Available online at www.sciencedirect.com
ScienceDirect
Journal of Memory and Language 58 (2008) 262–285
Journal of Memory and Language
www.elsevier.com/locate/jml

Object naming and later lexical development: From baby bottle to beer bottle ☆

Eef Ameel [a,*], Barbara Malt [b], Gert Storms [a]

[a] University of Leuven, Tiensestraat 102, 3000 Leuven, Belgium
[b] Lehigh University, 17 Memorial Drive East, Bethlehem, PA 18015, USA

Received 13 September 2006; revision received 22 January 2007
Available online 7 March 2007

Abstract

Despite arguments for the relative ease of learning common noun meanings, semantic development continues well past the early years of language acquisition even for names of concrete objects. We studied evolution of the use of common nouns during later lexical development. Children aged 5–14 years and adults named common household objects and their naming patterns were compared. Children showed a gradual convergence to the adult categories through addition of new words to the vocabulary as well as extended reorganizations of existing categories. Different theories of early lexical development make competing proposals about the differences in featural knowledge that result in discrepancies from adult word use. To evaluate these theories with respect to later lexical development, we used features collected from adults and children to predict the naming patterns of the different age groups. Consistent with [Mervis, C. B. (1987). Child-basic object categories and early lexical development. In U. Neisser (Ed.), *Concepts and conceptual development: ecological and intellectual factors in categorisation* (pp. 201–233). Cambridge: Cambridge University Press], children gradually learned to attend to the adult feature sets and to assign the features the appropriate weights. A sorting task showed that, furthermore, evolution of general conceptual knowledge as well as word-specific knowledge contributes to the convergence. We discuss implications for developing a theory of later lexical development.

Keywords: Object naming; Later lexical development; Feature-based theories

Introduction

Children learning the words of a first language must isolate word forms, identify potential meanings, and assign these meanings to the newly isolated words (Clark, 1995a, 1995b). The potential meanings may be based on conceptual categories already represented in memory (Clark, 1993, 2004), and it appears that children need only minimal exposure to a new form before assigning some meaning to it. As soon as a possible meaning is assigned, the word is ready for use. Carey (1978) introduced the term *fast mapping* for this process

☆ Eef Ameel is research assistant at the Fund for Scientific Research, Flanders. The research presented in this paper was partly sponsored by Grants OT/01/15 and IDO/02/004 of the Leuven University Research Council awarded to G. Storms. We thank Eve Clark and Mutsumi Imai for helpful comments on an earlier draft of this paper. We are also grateful to Sofie De Ceuster, An Brion, Stephanie Luyten, Sarah Vanderstraeten, Sofie Thijs, and Elke Bohnen for assisting in the data collection.
* Corresponding author. Fax: +32 16 32 59 16.
E-mail address: eef.ameel@psy.kuleuven.be (E. Ameel).

0749-596X/$ - see front matter
doi:10.1016/j.jml.2007.01.006

of quick initial learning. Fast mapping allows children to add words to their vocabulary at a rapid rate during the first years of language learning. By age two, children are able to produce 50–500 or 600 words. In the period from age two to six, they are estimated to acquire around 14,000 words, at a rate of ten words a day (Carey, 1978).

The meaning assigned through fast mapping, however, often comprises only a fraction of the meaning adults attach to a word. Learning the full conventional meaning of a word may take months or even years. Many studies have been devoted to understanding how children refine the meanings of words during the early years of language learning. For example, Mervis' (1987) provided a detailed description of the initial construction and subsequent development of some of her son's first labeled categories, such as *duck* and *mixer*. The evolution of these categories was characterized by underextension, followed by overextension which was subsequently reduced when new words were learned (for other illustrations, see Bloom, 2000; Clark, 1993; Waxman, 2002).

A much smaller literature demonstrates that semantic development may continue well past the early years of language acquisition for certain word classes. For example, the meanings of orientational terms (*top, bottom, front* and *back*) are not fully mastered until the age of 5 (Clark, 1980). Similar findings were reported for deictic terms, such as *this*, *that*, *here* and *there* (Clark & Sengul, 1978). Further, a number of studies have shown learning periods for verb meanings extending to age 8 or 9. Gropen, Pinker, Hollander, and Goldberg (1991) for instance, found that even relatively frequent verbs, such as *pour* and *fill*, are not fully understood until middle childhood (for more examples, see Bowerman, 1974; Clark & Garnica, 1974; Gentner, 1978; Pye, Loeb, & Pao, 1996).

In contrast, less attention has been paid to the learning trajectory of common nouns naming familiar, concrete objects past the early years of language acquisition. Gentner (1978, 1982, 2005) has suggested that acquisition of common nouns is a faster process than verb acquisition because common nouns refer to entities easily segregated from their context, while verbs convey relationships among entities. This suggestion implies that the meanings of common nouns will be relatively easy to learn. It is compatible with Rosch's (1975) proposal that common nouns capture sets of things sharing many inter-correlated properties, and with the assumption in the second-language learning literature (De Groot, 1993; Kroll, 1993) that the meanings of common nouns will tend to be closely equivalent across languages. Bloom (2000, 2001) has even suggested that it is not interesting from the perspective of understanding language learning to study the evolution of such word meanings past initial acquisition, because the process reflects only conceptual development.

However, evidence from several sources, which we discuss below, has begun to accumulate suggesting that the case of common nouns may be more complex than such proposals would suggest. This evidence implies that the knowledge required to use common nouns as adult speakers do may not be so readily acquired. Indeed, Andersen (1975) asked English-speaking children aged 3 through 12 to name ordinary drinking vessels, and she found that it was only at age 12 that children's use of terms such as *cup* and *glass* fully matched adult usage.

In the present paper, we investigate the learning trajectory for common nouns referring to familiar, concrete objects. Three issues are addressed: First, does this trajectory continue well past the early years of language acquisition? Second, if it takes children an extended period of time to learn the meaning of common nouns, what is the nature of the learning that must take place well past the early years of language acquisition? We compare several hypotheses about how featural knowledge associated with the words changes over time, and we evaluate whether any of these feature-based hypotheses fully explains naming choices. Finally, we address whether later lexical development for common nouns is purely lexical in nature—that is, concerns only adjustments to the knowledge associated with words—or whether it also involves changes in the child's underlying understanding of the entities referred to by the words.

The complex meanings of common nouns

Berlin (1978) and Hunn (1977) have suggested that some common nouns—names for plants and animals, specifically—label groupings of entities that reflect "discontinuities in nature" and that are so obvious to the human perceiver that they "cry out to be named." This suggestion is compatible with Rosch's (1975) notion that many common nouns, including names for artifacts, such as *chair* and *bowl*, capture sets of things sharing many inter-correlated properties. If common nouns in general label groupings of objects made obvious to the perceiver by the distribution of properties across them, then naming patterns should be similar across languages, and they should be predicted by judgments of the similarity among the entities.

Malt, Sloman, Gennari, Shi, and Wang (1999) examined naming and perceived similarity for a set of 60 common containers (mostly called *bottle* or *jar* in English) by speakers of American English, Mandarin Chinese, and Argentinean Spanish. They found substantial differences in the linguistic category extensions across the speakers of the three languages, while the perception of similarity across the languages was much the same. These results indicate that the linguistic categories of a language are not strictly formed around similarity-based clusters. Malt, Sloman, and Gennari (2003) examined in more detail the relation among the linguistic categories of the three languages for the 60 containers and found a complex pattern. Some of the categories were centered around similar prototypes across the three languages, whereas others were not. Some categories of one language were nested within those of another language, whereas others were not. And some cases of cross-cutting were found, in which pairs of objects were put into a single category by one language but into different categories by another language. Taken together, these findings show that the groupings captured by common nouns do not consist simply of obvious groupings of objects having many interrelated properties in common.

This conclusion is further supported by Ameel, Storms, Malt, and Sloman (2005). They replicated Malt et al.'s (1999) finding of a dissociation between naming and similarity using French- and Dutch-speaking monolinguals in Belgium. These groups are similar in culture and familiarity with particular types of objects. As expected their similarity judgments were highly correlated, yet they displayed distinctly different naming patterns for two sets of household objects.

Direct evidence for the complex learning trajectory of common nouns was provided by Malt and Sloman (2003). They found that second-language learners retained discrepancies from native speakers in their use of English nouns for common containers and other house-wares even after more than 13 years of immersion in an English-language environment, and even after they acquired the appropriate prototypes. These discrepancies appear to reflect non-equivalences of meaning between languages and the resulting complexity of the learning task.

Given this evidence for the complexity of the knowledge that must be grasped to use common nouns as a native adult speaker does, we suggest that learning common nouns may present challenges to children not yet fully appreciated, and the learning trajectory may extend well past the early years of language acquisition.

Feature-based theories of early lexical development

If it takes children an extended time to learn the full conventional meaning of common nouns, what is the nature of the learning that must take place well past the early years of language acquisition? To address this question, we draw on three theories of early lexical development put forward in the 1970s and 1980s. These theories proposed that the differences between child and adult word use arise through differences in the featural knowledge associated with words, and they are distinguished by what they take the nature of the featural differences to be.

