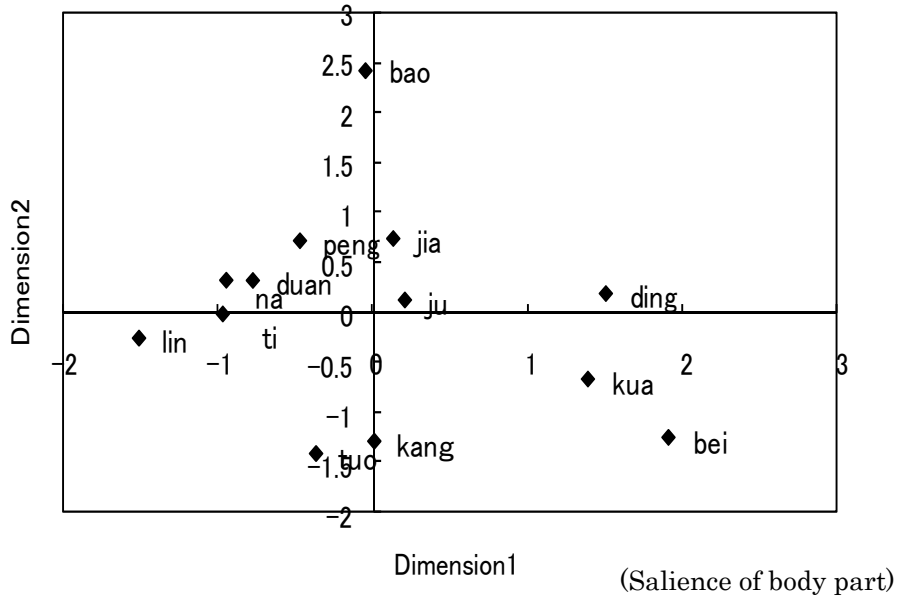
For the configurations along the three dimensions, the videos plotted in the positive direction on Dimension 1 include carry-actions where the object was supported by body parts other than hands (e.g., “ding” [carry on head], “kua” [hang on the shoulder] and “bei” [carry on back]), whereas the videos plotted in the negative direction were generally carrying actions where the object was carried with the hand (e.g., “lin”[dangle with one hand],“ti”[dangle around the arm], “na” [carry with one hand]). Thus, we can interpret Dimension 1 as representing the semantic feature distinguishing events via the manner-of-holding for the object. The interpretation of Dimension 2 is less transparent but it appears to distinguish the “bao” [carry in two arms] event (hugging a stuffed cat in two arms) from all other events. Given that the stuffed animal being carried in the “bao” event stands out from the other objects for children, Dimension 2 may be related to “salience of the object”. Dimension 3 could be interpreted as the dimension differentiating the events according to “objects to be held”. The events plotted along the positive direction of Dimension 3 included the “bei” [carry on back] events with a rucksack, “lin” [dangle with one hand] with a plastic shopping bag, “ti” [dangle around arm] with a tote bag, “kua” [hang on the shoulder] with a shoulder bag, “jia” [carry under one arm], with a square business bag

— where all the objects were bags of some kind. In contrast, the objects in the videos plotted along the negative direction were “bowls” —the “duan” [carry with two hands with caution] event with a glass bowl with water ,and the “ding” [carry on head] event with a wooden bowl.

How were the three dimensions weighted by the four different age groups? Figure 3A and 3B shows the weight plots for the four groups on the three dimensions in Common Space. As expected, there were large differences between children and adults in the weights for each dimension. While Dimension 1 (salience of body parts) was more important for adults than Dimension 2 (salience of object), the three child groups showed the reverse pattern (see Figure 3A). In Figure 3B, the weights for each age group are plotted for Dimension 1 and Dimension 3. Here, too, Dimension 3 (object to be held) was weighted more heavily by children than adults. These results suggest that young children weighted the salience and the kind of object more heavily than adults do, while placing less weight on the *manner* feature in selecting the most appropriate verb for each video. As children develop, they come to rely on Dimensions 2 and 3 less and in turn come to value Dimension 1 more.

Thus far, we found that (1) the pattern of children’s verb use differed from that of adults, and that (2) underlying this is the difference in the weights children and adults place on each dimension in their selection of a verb for a given event. In the next two analyses (Analysis 6 and Analysis 7), we analyze the data from a different angle. We ask which verbs are “easier” to learn (Analysis 6), and what properties of verbs influence ease of learning (Analysis 7).

(The salience of the object)



(Salience of body part)

Figure 2A. A common space extracted in a INDSCAL model :Dimension 1 x Dimension 2.

Note: each plot represents 13 videos and distances between plots represents the similarity of the verb production pattern.