None of these feature-based perspectives is currently proposed as a complete theory of early lexical development. Recent theories have emphasized the importance of principles that might govern mapping of conceptual knowledge to words. For example, Clark's principle of *contrast* (Clark, 1987, 1990) says that a child, hearing a new term, assumes that the speaker means something different from what has already been labeled. The principle of *conventionality* (Clark, 1983, 1993) constrains children to use conventional forms to express meanings, enabling them to be understood within their language community (see the General Discussion). Because the recent theories do not speak to how children's concepts or word meanings are represented, they do not lead to specific predictions about the trajectory of object naming. The feature-based theories, on the other hand, directly address the content of the meaning representations, providing testable predictions about how word meanings evolve, and so are more useful to our investigation. Besides their predictive power, there are other reasons to think that featural investigations remain a useful way of examining later lexical development. First, Sloman, Malt, and Fridman (2001) found that feature sets correctly predicted the names given by adults to 85–92% of objects in three large (60 objects apiece) sets of artifact pictures. Whether explicitly or only implicitly represented in the mental lexicon, features seem to capture a substantial portion of the knowledge upon which adult naming choices are based. Second, the lexical principles of recent theories may be most important for bootstrapping the early stages of word learning, whereas later lexical development may consist more heavily of the refinement of featural knowledge (see the General discussion). Finally, the knowledge acquired through the application of lexical principles may itself be featural in nature.

The first feature-based theory we draw on is Clark's (1973) Semantic Feature Hypothesis, which suggests that the meaning of a word initially consists of only a few semantic features. By adding more features, the child gradually learns the full meaning of a word. Consequently, the initial child lexical categories will tend to be larger than adult categories, since only one or two features are used to pick out referents instead of the whole set of adult features (for evidence on over-extensions in early language development, see Rescorla, 1980). Young children's over-extended categories are based primarily on perceptual or physical properties, such as shape, size and texture. Clark pointed out that children must not just add perceptual information to the meaning of a word, but must also learn functional or cultural roles before they can, for example, learn the distinction between meanings of words, like *chair* and *throne*. So, over-extensions gradually disappear when children narrow down the initially very general meanings of the overextended terms by adding more features to them.

Clark (1973) suggests that this narrowing-down process takes place in conjunction with the introduction of new words that take over subparts of an initially overextended semantic domain. Due to the addition of other features to word meanings and the new vocabulary acquisitions, individual word meanings become more specific and semantic domains are considerably restructured. For instance, children might initially use the word *ball* for a variety of round objects including balloons, apples, a round lamp, and a yoyo, since they might have characterized the word *ball* as meaning ROUND. If they next acquire the word *apple*, they must add features to make this word distinct from *ball*. For instance, they might add the feature STALK. At the same time, they will probably add more features to the meaning of *ball*, such as BOUNCING, to contrast this meaning to the meaning of the newly learned word.

An alternative hypothesis was offered by Nelson (1974), who suggested that a concept is formed through a child's interaction with her surroundings, and her representation of the object is closely tied to this interaction. When the child focuses her attention on a new object, for example, a new ball, this instance maps onto a concept consisting of relations to self, to other possible actors (e.g., MOTHER), to locations (e.g., LIVING ROOM) and actions (e.g., THROW, PICK UP, ROLL) and the effects of actions over time. The ball never exists for the child outside of one of these relations. When an instance of the concept BALL comes to be named, it would be named *ball* only if these relations hold. So, in contrast to Clark (1973), Nelson proposed that children initially attend to more features than adults do, rather than fewer when assigning names to objects. This explains why some of the child's initial lexical categories are narrower than the corresponding adult's categories. To name objects independently from their involvement in a set of relations, some relational features need to be identified as irrelevant to the concept's functional core, such as location of the activity. For example, the functional core of BALL will end up containing the functional features ROLL, BOUNCE, THROW. In addition, as instances are added to the concept, a set of identifying, mostly perceptual, features are attached to the functional core, for example, ROUND for BALL. Eventually, the meaning of a word will consist of the specification of obligatory (core) and optional relations. Nelson's claim that word use is tied to specific activities, rather than being connected to objects independently, has not received empirical support; for instance, Huttenlocher and Smiley (1987) found that even young children can learn names outside any interactive context. However, the possibility that children begin with more features than the adult set provides a useful alternative to Clark's proposal for our purposes.

A third featural view is that of Mervis' (1987) who suggested that the nature rather than the number of features associated with words is key to distinguishing child and adult lexical knowledge. Young children often do not share adults' knowledge of culturally appropriate functions of objects and the correlated form attributes (i.e., what objects do and how they are used). This leads children to deemphasize features of an object that are important from an adult perspective. At the same time, children emphasize features that are unimportant to adults. As a result, besides both over- and under-extension, "child-basic" lexical categories may also partially overlap adults' basic level categories such that the child's category may include objects that are excluded from the adult category while excluding objects that are included for adults. For example, a child may use *ball* for round piggy banks, but not for (oval) footballs. Through growing experience with objects and their place within the culture, children learn to attach the same weights to the same features used by adults. For example, the most important feature of a piggy bank is the slot on top, which determines its function. To attend to this feature in choosing names for objects, the child needs to grasp what the slot is used for and attach this cultural knowledge to the appropriate lexical item. The flexibility of this theory (allowing both over- and under-extensions) in some sense makes it weaker than the previous two. However, it describes a third possible pattern of development for our assessment.

We thus evaluate the three theories just described with respect to their ability to account for later semantic development. We make no claim about the utility of these theories in accounting for early semantic development. We draw on them here as a means of expressing the possible ways in which the knowledge attached to words may evolve in later semantic development.

Beyond a single set of features

A feature-based account may explain much of the evolution that takes place in later semantic development, but a single feature set may not fully account for all of the naming choices. In light of the cross-linguistic variability in naming patterns for common household objects, and the dissociation of naming from perceived similarity (Ameel et al., 2005; Malt et al., 1999), Malt et al. (1999) argued that the lexical categories of each language are also influenced by the linguistic and cultural histories of the language. Malt et al. (1999) proposed the existence of several mechanisms that might cause idiosyncratic complexity in naming that cannot be explained by the presence of particular features associated with a name. A particular name can be used for an object by linguistic *convention* rather than because of specific similarity relations to other objects associated with the category name; for instance, the name can be introduced by a manufacturer through advertising. People may avoid calling an object by a particular category name because using that name would lead to ambiguity or confusion with another type of object that already receives the name, a case they labeled *pre-emption*. Malt et al. (1999) gave the example of a soup tureen (for serving soups) that may be called *tureen* even though it shares many features with objects called *bowl* or *pot*. Calling it a soup bowl or soup pot would create referential confusion with vessels for eating or cooking soup. The use of *bowl* or *pot* for the serving container may therefore be ‘‘pre-empted’’ by the other uses of these names. *Chaining* is at work when an object, similar to central examples of one lexical category, receives a different name through links to near neighbors that are more typical objects of a second lexical category. Malt et al. (1999) further argued that the idiosyncratic mappings can only be mastered through growing experience with the naming of individual objects.

We suggest that children first have to learn a set of features that account for the naming of most members of a semantic domain. For a subset of the members, however, the correct names cannot be determined through application of this main feature set. Instead, the child must also learn language-specific conventions. For example, an aspirin *bottle* has a wide mouth and holds solids even though most bottles hold liquids and have narrow mouths, or a rectangular cardboard ice cream container with a lid is called *carton* even though most rectangular cardboard containers with lids are called *box*. The lexical conventions may be represented by specific combinations of features or by specific values on the main features that are not captured in the main feature set. They may be learned through experience with specific word-object pairings in adult speech, and this learning will contribute to the extended trajectory for mastery of common nouns.

Non-linguistic development

The three theories of early lexical development described above propose that the differences between child-based and adult-based categories are due to differences in the features to which children attend when assigning names to objects. One possibility is that these differences are purely lexical—children understand the domain non-linguistically in much the same way was as adults but have not yet fully mastered the mapping of non-linguistic knowledge to lexical items. As a result, they use the wrong features or the wrong set of feature weights to govern their use of words. On the other hand, these differences may be due, in whole or part, to differences in the child's conceptualization of the objects themselves.

Clark (1973), Nelson (1974) and Mervis' (1987) all take conceptual development as an important part of early lexical development, suggesting that children acquire semantic knowledge through growing cultural and functional knowledge about objects and the world. Waxman (2002) and Booth et al. (2005) have demonstrated that both perceptual and conceptual information are acquired in early word learning. These theories and studies, however, address semantic and conceptual development in very young children, whereas our interest is in children past the early years of lexical development. On the one hand, children between 5 and 14 years old are still developing their understanding of many basic aspects of their world, which might include the household objects studied here. On the other hand, Malt and Sloman (2003) found that second-language learners who presumably had a full conceptual grasp of the objects showed substantial lexical learning in their use of English nouns for common containers and other house-wares over years of immersion in an English-language environment. This finding suggests that later semantic development could be a purely lexical process.