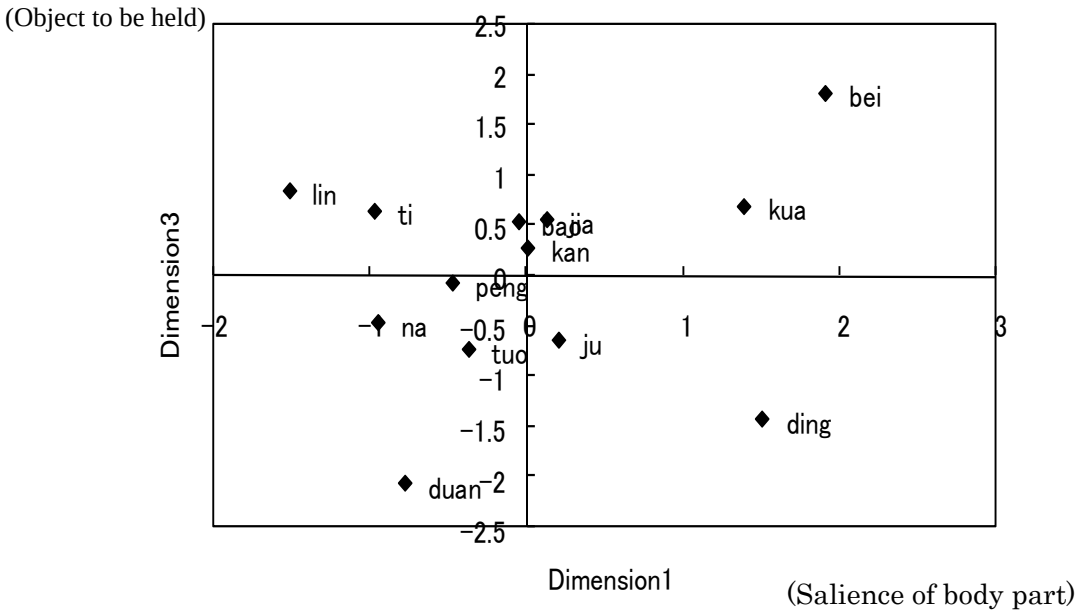


Figure 2B. A common space extracted by a INDSCAL model: Dimension 1 x Dimension 3.

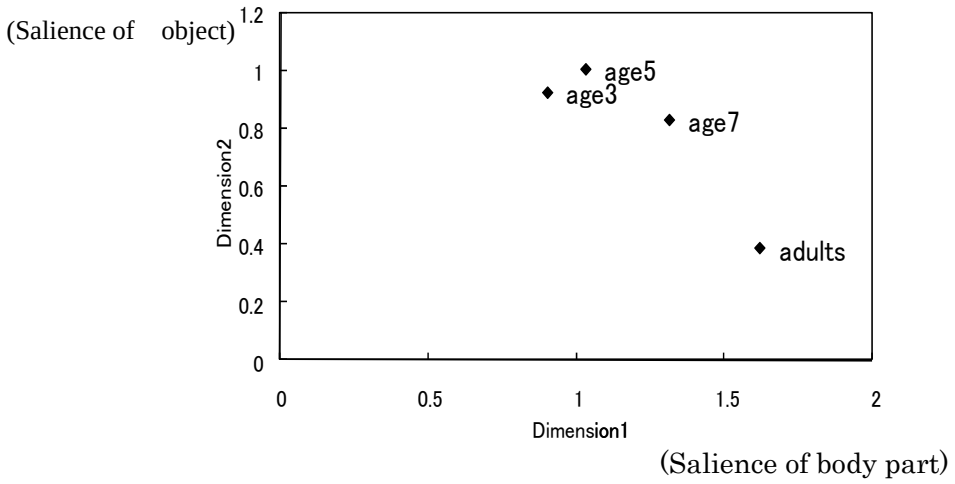


Figure 3A. An Individual space extracted in an INDSCAL model: Dimension 1 x Dimension 2.

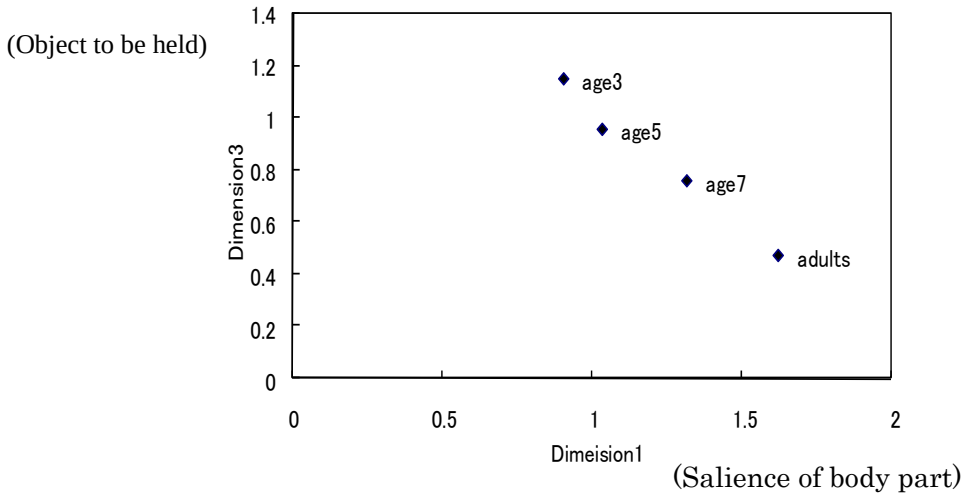


Figure 3B. An Individual space extracted in an INDSCAL model : Dimension 1 x Dimension 3.

Analysis 6: Which Verbs Converge with Adults' Production Pattern Earlier?

In the previous analysis, we examined the degree of convergence in the *pattern* of verb use for the domain as a whole. However, the degree of convergence with the

adult pattern could differ across verbs. Examining which verbs are used in an adult-like way from an early age, and which ones are used differently may provide insight into understanding the factors that affect the acquisition of verb meanings. For this purpose, we adopted entropy (*H*) as a quantitative index to represent how children and adults differentially use verbs. Entropy is originally a measure for showing the proximity for a thermodynamic system to equilibrium, but it is now widely used in information theory and statistics (Mori & Yoshida, 1990). The notion of entropy in statistics is often used in descriptive statistics as an index to represent the degree of dispersion of responses for a categorical variable. If the responses are concentrated in one or a small number of response categories, the entropy value becomes low; if they are widely dispersed across different response categories, the value becomes high (see footnote 3 for the formula)[6]. In the current context, if participants produce a single verb for a range of videos, the entropy value will be high; in contrast, if the range of application of the verb is restricted to one or a small number of videos, the entropy value will be low.

Figure 4 shows the entropy values for the eight verbs produced by at least 5 individuals in all age groups (min 0 to max 3.7). The remaining verbs were not included in the analysis because the entropy measure is not reliable when responses are produced at very low frequencies. The low entropy values for the adults suggest that for a given action, they used the verb that we had originally intended (e.g., used the verb "ding" [carry on head] for the video of what we intended to be a "ding" action) most of the time, and hence the degree of dispersion of the verb use was small. In contrast, children tended to apply each verb to a broader range of videos, resulting in higher entropy values. However, the entropy values differed substantially across verbs within

each age group. In all three child groups, the entropy values for “na” [carry with one hand] were much higher than those in the adult groups. This is because children applied “na” more broadly than adults, using it for actions for which adults used more specific verbs. In contrast, the entropy value for the verb “ding” was close to 0 for all age groups, suggesting that even the 3-year-olds used the verb “ding” exclusively for the video created to represent a “ding” action.

Taken together, two important trends emerged from entropy analyses of the production data. First, young children tended to use various verbs for a given action, while adults tended to use a specific verb for a specific event with high agreement. On the whole, children between 3 and 7 years of age are still in the process of finding out how the semantic domain is structured and how each verb is mapped into the semantic space. Second, in so doing, the timing of convergence to adult-like use does not occur evenly across verbs. Some verbs (e.g., “ding” [carry on head]) converged on the adult pattern almost from the beginning. Children used “ding” only for the action adults also described with “ding”, without applying other verbs such as “na” [carry with one hand] to this action, nor did they over-use “ding” for other hold/carry actions in the domain. In contrast, “na” was applied much more broadly, applied to many different actions, by children than by adults, and the range of application for this verb was only gradually narrowed with development.

The findings from the entropy analyses suggest that, in a semantic domain, some words tend to be over-extended but are gradually restricted, with development, to match adult use. Because some words are used more broadly, it is possible that neighboring words are in turn used more narrowly than in adult usage.

If this is the case, words that are at first used broadly may converge on the adults' extension boundary quite late, as the real convergence does not take place until the meanings of all other neighboring words are learned. Here, it is interesting and somewhat paradoxical that words that children use broadly are often those that they produce earlier than other words. In fact, "na" is one of the 10 earliest words Chinese children learn both in comprehension and production (Hao et al., 2007). In this light, it is important to revisit what factors make the word easy or difficult to learn.

As discussed above, "na" [carry with one hand] and "ding" [carry on the head]—the two verbs that contrast greatly in the timing of the convergence to the adults' use— seem to differ in the degree to which the word shares boundaries with other close neighbors. Perhaps the convergence may be influenced by the presence of similar-meaning words sharing the boundaries in the same semantic domain. If a word does not have close neighbors with overlapping boundaries, the degree of convergence may be high even from very early stages of lexical development. In contrast, if a word has overlapping boundaries with many other words, the degree of convergence between children's meaning and adults' meaning may be low at early ages, and it may take a long time for children to arrive at a meaning equivalent to that possessed by adults, because children must delineate many boundaries with many similar-meaning words.