Overview of studies

Following from the issues we have just reviewed, we conducted three studies aimed at asking: (1) Does the learning trajectory for common nouns referring to familiar, concrete objects continue well past the early years of language acquisition? (2) If so, what is the nature of the featural learning that takes place as the child converges on adult word meanings? And to what extent can a single set of features explain the naming patterns of children and adults? (3) Is any observed extended development of word use purely lexical in nature, or does conceptual development continue to play an important role, even for common household objects?

In the first study, we collected naming data for two sets of household objects from children aged 5 to 14 and from adults. We evaluated whether there was substantial evolution in the use of the terms for this domain across these ages and whether observed changes could be accounted for by the entry of new words into the vocabulary. In the second study, we gathered features from adults and children for the major linguistic categories in the naming data. The features were used to provide further evidence for the convergence onto adult word use, to evaluate several hypotheses about how the knowledge associated with the words changes over time, and to study the extent to which the main feature set associated with a word at a given age can explain the naming patterns of the respondents at that age. Finally, in the third study, similarity sorting data were collected from adults and children to investigate whether development at the conceptual level may contribute to later lexical development or whether development at this point is purely lexical.

Study 1

Study 1 was aimed primarily at examining the learning trajectory of common nouns. As in Andersen's

(1975) naming study with drinking vessels, naming data for common household objects were collected from children of different ages. Our study went beyond Andersen's (1975) study in several ways. First, while Andersen apparently determined adult names for the objects only on intuition (they did not gather adult naming data for the stimulus set, nor specify how they determined the names used as a standard), we used adult naming data collected for the same stimulus set in an earlier study (Ameel et al., 2005). This gave us a more objective basis for comparing the child- and adult-based categories. In addition, because even adults are often not in complete agreement on the name for an object, it allowed us to consider the probability of each name choice for a given object rather than designating each child choice merely as matching or not matching adult use. Finally, Andersen's stimulus set was relatively small (25 drinking vessels) and she used informal analyses to examine the categories of the children. We replicated and extended her findings and allowed for more detailed analyses by collecting naming data for two much larger stimulus sets of common household objects.

We also used the naming data to investigate what pushes the child towards greater convergence with the adult use after she has established a working grasp of a word. According to Clark (1973), semantic development occurs through adding more features to word meaning. This process is initiated through the introduction of new words into the child's vocabulary that take over parts of the over-extended semantic domain and bring attention to features that distinguish meanings of contrasting words. Thus, we assessed whether the entry of new words into the vocabulary could account for the observed changes.

Methods

Materials

The two sets of common household objects originated from Ameel et al. (2005). One set, which we will call the bottles set, contained 73 pictures of household storage containers. These objects were selected to be likely to receive the name *bottle* or *jar* in American English or else to share one or more salient properties with bottles and jars. The other set, which we will call the dishes set, consisted of 67 pictures of cups and dishes for preparing food and serving food and drinks. For this set, objects were selected to be likely to be called *dish*, *plate* or *bowl* in American English. Objects were photographed in color against a neutral background with a constant camera distance to preserve relative size. A ruler was included in front of each object to provide additional size information.

Figs. 1 and 2 provide typical exemplars of the 'main' lexical categories, as derived from the adult naming data, for the bottles and dishes sets, respectively. The objects in Fig. 1 (from 1 to 6) are called *fles*, *bus*, *pot*, *brik*, *doos* and *tube*. The objects in Fig. 2 (from 1 to 6) are called *kom*, *tas*, *schaal*, *bord*, *beker* and *pot*. American English naming data for the same stimulus sets gathered in another study show that the objects named *fles* in Dutch were mostly called *bottle* in English, objects called *bus* mainly received the name *bottle* or *can* in English, objects called *pot* were mainly *container* or *jar* in English, objects called *doos* or *brik* were *box* in English and the *tube* objects were also *tube* in English. (Note that *brik* is used in Belgian Dutch to refer to box-like objects but this word is not used in Dutch spoken in the Netherlands.) For the dishes set, objects named *kom* in Dutch were mostly called *bowl* in English, *tas* objects mainly received the name *mug* or *cup* in English, objects called *schaal* were mainly *dish* or *bowl* in English. For objects called *bord*, *beker* and *pot*, English speakers, respectively, used *plate* or *bowl*, *mug*, and *cup*.

Participants

A total of 120 volunteer children of six different ages in the Leuven, Belgium region named the objects of the bottles set: 25 5-year-olds, 25 8-year-olds, 25 10-year-olds, 25 12-year-olds and 20 14-year-olds. For the dishes set, 101 children from the same region performed the naming task: 26 5-year-olds, 25 6-year-olds, 25 8-year-olds and 25 10-year-olds. We tested up to the age of 14 for the bottles set and only up to the age of 10 for the dishes set because the correspondence in naming between the 10-year-olds and the adults for the dishes set was as high as the correspondence in naming between 14-year-olds and the adults for the bottles set. The naming differences between 5- and 8-year-olds were also larger for the dishes set than for the bottles set (see Results and discussion below). Apparently, children's naming converges faster on the adult naming pattern for the dishes set than for the bottles set. Therefore, to best see the convergence we collected naming data from 6-year-olds instead of the older children. Each child took part in only one of the two naming tasks. All the children were native speakers of Dutch. Children through age 10 had knowledge of other languages that was limited to a few words of French or English, picked up from television or while on holiday. The 12- and 14-year-old children had minimal additional knowledge of French through formal instruction at school that started at age 12. The naming data of 32 Dutch-speaking adults were taken from Ameel et al. (2005). All adults named both the bottles and dishes set with the order counterbalanced across participants. All adults considered themselves to have one native language, Dutch. They had some knowledge of French and English through formal instruction. However, only three used French or English in daily activities (i.e., occasionally at work).

Fig. 1. Some of the exemplars of the bottles set.

Procedure

The participants looked through all the pictures of a set to familiarize themselves with the variety of objects and then named each one. Their answers were written down by the experimenter. Following Malt et al. (1999) and Ameel et al. (2005), they were asked to give whatever name seemed the best or most natural, and they were told that they could give a single-word name or a name with more than one word. The instructions emphasized naming the object itself and not what it contained. Order of presentation was random. The experiment was conducted in Dutch.

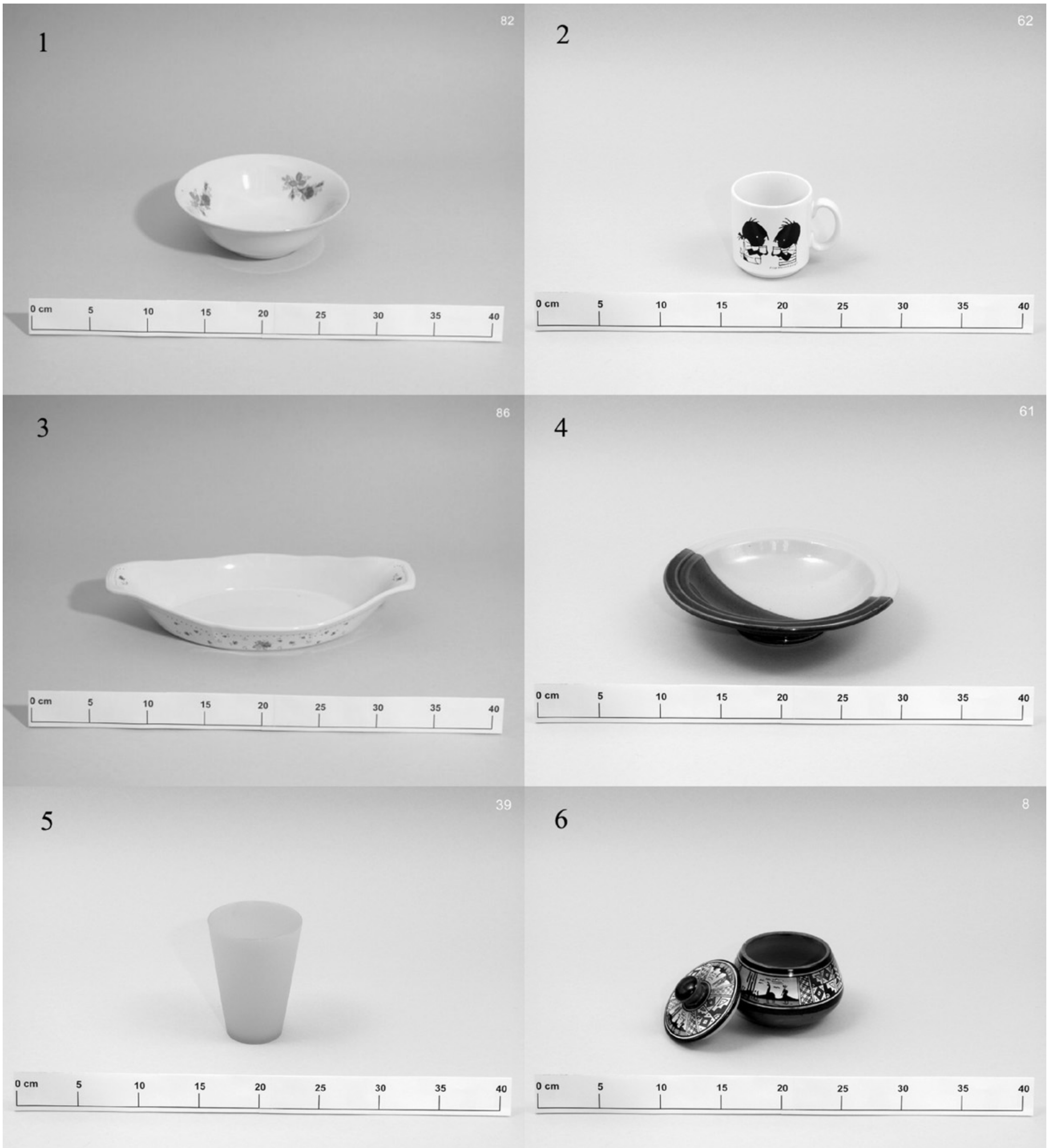

Fig. 2. Some of the exemplars of the dishes set.