Second, "na" and "ding" also differ greatly in the range of instances adults accept as referents. In the production task, adult Chinese speakers used "na" for the video we assumed to be the "na" action, and did not use it for other actions, as they preferred to use verbs that specifically designated those actions. However, the comprehension data indicated that adults would also accept actions denoted by other hand-holding actions such as "ti" [dangle around the arm] and "lin" [dangle with one

hand] as referents of “na”, although to a lesser degree (The verb “na” was accepted for both “ti” and “lin” videos 69% of the time whereas the proportion of acceptance of “na” for the “na” video was 85%). The reverse direction was not observed: Adults did not judge the verbs “ti” or “lin” to be acceptable to refer to the “na” video. Thus, “na” has a broader range of applicability than the neighboring verbs “lin” and “ti”. Importantly, children used “na” not only for the actions adults accepted as referents of this verb, but also for those adults did not accept (e.g., the “bao” [carry in two arms] , “duan” [carry with two hands with caution] action, “jia” [carry under one arm] action, etc.). Thus, children did seem to overextend “na” beyond its extension boundary in the adults’ sense. Interestingly, the adult comprehension data revealed that “bei”[carry on back] and “bao” also cover broader ranges than other verbs, though it is not as broad as “na”: “bei” was accepted not only for the “bei” video (93%) but also “kua” [hang on the shoulder] video at a high proportion (23%); “bao” was accepted not only for the “bao” video (100%) but also “jia” [carry under one arm] video (36%) . However, the entropy values for these two verbs were not nearly as high as that of “na.” This was because young children, especially 3-year-olds, used “na” even for the “bei” “kua” “bao” “jia” videos and they did not use “bao” and “bei” as broadly as they did “na”. It may be the case that children over-extend a word that covers the broadest range of referents in the semantic domain, which might result in late convergence with adults’ meanings.

In the next analysis (Analysis 7), we examined if these observations could be quantitatively supported, and tested what factors best explain the ease of learning verbs, when the ease of learning is defined by two different criteria:(1)“early entry into children’s vocabulary” and (2)“early convergence with the adult use.”

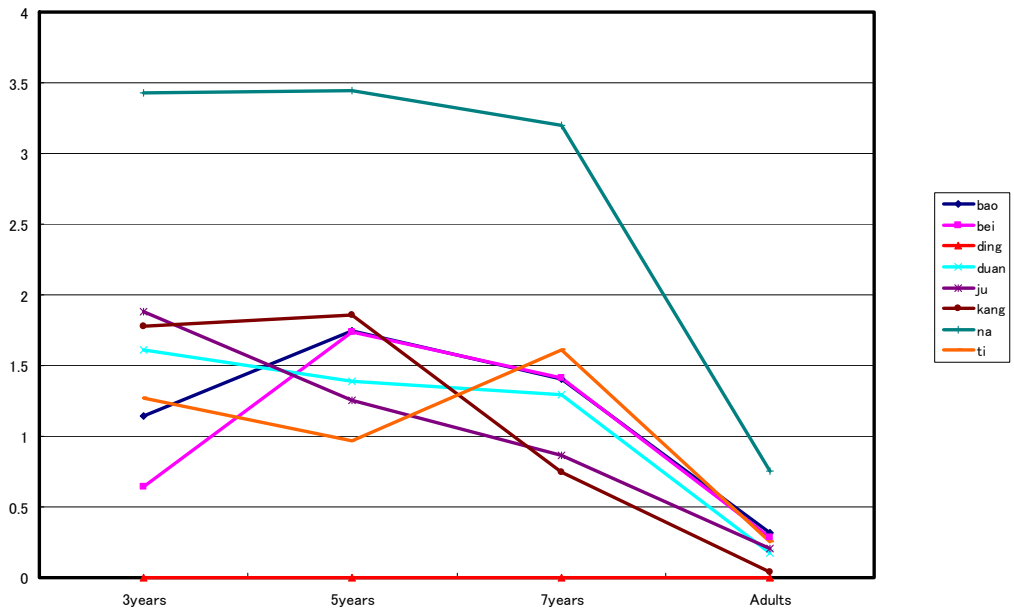


Figure. 4 Entropy values of the 8 verbs in for each of the 4 age groups.

Note: Only eight of the 13 verbs were included in the analysis. The remaining verbs were excluded because the entropy measure is not reliable when verbs are produced by less than 5 individuals.

Analysis 7: What Factor(s) Best Explain the Ease of Learning Verbs?

Measures representing "ease of learning" and predictors. In our final analysis, we examined whether the two semantic properties of the verbs—the degree of boundary overlap with neighboring words (*boundary overlap*) and the range to which the verb is applied (*verb coverage*)— affect how "easily" children learn verbs using regression analyses. To quantify these values, we used the data from the adult comprehension task.

To represent the degree of *boundary overlap*, we calculated the entropy value for *each action*. If many verbs are accepted for a given action, it means that the video

originally created to represent the verb allows other verbs to name the action. Hence, the boundary of the verb with other neighboring verbs is somewhat continuous and the verb has a high degree of boundary overlap with other verbs. On the other hand, if only one verb is accepted for the action across different adult participants, there is little boundary overlap with other verbs. To quantitatively represent the second predictor, *verb coverage*, the entropy value was obtained for *each verb*. Here, if a given verb was accepted for many different actions, i.e., if the verb covers a wide range of action instances, the entropy for the verb is high.

As discussed earlier, word frequency has been considered as an important predictor in accounting for how early the word enters children's vocabulary (e.g., Li, Zhao, & McWhinney, 2007). However, how word frequency is related to the ease of acquisition of *adult-like* word meanings is not known. We included the frequency of the verb as a predictor (*corpus frequency*) in addition to the degree of boundary overlap and the degree of coverage. The frequency counts for the 13 verbs were taken from the corpus of Frequency Dictionary of Modern Chinese (Beijing Language Institute, 1986)[7].

We carried out a series of regression analyses to test the contribution of the three predictors above—boundary overlap, verb coverage, and corpus frequency. Here, we wished to see if the three factors contribute differently for "ease of learning" when this concept is defined by the criteria—one representing the ease of initial learning, and the other the degree of convergence with the adult meaning.

The ease of initial verb-world mapping was indexed by the frequency with which each of the 13 verbs was produced by children for the 13 carrying videos. As mentioned, we assumed that the verbs children use frequently are those that children

feel most familiar and comfortable in using. To represent this measure, we counted the total produced frequency of the 13 verbs from the production matrix for each age group. For example, in the 3-year-old children's matrix, the verb "bei" [carry on back] is produced a total of 17 times (not only for the "bei" video but also for videos intended to represent other verbs) and the verb "ding" [carry on head] is produced just 7 times. In this case, we interpret that children were more familiar with "bei" than "ding" and were more willing to use the former than the latter.

The degree of convergence with adults' use was represented by the similarity of the pattern of verb use between adults and children in each age group. Specifically, for each age group of children, the similarity of the verb use was calculated for each of the 13 verbs by correlating each row vector in the matrix (i.e., the frequency of produced verbs for a given action) with the corresponding vector in the adults' production matrix.

Regression models were conducted separately for each age group, one with the production frequency and the other with the degree of convergence as the dependent measure.

The results of the regression analyses revealed that the three factors contributed differently in accounting for the "ease of learning" for the two different definitions of "ease." There was also an interesting developmental trend in the relative weights of the three factors. In the models in which the ease of learning for the 13 verbs was indexed by how willingly children used these verbs[8], the word frequency in the adult corpus made the strongest contribution for all three age groups (3 years: $\beta = .65$, $t = 3.5$, $p < .01$, 5 years: $\beta = .60$, $t = 2.8$, $p < .05$, 7 years: $\beta = .59$, $t = 3.0$, $p < .05$), suggesting that the verbs young child tend to produce frequently are also the ones that they hear most frequently. The degree of verb coverage did not make a significant

unique contribution to the model (3 years — β = .42, t = 2.0, n.s.; 5 years — β =.41, t = 1.6, n.s.; 7 years — β =.45, t = 2.0, n.s.). On the other hand, the degree of boundary overlap contributed to the model in 7-year-olds but not in younger children (3 years — β = -.27, t = -1.5, n.s.; 5 years — β = -.39, t = -1.9, n.s.; 7 years — β = -.49, t = -2.6, p <.05). This result suggests that older children tend to produce words with distinct boundaries with neighboring verbs (see Table 3).

For the models using the degree of convergence with adults' use of the verbs[9] as the dependent variable, the degree of boundary overlap contributed the model most strongly. The β value for the degree of boundary overlap was significant for all ages (3 years — β = -.73, *t* = -.2.9, *p* <.05, 5 years — β = -.81, *t* = -3.1, *p* <.05, 7 years — β = -.86, *t* = -3.8, *p* <.01). The negative direction of the β values indicates that the higher the degree of boundary overlap, the lower the degree of convergence in children's use of verbs with that of adults. For none of the three age groups did *verb coverage* and *word frequency* make a significant contribution (verb coverage: 3 years: β =.09, t = .29; 5 years — β = .18, t = .58; 7 years — β =.17, t = .66; word frequency: 3 years — β = .39, t = 1.5; 5 years — β = .00, t = -.01; 7 years — β = -.19, t = -.84, all *p*s>.1, see Table 4 for detail).

The results of the regression analyses thus suggest that different factors underlie the two different processes of word learning. At early stages of word learning, fast word-world mapping is very important. There, the input frequency plays a more prominent role than semantic properties of the target word such as boundary overlap and breadth of meaning: children produce the words they hear most often. However, for the later process of word learning, the degree of boundary overlap with other verbs is more strongly related to the degree of convergence with adults' use: The more the

word has neighboring words with overlapping boundaries, the longer it takes for children to attain adult-like meanings.