Results and discussion

Comparison of naming patterns across ages

For each stimulus set, we tallied the frequency of each noun produced for each object separately by age group. Only the head noun of the response was considered. Diminutive markers and additional adjectives were disregarded. The first analysis is restricted to the dominant name for each object, that is, its most frequently produced name. Table 1 shows the results for the bottles set. For each age group, all names are shown that emerged as dominant for at least one object, along with the number of objects out of 73 for which each name is dominant. The adult naming data were taken from Ameel et al. (2005).

Table 1
Linguistic categories for the bottles set for the different age groups, together with the number of objects out of 73 included in the respective categories

5-year-olds	N	8-year-olds	N	10-year-olds	N	12-year-olds	N	14-year-olds	N	Adults	N
fles	46	*fles*	34	*fles*	30	*fles*	28	*fles*	26	*fles*	25
pot	17	*pot*	21	*pot*	19	*pot*	18	*bus*	14	*bus*	16
doos	7	*doos*	7	*brik*	5	*bus*	8	*pot*	13	*pot*	13
blik	1	*blik*	2	*bus*	5	*brik*	5	*doos*	6	*brik*	4
fles/doos	1	*bus*	2	*doos*	4	*doos*	4	*brik*	4	*doos*	4
mand	1	*fles/pot*	2	*fles/pot*	3	*tube*	4	*blik*	2	*tube*	4
		tube	2	*blik*	2	*blik*	2	*fles/bus*	2	*blik*	2
		brik	1	*doos/pot*	1	*fles/bus*	2	*tube*	2	*mand*	1
		fles/bus	1	*fles/doos*	1	*mand*	1	*fles/roller*	1	*molen*	1
		mand	1	*mand*	1	*pot/vat*	1	*mand*	1	*roller*	1
				tube	1			*pot/doos*	1	*stick*	1
				tube/fles	1			*vat*	1	*vat*	1

When two names were generated equally frequently, both names are listed, e.g., *fles/doos*.

The naming frequencies in Table 1 demonstrate that considerable development in the use of the names took place between 5 and 14 years. The naming frequencies for the children gradually converged to the corresponding frequencies for the adults[1]. The set of objects called *fles* started off very broad and gradually narrowed from 5-year-olds to adults. The same pattern was found for *pot* and *doos*. In contrast, for *bus*, *brik* and *tube*, the opposite pattern was found: these names were not used by the youngest children, but from 8 years onward the category broadened over age. These results yield clear evidence for both over- and under-extension for different age groups, and it is especially noteworthy that both occur within the same semantic domain and based on systematically collected data for a large stimulus set. This finding is consistent with Mervis' (1987) view of semantic development. In contrast, Clark's (1973) theory can only explain over-extensions, while Nelson's (1974) theory only accounts for under-extensions.

Table 2 shows similar findings for the dishes set. As with the bottles set, the children's naming frequencies for the dishes set gradually converged to the corresponding adult naming frequencies and there is evidence for both early over- and under-extensions. *Kom* and *bord* started off very broad and gradually narrowed from 5-year-olds to adults, while the opposite pattern was found for *schaal* and *pot*, which were only used from the age of 6 onward. The name *tas* was used from the age of 5 onward and its use also slightly increased over age. These results are again in line with Mervis' (1987) view of semantic development.

Quantitative evidence for the gradual shift to the adult naming pattern was found in the name distributions. The name distribution for an object is a vector of numbers indicating, for each name produced to the entire stimulus set, the number of participants who gave that name for that particular object. For instance, a given object's vector might show that 15 participants called it *fles*, 4 called it *pot*, 6 called it *bus* and none called it by any other name. To compare the naming patterns of the different age groups, we first computed the similarity of each object's name distribution to every other object's name distribution within each age group by correlating each pair of vectors. These correlation values reflect the extent to which each pair of objects was named similarly by participants of the same age group. We then correlated the matrix of 2628 (for the bottles) or 2211 (for the dishes) name similarity values for each age group with the matrix of corresponding values for each other age group. These correlations, shown in Tables 3 (bottles) and 4 (dishes), indicate in a single value the extent to which two age groups had similar naming patterns.

The last column of Table 3 shows that the correlations with the adult naming pattern increased gradually from 5- to 14-year-olds for the bottles set. The increase was tested by calculating the Spearman rank order correlation between age and the correlation value of that age group with adult naming. This correlation was significant ($\rho = 1$, $p < .01$). The correlations between each pair of age groups also showed a gradual increase as ages came closer to each other (e.g., 14-year-olds agreed better with 12-year-olds than they did with 10-year-olds). The only exception to a monotonic upward trend was the correlation between 5-year-olds and 14-year-

[1] One might raise the question whether the vocabulary convergence is a cohort effect rather than an age effect. It is possible that participants of different ages belong to different cohorts that name the objects in different ways. However, the fact that all adult names were used by the children (except for a few names that were absent in the youngest age group), indicates that a cohort effect is unlikely. Furthermore, the gradual convergence observed here mirrors that found by other researchers for verbs and prepositions, discussed earlier, for which a cohort explanation is highly unlikely.

Table 2
Linguistic categories for the dishes set for the different age groups, together with the number of objects out of 67 included in the respective categories

5-year-olds	*N*	6-year-olds	N	8-year-olds	*N*	10-year-olds	*N*	Adults	*N*
kom	30	*kom*	23	*kom*	20	*kom*	21	*kom*	19
bord	13	*tas*	16	*tas*	16	*tas*	16	*tas*	15
tas	12	*bord*	12	*bord*	13	*bord*	12	*schaal*	13
glas	4	*schaal*	6	*schaal*	6	*schaal*	10	*bord*	8
beker	3	*beker*	3	*beker*	3	*glas*	3	*beker*	4
bord/kom	1	*glas*	3	*pot*	3	*pot*	2	*pot*	4
kom/pan	1	*pot*	2	*glas*	2	*beker*	1	*glas*	2
kop	1	*pan*	1	*schaal/kom*	2	*pan*	1	*asbak*	1
pan	1	*schaal/kom*	1	*kom/pot*	1	*schaal/bakvorm*	1	*houder*	1
tas/beker	1			*pan*	1				

When two names were generated equally frequently, both names are listed, e.g., *bord/kom*.

Table 3
Correlations for the bottles set between the name distribution similarities for each pair of age groups

Age	8	10	12	14	Adults
5	.78	.7	.63	.7	.56
8		.86	.83	.79	.68
10			.84	.79	.73
12				.85	.82
14					.88

Table 4
Correlations for the dishes set between the name distribution similarities for each pair of age groups

Age	6	8	10	Adults
5	.88	.89	.86	.72
6		.95	.94	.82
8			.94	.8
10				.86

olds, which was significantly higher than the correlation between 5-year-olds and 12-year-olds ($p < .0001$).

For the dishes set, a similar (although non-significant) pattern of increasing correlations with adult naming was found from 5- to 10-year-olds. Further, the correlations between pairs of age groups gradually increased, as ages came closer to each other. There were only two exceptions to this pattern: 5- and 6-year-olds agreed better with 8-year-olds than they did with each other (both $p < .0001$). Overall, the correlations between age groups for the dishes set were higher than the corresponding correlations for the bottles set. There seems to be less variability in naming this set among the age groups. Note also that the correspondence in naming between the 10-year-olds and the adults found for the dishes set was as high as the correspondence in naming between the 14-year-olds and the adults found for the bottles set. So, for the dishes set, convergence on the adult naming pattern was reached faster than for the bottles set.

What pushes the child to greater convergence with adult word use?

The data provide some information about what drives children to refine their use of these words over a period of 9 or more years beyond their early grasp of the meaning. Clark (1973) and Bloom (1973) have suggested that the entry of new words into a child's vocabulary triggers refinement in early lexical development (see also Haryu & Imai, 2002). Tables 1 and 2 show a small increase in total vocabulary for the object sets across ages. For the bottles stimulus set, adults' main names – *fles*, *bus*, and *pot* – were used by all the other age groups, except for *bus* by 5-year-olds. The next most common adult names, *doos*, *brik* and *tube*, dominant for 4 objects each, were also used by the other age groups with the exception of *brik* and *tube* for the 5-year-olds. Four other names that entered the vocabularies very late (*vat* and *roller* at 14, and *molen* and *stick*, first used by adults) were applied to only a total of 4 objects. The dishes set received three main names from the adults: *kom*, *tas* and *schaal*. All three names were used by all the other age groups, except for *schaal* by 5-year-olds. The next three names, *bord*, *beker* and *pot*, dominant for, respectively, 8, 4 and 4 objects, were also used by the other age groups, except for *pot* by the 5-year-olds. Two other names entered the vocabularies very late (*asbak* and *houder*, first used by adults), but both names were applied to only one single object.

These additions to vocabulary, however, can explain only a small part of the refinements in use of the main names. For instance for the bottles stimuli, 8-year-olds used *bus* for only two objects whereas adults used *bus* for 16. For the dishes set, 6-year-olds used the name *schaal* for only 6 objects, while adults used this name for 12 objects. A finer partitioning of semantic space due to a larger vocabulary would not predict this further

Table 5
Adult compositions of the children's categories for the bottles set

Age group	*N*	Adult composition
5-year-olds		
fles	46	23 *fles*, 15 *bus*, 3 *tube*, 2 *pot*, 1 *brik*, 1 *molen*, 1 *roller*
pot	17	11 *pot*, 2 *fles*, 1 *blik*, 1 *bus*, 1 *tube*, 1 *vat*
doos	7	4 *doos*, 2 *brik*, 1 *stick*
blik	1	1 *blik*
fles/doos	1	1 *brik*
mand	1	1 *mand*
8-year-olds		
fles	34	19 *fles*, 12 *bus*, 2 *brik*, 1 *tube*
pot	21	12 *pot*, 5 *fles*, 2 *bus*, 1 *molen*, 1 *vat*
doos	7	3 *doos*, 1 *brik*, 1 *bus*, 1 *pot*, 1 *stick*
blik	2	2 *blik*
bus	2	1 *doos*, 1 *roller*
fles/pot	2	1 *fles*, 1 *tube*
tube	2	2 *tube*
brik	1	1 *brik*
fles/bus	1	1 *bus*
mand	1	1 *mand*
10-year-olds		
fles	30	20 *fles*, 9 *bus*, 1 *pot*
pot	19	11 *pot*, 3 *fles*, 1 *molen*, 1 *roller*, 1 *stick*, 1 *tube*, 1 *vat*
brik	5	4 *brik*, 1 *doos*
bus	5	5 *bus*
doos	4	3 *doos*, 1 *bus*
fles/pot	3	2 *fles*, 1 *tube*
blik	2	2 *blik*
doos/pot	1	1 *pot*
fles/doos	1	1 *bus*
mand	1	1 *mand*
tube	1	1 *tube*
tube/fles	1	1 *tube*
12-year-olds		
fles	28	21 *fles*, 5 *bus*, 1 *pot*, 1 *roller*
pot	18	12 *pot*, 4 *fles*, 1 *molen*, 1 *stick*
bus	8	8 *bus*
brik	5	4 *brik*, 1 *doos*
doos	4	3 *doos*, 1 *bus*
tube	4	4 *tube*
blik	2	2 *blik*
fles/bus	2	2 *bus*
mand	1	1 *mand*
pot/vat	1	1 *vat*
14-year-olds		
fles	26	23 *fles*, 3 *bus*
bus	14	10 *bus*, 2 *tube*, 1 *brik*, 1 *fles*
pot	13	11 *pot*, 1 *fles*, 1 *molen*
doos	6	3 *doos*, 2 *pot*, 1 *bus*
brik	4	3 *brik*, 1 *doos*
blik	2	2 *blik*
fles/bus	2	2 *bus*
tube	2	2 *tube*
fles/roller	1	1 *roller*
mand	1	1 *mand*
pot/doos	1	1 *stick*
vat	1	1 *vat*

growth in category size. Rather, there seems to be an extended reorganization of the existing categories that continues well after the new vocabulary triggered the first refinements. To investigate this possibility further, we described the children's categories in terms of their adult composition. For instance, for each of the 46 objects called *fles* by the 5-year-olds, we identified what the adults called it. Table 5 provides this breakdown for the bottles set and Table 6 provides it for the dishes set.

As is evident by examination of Table 5, the *fles* category of 5-year-olds not only contained objects called *fles* by adults, but also 15 objects called *bus*. Eight-year-olds had added *bus* to their vocabulary, but continued to use *fles* for a substantial number of objects called *bus* by adults (12). Striking is that the three *bus* objects that were excluded from the *fles* category of 10-year-olds did not move into the *bus* category. One of the three objects was called *pot*, another was called *doos*, and the last one was called *bus* as frequently as *fles*. So, the entry of *bus* into the vocabulary of 10-year-olds did not imply that these children fully grasped the meaning of *bus* and used this knowledge to narrow in on the adult meaning of *fles*. Across ages, the meaning of this new word was gradually refined along with the meaning of others, as was evidenced by the increasing number of adult *bus* objects that moved into the *bus* category. Similarly, the set of objects called *brik* by adults was initially dispersed over the 5-year-olds' categories of *fles* and *doos*. For the older children, a *brik* category emerged that gradually contained the adult *brik* objects, although the children continued to use *fles* for some *brik* objects initially.

For the dishes set, we found similar shifts of objects from over-extended categories to initially non-existing categories. For example, objects called *schaal* by adults were initially spread out over the (over-extended) child categories of *kom* and *bord*. Six-year-olds had added *schaal* to their vocabulary, but they continued to use *kom* and *bord* for one third of the objects called *schaal* by adults. Across ages, the number of objects moving from the *kom* and *bord* categories to *schaal* gradually increased. The dishes and bottles data together show that acquisition of new words even at the ages studied here initially triggers some reorganization, but it does not necessarily result in the right distribution of objects into lexical categories. The meaning of a new word still must be gradually refined over time. We found no evidence for reorganizations that took place without the entry of a new word.

Table 6
Adult compositions of the children's categories for the dishes set

Age group	N	Adult composition
5-year-olds		
kom	30	17 *kom*, 8 *schaal*, 3 *pot*, 1 *asbak*, 1 *tas*
bord	13	7 *bord*, 4 *schaal*, 1 *houder*, 1 *kom*
tas	12	9 *tas*, 2 *beker*, 1 *pot*
glas	4	2 *glas*, 2 *tas*
beker	3	2 *beker*, 1 *tas*
bord/kom	1	1 *bord*
kom/pan	1	1 *kom*
kop	1	1 *tas*
pan	1	1 *kom*
tas/beker	1	1 *tas*
6-year-olds		
kom	23	18 *kom*, 2 *pot*, 2 *schaal*, 1 *asbak*
tas	16	14 *tas*, 2 *beker*
bord	12	8 *bord*, 2 *schaal*, 1 *houder*, 1 *kom*
schaal	6	6 *schaal*
beker	3	2 *beker*, 1 *pot*
glas	3	2 *glas*, 1 *tas*
pot	2	1 *pot*, 1 *schaal*
pan	1	1 *kom*
schaal/kom	1	1 *schaal*
8-year-olds		
kom	20	16 *kom*, 3 *schaal*, 1 *pot*
tas	16	14 *tas*, 2 *beker*
bord	13	8 *bord*, 3 *kom*, 1 *houder*, 1 *schaal*
schaal	6	6 *schaal*
beker	3	2 *beker*, 1 *tas*
pot	3	2 *pot*, 1 *asbak*
glas	2	2 *glas*
schaal/kom	2	2 *schaal*
kom/pot	1	1 *pot*
pan	1	1 *kom*
10-year-olds		
kom	21	16 *kom*, 2 *pot*, 1 *asbak*, 1 *schaal*, 1 *tas*
tas	16	13 *tas*, 3 *beker*
bord	12	8 *bord*, 3 *kom*, 1 *schaal*
schaal	10	9 *schaal*, 1 *houder*
glas	3	2 *glas*, 1 *tas*
pot	2	2 *pot*
beker	1	1 *beker*
pan	1	1 *kom*
schaal/bakvorm	1	1 *schaal*

In sum, Study 1 demonstrated continued semantic development well into adolescence for nouns labeling familiar household objects. Evidence was found both for over- and under-extensions. The entry of new words into the vocabulary triggers initial reorganization of the existing lexical categories, but the shifts of objects from over-extended categories to under-extended categories continue well after the new word enters the vocabulary. The refinement is an extended process that may be prompted by noticing discrepancies from adult word use or receiving explicit feedback.