Table 3. Beta values from the Multiple Regression model using production frequency as the dependent measure.

β value	3 years (R^2=.78, F(3,9)=11.0, <.01)	5 years (R^2=.71, F(3,9)=7.2, <.01)	7 years (R^2=.76, (3,9)=9.5, <.01)
Boundary overlap	-.27	-.39	-.49*
Verb coverage	.42	.41	.45
Corpus frequency	.65**	.60*	.59*

Table 4. Beta values from the Multiple Regression model using the degree of convergence with adults as the dependent measure.

β value	3 years (R^2=.58, (3,9)=4.1, p<.05)	5 years (R^2=.54, (3,9)=3.5, n.s)	7 years (R^2=.67, (3,9)=6.1, <.05)
Boundary overlap	-.73*	-.81*	-.86**
Verb coverage	.09	.18	.17
Corpus frequency	.39	.00	-.19

General Discussion

In contrast to the majority of research in word learning, whose main focus has been to reveal the mechanism of young children's initial mapping between words and the world, the goal of this research was to uncover the processes and mechanisms by which children reorganize their initial meanings to attain adult-like meanings. Representational change in word meanings has been documented by some researchers (e.g., Bowerman, 1982; Clark, 1982, 1987; Nelson, 1974; Ameel et al. 2008). However, our research is unique in that we examined the process of evolution of word meanings by looking at a set of verbs belonging to the same semantic domain. In other words, we attempted to uncover the dynamics of learning different verbs in the same semantic domain rather than examining the representational change of a single verb in isolation from other verbs similar in meaning.

In lexicalizing actions that English speakers would refer to as "*carrying*" and "*holding*", the Chinese language divides the semantic space very finely with respect to the manner in which the object is held. Here, however, the space is not divided equidistantly among the verbs belonging to this semantic domain, nor is each verb clearly separated from the neighboring verbs. Instead, one part of the semantic space is densely covered by several close synonyms sharing boundaries, while other parts of the space are only sparsely covered. Some verbs cover a broad range of the semantic space, while others cover a relatively narrow space. In this research, we wished to understand how young children learn these various verbs and connect the findings to important theoretical issues in the literature.

What Does It Mean To Say That Children "Know" Meanings of Words?

We first asked how many different verbs children produced for the set of videos we prepared, and whether the number of verbs children produced could be a direct indication of how well children "know" the meanings of the verbs in this semantic domain. We found that the number of verbs children produced for the set of videos was indeed smaller than that produced by adults. However, importantly, although the number of the verbs produced by 3-year-olds and 7-year-olds was not different, the 7-year-olds' *pattern* of verb use as a whole was much closer to the pattern of adults' use than that of 3- or 5-year-olds was. Thus, the number of verbs children produce could not by itself be taken as a direct index of the *depth* of the knowledge children have for this semantic domain, which in turn suggests that the fact children know particular words (in the sense that they have these words in their vocabulary and use them) does not always guarantee that children possess adult-like representations of the word-meanings (see also Imai et al., 2005, 2008;Bowerman, 2005; Clark, 1995, 2009).

Relation between Care-takers Input and Children's Word Use

We suspected that children's overextension of some verbs like "na" [carry with one hand] could be due to overextension of these verbs by care-takes: Children use "na" in the contexts in which adults usually would not, but this was because caretakers would overuse "na" in favor of other more appropriate verbs. However, the pattern of verb use by 2-year-olds' mothers was no different from the verb use by 5-year-olds' mothers or by undergraduates. Thus, children's early use of these verbs is not merely a reflection of care-takers' adjustments in verb use.

Children and Adults Weigh Different Semantic Features in Their Use of Verbs

We not only found that the pattern of word use by young children is largely different from that of adults, but also uncovered what underlies the change from children's meanings to adults' meanings for the verbs in the semantic domain we investigated (Analysis 5). Adults differentiated the verb use according to the manner with which the actor held the object. In contrast, children focused on the object involved in the carrying events more strongly than the manner. With development, the relative weights placed on the two semantic dimensions shifts from the object to the manner.

It has been pointed out that objects involved in action events play an important role in early verb learning. Many novel verb learning studies have demonstrated that children have difficulty in extending a newly introduced verb to a same-action event with a different object, whether the object is the actor (Kersten, & Smith, 2002; Maguire et al., 2006; Imai, Kita, Nagumo, & Okada, 2008) or the patient object (Imai et al., 2005, 2008), which suggests that children first incorporate the object into the verb meaning; Only gradually do children separate the core verb meaning from the object (see Bowerman, 2005 for relevant points).