Study 2

Given the evidence from Study 1 that semantic development occurred across an extended period of time for the common nouns studied, we investigated the nature of the learning that takes place during this time. Evidence on what is learned in early semantic development has mainly come from descriptive diary studies (e.g., Clark, 1995a; Mervis', 1987). In addressing this issue for later development, we provided a larger-scale experiment that allowed us to use regression techniques to gain insight in what children learned over time. We collected features from adults and children of the different age groups for the most frequently generated names to get information about the knowledge attached to the words at each age, and then we used the features to optimally predict the naming of the different age groups.

The goals of Study 2 were threefold. First, we provided further evidence for the convergence on adult naming. To do so, the set of features that optimally predicted the adult naming was selected from all the features generated. This set of optimal adult predictors was then used to predict children's naming. We expected that the naming of children would be gradually better predicted from the optimal set of adult predictors, reflecting their increasing refinement of word meanings.

Second, we evaluated three theories offering a feature-based approach to early semantic development with respect to their ability to account for later semantic development. The three views, described in the introduction, differ in the type of change in attention to features they claim to be responsible for the gradual fine-tuning of child toward adult lexical categories. Clark (1973) claimed that children add relevant features to fine-tune their categories towards adult categories. According to Nelson (1974), children subtract irrelevant features over time. Mervis' (1987) proposes that children change attention from child features to (different) adult features and/or attend to the same features but with different weights.

To find out which of these theories best describes later lexical development, for each age group, we selected the set of features that optimally predicted the naming data at that age. Then we compared the features included in the sets of optimally predicting features across ages. Clark's (1973) view suggests that fewer features will contribute to the prediction of children's naming than to the prediction of adult naming, and the number of significant features will increase over age. Nelson (1974) view predicts the opposite: more features are required to explain the naming of younger children than the naming of adults, and the number of significant features will decrease over age. Based on Mervis' (1987) view of semantic development, no difference is necessarily expected in the number of features that contributes to the naming predictions for the different age groups. Instead, her view predicts that children's and adult naming will be accounted for by different features. Some features that are significant in predicting the naming of the youngest children will become less important over time and some features that are not significant will become more important.

The third goal of this study was to examine whether the feature sets identified by these methods could fully explain the naming patterns of the different ages. In light of the substantial cross-linguistic variability in the composition of the lexical categories partitioning the domain studied here (Ameel et al., 2005; Malt et al., 1999), and the perception of similarity that was strongly correlated across the languages, Malt et al. (1999) argued that the lexical categories of each language are not only similarity-based, but they are also influenced by language-specific idiosyncrasies. Hence, we expect that a single feature set will not be able to fully predict name choices, especially for older children and adults who have had more time to learn idiosyncratic exceptions to the general feature set that governs much of the naming.

Methods

Materials

For Study 2, we only used the bottles stimulus set, since there was more variability in naming between different age groups for this set. The linguistic categories for which features were generated were extracted from the adult naming data (Ameel et al., 2005). We selected the four names that were dominant for the largest numbers of objects in the adult naming data: *fles*, *bus*, *pot* and *brik*[2], and we asked participants from each age group to indicate what features they associated with each name. The 73 pictures of the bottles set (Ameel et al., 2005) were then used in a feature applicability judgment task in order to derive feature vectors for the prediction of naming. In this task, a different set of participants judged whether or not each of the generated features applied to each of the objects.

Participants

Ten participants of each age group (5-, 8-, 10-, 12-, and 14-year-olds and adults) generated features for the different category names. An additional twelve adults filled out feature by exemplar matrices with applicability judgments. All participants were native speakers of Dutch. Some of the younger children knew a few words of French and English, picked up from television or while on holiday. The 12- and 14-year-old children and adults had a limited knowledge of French through formal instruction at school.

Procedure

Feature generation task. To collect features for the different names, we followed Hampton's (1979) procedure. For adults, we used a set of four questions designed to encourage participants to generate as many different features as they could. English translations of the questions are: (1) What are—in general—the features of a typical X? (2) What features are common to all typical X? (3) Imagine an atypical example of X. What features make this X still be called an X? (4) Can you give some more specific features of a typical X? (a) What does X look like? (b) What can X contain? (c) Of what material is X made? (d) What is X used for? (e) How is X used? (f) Where do you find X? The categories were presented to each participant in a random order.

For the children, we adapted the interview by asking them to imagine that a child from a different planet had arrived on earth. The child of the other planet did not know any objects on earth and hence, the child also did not know what an X was. The participating child had to explain to this alien child what X was. We also asked the child participants how they would describe X and what all Xs had in common.

After feature generation, all legible responses of the adults were tallied for each category name. Using a procedure similar to McRae, de Sa, and Seidenberg (1997) Experiment 1, synonymous features (i.e., features that we judged to have essentially the same meaning, such as "large" and "big") were recoded as identical. Redundant quantifiers (e.g., 'most of them') were dropped and both adjective-noun features (e.g., 'white porcelain') and conjunctive features (e.g., 'round and transparent') were split and the parts treated as separate features if they provided different information. For each name, features that were generated by at least two participants were retained to construct the exemplar by feature matrices. For the features of the children of the different age groups, the same tallying procedure was followed.

Exemplar by feature applicability task. For each of the four names a matrix was constructed. The rows corresponded to the 73 pictures, and the columns were labeled with all features generated for the category name by at least two adults plus any non-overlapping features generated for that name by at least two children of the same age. Participants were asked to fill out all entries in the matrix with a 1 or a 0 to indicate whether or not each feature characterized the exemplar corresponding to the row of the entry. From this task, vectors of applicability scores for the features were derived that were used to predict naming. Completion of an applicability matrix took half an hour on average. Each of the four matrices was filled out by three participants.

[2] While adults also generated features for *doos* and *tube*, children did not, due to attention limits. The lack of child features for *doos* and *tube* prevents us from predicting the naming data for *doos* and *tube* in the same way as we did for the other four categories.

Results and discussion

Further evidence for convergence on adult naming

To address whether children learn to attend to the features that significantly contributed to the prediction of adult naming, we selected the set of features that optimally predicted the adult naming from all adult features and non-overlapping child features. This set of optimal adult predictors was used to predict children's naming. Child features were included in predicting adult naming since children could have generated features that also have value in predicting adult performance even if not generated by adults.

Defining the optimal set of adult predictors. For each category name, the feature by exemplar matrices were summed over participants. This resulted in a vector of summed applicability scores for each adult and non-overlapping child feature associated with a name. For each category name (*fles*, *bus*, *pot*, *brik*), a multiple regression analysis was performed in which the percentage of adults calling each object by the category name was predicted from the applicability vectors of all the adult features and non-overlapping child features generated for the category name (see Fig. 3 for an example). For economy reasons, only main feature effects were included in the models and no interaction was allowed between features. For *fles*, 25 features (19 adult features + 6 non-overlapping child features) were included as predictors in the regression analysis, for *bus* 21 (13 adult + 8 child features), for *pot* 22 (17 adult + 5 child features) and for *brik* 15 (7 adult + 8 child features) features were included in the model as predictors.

Note that these numbers of feature predictors are rather high, given the rule of thumb that, in a regression analysis, the number of stimuli for which we predict the criterion (73 in this case) should be larger than ten times the number of predictors. Therefore, to select from these the optimal set of predicting features, we made use of the STEPWISE method of model selection, implemented in the regression procedure available in SAS (SAS Institute Inc., 1999). This method begins with no variables in the model and adds variables one by one according to their contribution to the prediction of the criterion until no remaining variable produces a significant increase in the proportion of variance in the criterion. A variable that was added can be removed from the model if its contribution is not significant anymore after inclusion of other variables. The final number of features included in each model was, respectively, 6, 8, 8 and 6 for the names *fles*, *bus*, *pot* and *brik*. The proportions of variance in adult naming explained by the sets of optimal predictors were, respectively, 82, 64, 75 and 89% for *fles*, *bus*, *pot* and *brik*. Appendix A shows the set of optimal adult predictors for each name together with the sign of the beta weight attached to each feature and the age group that produced the feature.

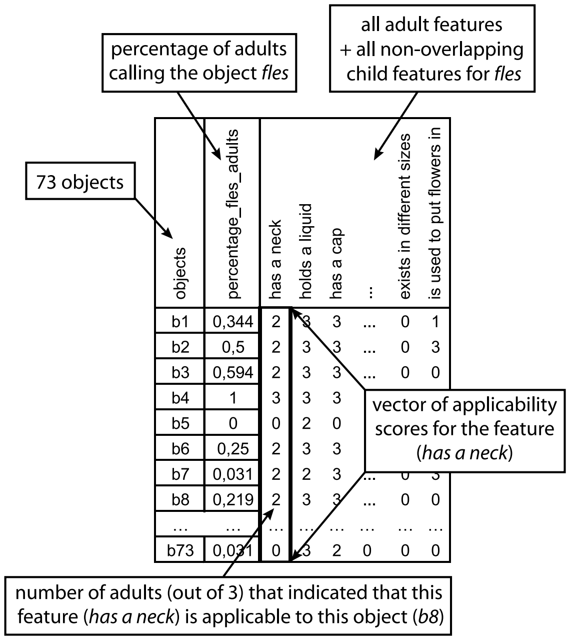

Fig. 3. Example of a multiple regression analysis in which the naming percentages of *fles* for adults are predicted by all the adult features and non-overlapping child features generated for *fles*.

Predicting child naming. The set of features that optimally predicted the adult naming data for each category was then used to predict the naming percentages of the children of the different ages. For each category, the proportions of variance in the naming percentages of the different age groups explained by the optimal set of adult predictors selected for each category are shown in Fig. 4 (solid line with black diamonds).

In each case, the proportion of variance explained by the optimal set of adult predictors gradually increased from 5-year-olds to adults (significantly increasing trend for all categories, except for *bus*; *fles*: $\rho = 0.69$, $p < .05$; *pot*: $\rho = 0.73$, $p < .05$; *brik*: $\rho = 0.69$, $p < .05$). Further, the number of optimal adult predictors that contributed significantly to the prediction of the naming percentages increased significantly from 5-year-olds to adults (averaged across categories, there were 2, 3.25, 4.25, 4.75, 4.75 and 5.75 significant predictors for, respectively, 5-, 8-, 10-, 12-, 14-year-olds and adults; $F(5, 18) = 6.36$, $p < .005$). These findings indicate that children gradually learned to attend to the set of features used by adults. Appendix B contains the optimal adult predictors that were significant for the different child age groups.

Evaluating feature-based theories of semantic development

To find out which of the three views of early semantic development best describes later semantic develop-

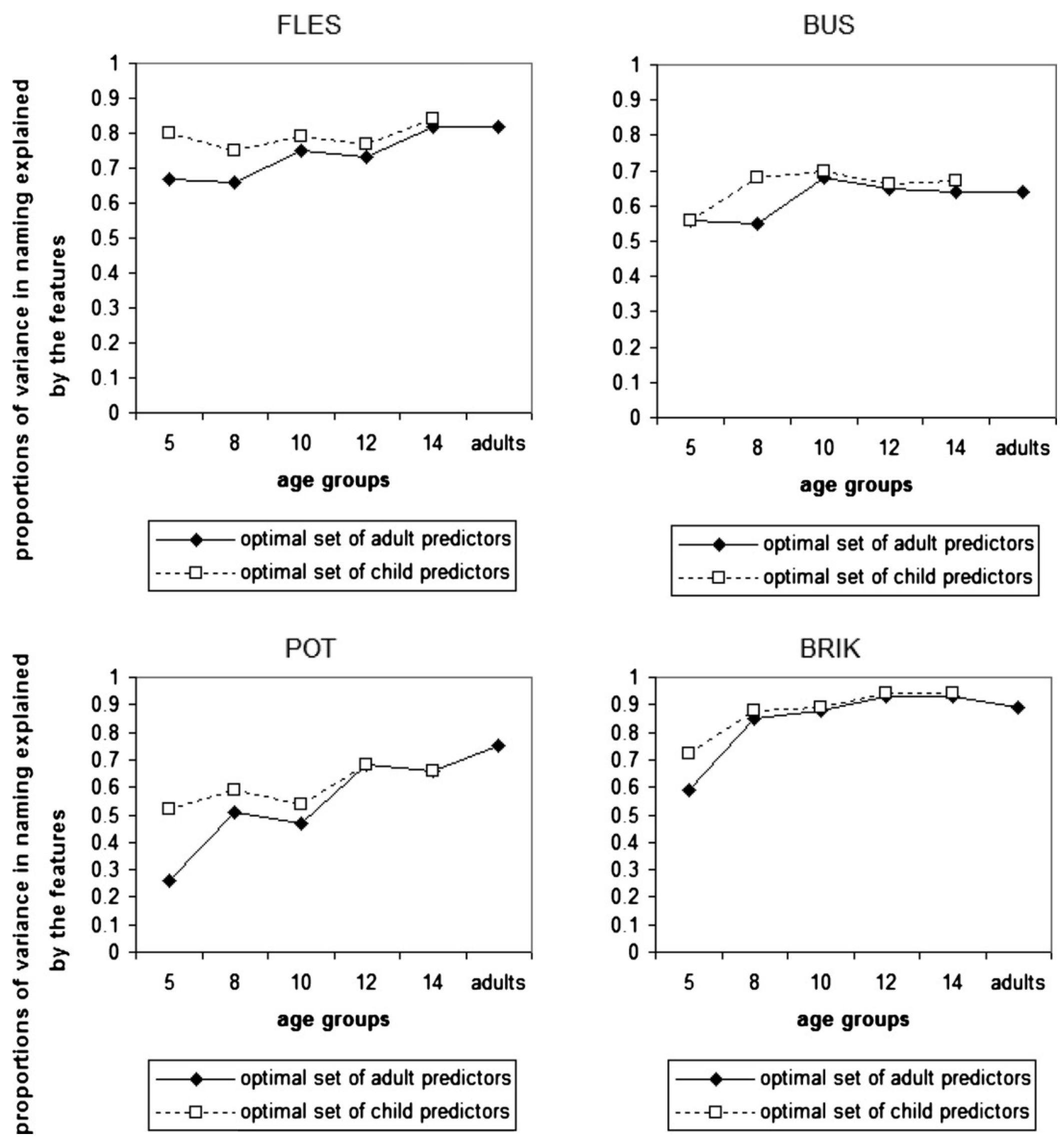

Fig. 4. Proportions of total variance in the naming percentages of each category explained by the optimal set of adult predictors for the category (solid lines with black diamonds) and by the optimal set of child predictors for the category (dotted lines with white squares) for the different age groups.

ment, we defined the sets of features that optimally predicted child naming for the different ages, following the same procedure as for the adults. For each category name (*fles*, *bus*, *pot*, *brik*), a multiple regression analysis was performed in which the percentage of children calling each object by the category name at each age was predicted from the applicability vectors of all the adult features and non-overlapping child features generated for the category name. The STEPWISE selection method selected the most predictive features for each age group. The proportions of variance explained by the optimal set of child predictors for each category name and for each age group are shown in Fig. 4 (dotted lines with white squares). For each child age group and for each category, child naming was better predicted from the optimal set of child predictors for that age than from the optimal set of adult predictors. This finding is not surprising, since all theories claim that there is a difference between adults and children in the features attended to when naming objects. The increase in proportion of variance explained was strongest for the youngest children.

When comparing the number of features that were significant predictors of the naming percentages, we found no significant difference among the age groups (4.7 significant features on average). This finding contradicts both the possibility based on Clark's (1973) proposal that children are attending to fewer features than adults and the possibility based on Nelson's (1974) view that children attend to more features than adults. Instead, the increase in proportions of variance in naming explained by the optimal sets of child predictors was due to the fact that the optimal sets of child predictors at each age consisted of other features than the features included in the optimal set of adult predictors. This finding is consistent with Mervis' (1987) view that children attend to different features than adults do. Appendix C contains the features that were significant for the different age groups.

To further explore which of the features were subject to attention change from 5-year-olds to adults, we performed simple regression analyses in which the naming percentages were predicted by one feature at a time for each age group. These analyses allowed us to evaluate the individual contribution of a feature to the prediction of the naming, without any influence of other possible predictors.

We only discuss the results for *fles* and *pot*, since these are the most frequently used names for the 5- to 12-year-old children and are among the three most frequently used names for the 14-year-olds and adults. For the other categories, the simple regression analyses yielded similar results. Figs. 5 and 6 show the absolute proportions of variance in the naming percentages of the different age groups explained by different features of, respectively, *fles* and *pot*. For each name, we only selected the features that were significant for at least two of the different age groups in the multiple regression analyses.

Fig. 5 shows that for *fles*, the proportion of variance explained by the features 'has a neck' and 'is made of glass' gradually increased from 5-year-old children to adults (from 54 to 68%, from 2 to 22%, respectively). Conversely, for the features 'holds a liquid,' 'has a cap,' and 'is elongated,' a decreasing pattern was found. For the 5-year-old children, these features explained, respectively, 35, 25 and 10% of the variance in naming, in contrast to 21, 20 and 0% for the adults. These results show that the children gradually learned to attach the appropriate weights to the features that are important in adult word use.

The gradual attention shift to the adult-like features can explain both the over-extension of *fles* and the under-extension of *bus* and *brik*. When determining whether an object should be called *fles*, younger children make less use of the features 'has a neck' and 'is made of glass' compared to adults. Therefore, younger children will also use *fles* for objects without a neck and objects made of materials other than glass, which include objects called *bus* and *brik* by adults[3]. Instead, children pay much more attention to whether an object holds a liquid, has a cap, and is elongated in determining whether to apply the name *fles* to it. However, these features do not discriminate among the adult *fles*, *bus*, and *brik*, which also contributes to why the child use of *fles* also encompasses objects called *bus* and *brik* by adults. Note that although 5-year-old children did not attach adult weights to the features present in the optimal set of adult predictors for *fles*, this set still explained a rather large portion of the variance in the naming of the 5-year-olds (67%, see Fig. 4). The reason is that the 5-year-olds heavily weighted the features 'holds a liquid,' 'has a cap' and 'is elongated,' which are included in this set.