Two criteria for "ease of learning words"

This research also provides important implications for a key issue in the literature on lexical development—the issue concerning what types of words are easy (or hard) for children to learn. We demonstrated that "ease of learning words" defined by two different criteria gives rise to different conclusions. When the ease of learning is defined as the ease of an initial mapping of the word to a preliminary, partial meaning,

corpus frequency turned out to be the most important among the three factors examined. Children tend to say words that they hear frequently.

Note that other factors that have been considered to be critical, i.e., conceptual factors such as ease of individuation, concreteness and imageability of the meaning, were not incorporated in our analysis. Given the results of previous research (e.g., Gentner, 1982; Gentner, & Bowerman, 2009; Imai et al., 2005; Maguire et al., 2006), these conceptual factors may strongly influence the ease of word learning at early stages of lexical development, with initial fast-mapping. However, the verbs we dealt with in this research all denoted concrete and imageable actions. Nonetheless, the 13 verbs differed considerably both in their frequency in children's production and in their degree of convergence with the adults' pattern of verb use.

We suspected that two factors inherent to verbs—breadth of extension (represented by *verb coverage*), as proposed by Ameel et al. (2008), and the degree of boundary overlap with other close synonyms in the same semantic domain—may affect the *ease* of learning, especially when we define "*ease*" as the degree of convergence with adults' use of the verb. In all three child groups, the factor that significantly contributed to the degree of convergence was the degree of boundary overlap but not the breadth of meaning per se. Thus, having a boundary that is not overlapping with other verbs makes the verb easier to learn than it would otherwise be; The more close neighbors a verb have that share the boundary, the longer it will take for children to attain the adult-like meaning.

It is interesting that the verb "na" [carry with one hand], which children produced most frequently in the production task, had the lowest degree of convergence with the adults' use. When we use CDI data or corpus data, words like "na" are usually

considered to be “easy words to learn” (e.g., Hao et al., 2007; Ma et al., 2009). Yet these words could also be considered as “difficult words” when the ease of learning is defined in light of the age at which adult-like use finally emerges.

It has been a common practice for researchers to discuss what types of words are *easier to acquire* than others without even specifying what they mean by “acquisition of the meaning of a word.” However, our results should urge them to revisit the very notion of “acquisition of word meaning” before discussing what types of words are easy or difficult to learn. It also cautions against the mere reliance on the CDI or corpus data as the index for “acquisition of word meaning,” as our data suggest that the fact that children produce certain words does not mean that they understand the meanings of the words in the same way adults do: children “know” and “say” a fair number of verbs in the carrying/holding domain, yet their representation is incomplete. When researchers state that “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 it is not quite the same as the knowledge possessed by adults.

Importance of Examining the Development of Word Meanings as a Whole within a Single Semantic Domain

This research underscores the importance of studying word meaning acquisition in light of how words in the same semantic domain are learned and how such word meanings evolve as parts of a connected system. It is important to note that the meaning of a word is largely dependent on its relation with neighboring words (e.g., Lyons, 1977; cf. de Saussure, 1916/1983), and hence acquisition of the meaning of a word cannot take place in isolation of acquisition of other relevant words. However, in

investigating how children acquire meanings of words, this has often been overlooked. While much effort has been devoted to uncover how children break the initial barrier between words and the world, other important questions for lexical acquisition have been under-investigated.

In this research we asked: how learning of new words influences the meanings of words that are already present in children's lexicon and how children's word meaning representation evolves to match the representation possessed by adults. There has been some important research addressing these questions (e.g., Clark, 1987, 1995, 1997, 2009; Bowerman, 1982; Haryu, & Imai, 2002; Waxman, & Senghas, 1992), but few studies have systematically investigated how meanings of words belonging to the same semantic domain are learned in the process of the restructuring of the semantic domain as a whole(but see Clark 1972; 1973b; 1975; 1980; Gentner 1975; Haviland & Clark 1974, for early works looking at how relative complexity of meaning affected order of acquisition within a domain).

By investigating the set of verbs belonging to a single semantic domain, this research addressed the dynamics of what kinds of words enter the children's lexicon early, how these words are used, and how they go through changes in meaning as other words in the semantic domain are added to the lexicon. Verbs that are likely to be included in children's early lexicon tend to be those that they hear most frequently. Words that are frequently used by adults should be correlated with breadth of meaning. Children thus start to say these verbs early and use them to broad range of events.

When these frequent and broad-covering verbs have close neighbors that cover a relatively narrow range of referents, the more frequent ones may tend to be overextended to cover the actions that adults would denote with a less frequent, specific

verb. As children's lexical knowledge of the domain develops with increase of verb types and with experience of using them, the boundary of the verb that has been overextended is gradually modified. Attainment of the adult-like representation of the verb, however, may not take place until children have sufficiently acquired the neighboring verbs that have been originally under-extended because of the overextension of the frequent verb.

It should be noted with interest that breadth of verb meanings did not make a significant contribution to the degree of convergence with adults' verb use in our regression models, contrary to Ameel et al.'s (2008) suggestion. Even when a verb covers a wide range of referents, if the verb's boundary is clear with no overlap with other related verbs, children's meaning of the verb converges to that of adults faster and more easily than when the verb has many close neighbors whose boundaries overlap.

In this sense, it is important to extend our research cross-linguistically. For example, do children find it easier to learn the English verbs "to carry" and "to hold" than the Chinese verbs belonging to same carry/hold domain investigated here? According to our findings, we might expect that the English system is easier than the Chinese system. Even though English-speaking children need to learn broad extension ranges for the two verbs, they need to delineate only one boundary (between "carrying" and "holding"). Chinese children, in contrast, need to sort out the relation among many similar meaning verbs, whose boundaries largely overlap with one another.

Of further interest is to see whether the English-type of division of the semantic domain or Chinese-type of division is crosslinguistically more prominent. Gentner and Bowerman (2009) have proposed a hypothesis that a crosslinguistically dominant way of lexicalizing a given domain might reflect a natural way of categorizing the world for

humans. Thus, children should find it easy to learn words if the language they are learning follow the crosslinguistically prominent pattern of lexicalization. It is interesting to find out which type of division is crosslinguistically more common to test their hypothesis as well.

All in all, this research underscores the importance of examining children's word meaning acquisition in a broad scope, from the initial stage of word learning to much later stages. It also highlights the importance of systematic investigation of words that belong to the same semantic domain as a whole, examining how word meanings in the domain develop as parts of a connected system, instead of examining each word separately.

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[1] We acknowledge that, although our view of word meaning is certainly in keeping with previous theories of lexical development (e.g., Bowerman, 1982, 2005; Clark, 1972, 1982, 1995, 2009; Ameel et al, 2008), from a different theoretical stance, one may argue that the applicability of words has little to do with true word meaning, and hence developmental changes in the applicability of a word cannot suggest changes in word meaning representation. As noted, it is beyond the scope of the paper to review and evaluate different theories of word meaning. However, we would like to stress that it is virtually impossible to reveal the *denotation* of a word directly through observation or experiments (as it is not possible to test whether every single entity in the world is or is not a referent of the word), let alone the *sense*. We thus assume that knowledge of the applicability of a word is a window that allows us to infer the meaning representation of that word. In this sense, if the application of a word by a child largely differs from that of adults, we consider this to be an indication of a difference between the children's meaning and the adults' meaning of the word.

[2] Cases where the character was used as a morpheme of other words were excluded in the frequency count.

[3] Some readers may be concerned that the methodology of the experiment has encouraged the differential use of verbs for different videos, as quite similar events of carrying and holding an object were presented in sequence. However, even if that was the case, this would not affect the interpretation of our findings. The developmental differences found in the present research could not be attributed to this effect, as it was not the number of verb types but the pattern of verb use that children in different age

groups differed.

[4] We had originally conducted separate analyses both for the “carrying” and “holding” matrices, but the results were very similar. Thus, we only report the results of the analysis using the matrix for the “carrying” events to avoid redundancy.

[5] Ameel et al. (2008) addressed the same question for the domain of container names. They had their participants (5-14 year-olds and adults) generate features of each object in their stimuli set and tested how these features predicted the pattern of naming for each age group by regression analysis. However, this method was practically too difficult, as it would be too demanding for children of the age in our study (3-,5-, and 7-year-olds) to describe features for verbs, especially given that our stimuli were videos that included both objects and actions. Because the object properties would be easier to perceive and describe than action properties, it is likely that children would simply talk about the objects, even though they consider manner properties of actions. Thus, even if we obtained the results showing that object features were more important than manner features for children, it may simply because object properties are easier to describe for children.

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

[7] In Chinese, the distinction between a morpheme and a word is difficult to make.

The 13 verbs were words consisting of a single morpheme. To make sure that the frequency count for each verb does not contain cases in which the same morpheme is a part of a different word (e.g., "ti" [dangle around the arm] used in "ti-gao" [to raise, to improve), we went through the examples manually and excluded the latter cases from the counts.

[8] There was no multi-collinearity among the three predictor variables in every model. Thus, the three independent variables were all entered in the model using the forced entry method. The model fit with the three variables were significant for all three ages (3 years: R^2 =.78, F (3,9) = 11.0, p < 01; 5 years: R^2 =.71, F (3,9) = 7.2, p < 01; 7 years: R^2 =.76, F (3,9) = 9.5, p < .01).

[9] Again, there was no multi-colinearity among the three variables, so all three variables were entered in the model. The model fit was not quite as good compared to the production frequency models (3 years: R^2 =.58, F (3,9) =4.8, p <05; 5 years: R^2 =.54, F (3,9) =3.5, n.s; 7 years: R^2 =.67, F (3,9) =6.1, p <.05)