In Fig. 6, similar findings are shown for *pot*: the five features displayed in the graph all explained more variance in naming percentages over age. Since younger children pay less attention to these features (i.e., to them, it does not matter whether an object possesses these features or not), the category *pot* is much broader for children than for adults. Unlike for *fles*, the analyses did not reveal features that explained more variance for children than for adults. However, the relative proportions of variance (i.e. the ratio of the absolute portion of variance of a feature, displayed in Fig. 6, to the sum of portions of variance explained by the five simple regression analyses in Fig. 6) revealed that the features 'has a lid' and 'has a large opening at top' were proportionally the most important features for the 5-year-old children, but the importance of these features gradually decreased over age. So, although these features explained less variance of the naming in 5-year-olds in absolute terms (see Fig. 4), they are proportionally more important for the 5-year-olds than for the adults. Five-year-olds gradually have to learn to shift their attention from the features 'has a lid' and 'has a large opening at top' to other features. For the other three features, the pattern of relative proportions of variance increased over age. (For *fles*, the pattern of relative proportions of variance was similar to the pattern of absolute proportions of variance.)

Overall, the results of the multiple and simple regression analyses show that the reorganization of the categorical structure, found in Study 1, seems to be driven by gradual attention shifts to the set of adult features. In line with Mervis' (1987), children attended to different features from adults. Some features were significant for all age groups. However, the weights attached to these

[3] A multiple regression analysis of the naming percentages of *bus* and *brik* based on the features of *fles* yielded negative regression weights for 'has a neck' and 'is made of glass', indicating that *bus* and *brik* objects usually do not have a neck and are not made of glass.

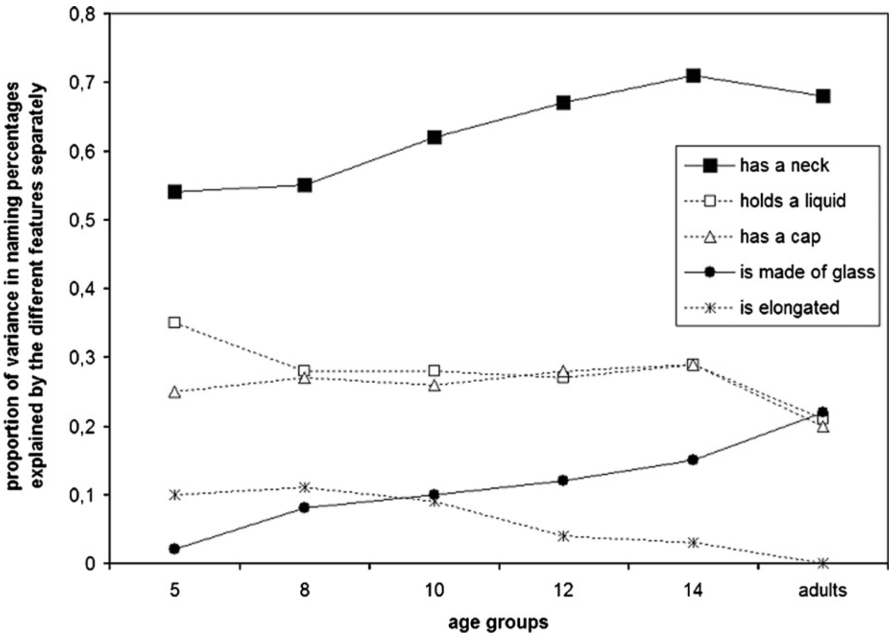

Fig. 5. Proportions of variance in the naming percentages of the different age groups explained by the significant features of *fles*.

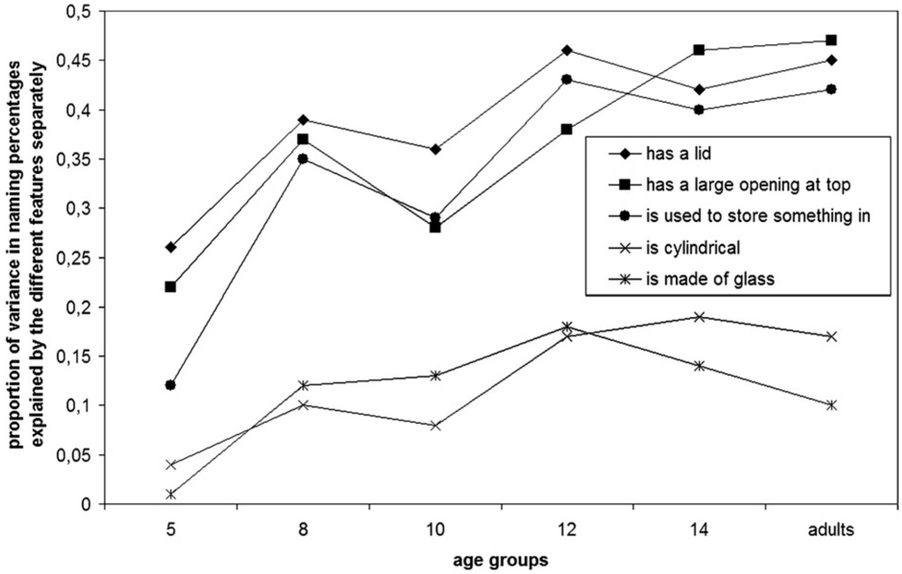

Fig. 6. Proportions of variance in the naming percentages of the different age groups explained by the significant features of *pot*.

features differed among the age groups, and children had to learn to attach the appropriate weights to these features.

Beyond the scope of a single set of features

Although changes in the features attended to accounted for substantial amounts of the shifts in naming, as we expected, even the naming pattern of adults could not be fully explained by the features. The total variance in adult naming explained by the features varied from 64% for *bus* to 89% for *brik*, leaving 36% and 11% of the variance unexplained, respectively. In light of the substantial degree of cross-linguistic variability in the composition of the lexical categories partitioning the domain studied here (Ameel et al., 2005; Malt et al., 1999), we suggest that the additional knowledge

Fig. 7. Some examples of object-name associations that were poorly accounted for by the features.

is likely in the form of language-specific object-name pairings that arise for idiosyncratic reasons. These language-specific conventions may be represented by combinations of features or by values on the main features not captured in the present feature set. Fig. 7 shows some examples of object-name associations that were poorly accounted for by the features.

The elongated objects Fig. 7A and B were called *bus* by adults, although almost all *bus* objects have a push button. We computed the percentages of respondents calling these objects *fles* and *bus* that would be predicted based on the significant features for the respective category names. For both objects, a higher probability of calling it *fles* than *bus* was predicted. Features other than those included in the main feature set for *bus* may be decisive for calling these objects *bus*, for example, the handle and the content (cleaning product), which link it to other objects called *bus*. Similarly, the plastic object Fig. 7C, containing sun lotion, was called *bus*, despite the lack of a push button. The present feature set predicts a higher probability of naming it *fles* than *bus*. The reason for calling this object *bus* might, again, be a link to other category members through its contents (beauty product).

In sum, Study 2 demonstrated that the reorganization of the lexical categories seems to be driven by gradual attention shifts to the adult features. In line with Mervis' (1987) view, children initially attend to different features from adults and gradually learn which features are relevant in assigning names to objects and gradually attach the appropriate weights to them. However, some object names may not be predictable by the features that account for the bulk of the name use and may need to be learned separately.

Study 3

The differences that we found in Study 2 between children and adults in the features and feature weights used may be due to differences in the conceptualization of the objects or they may be purely lexical. Clark (1973), Nelson (1974) and Mervis' (1987) all suggest that conceptual development is important to early lexical development. For example, as long as children do not understand what the slot on top of the piggy bank is used for, they will continue to call the piggy bank *ball* (Mervis', 1987). Waxman (2002, see also Booth et al., 2005) also demonstrated that conceptual knowledge influences early lexical acquisition. These studies address semantic development in very young children, and it is obvious that the understanding of the world changes dramatically in the early years. It is possible that conceptual knowledge for many familiar things, including the household objects studied here, is still developing in the older age range we have studied. Children's word use would then change along with their understanding of the objects or with what they see as salient in the objects. On the other hand, the featural differences between children and adults in this age range may be purely lexical. Children may understand the domain non-linguistically in much the same way as an adult but pick up on the wrong set of features or the wrong set of feature weights to govern their use of words. Malt and Sloman (2003) found that for second-language learners, whose conceptual knowledge of common containers was presumably fully developed, much lexical learning nevertheless needed to take place over years of immersion in an English language environment. This finding implies the possibility that later semantic development is a purely lexical process.

To find out whether later lexical development for common nouns is purely lexical in nature or whether it also involves changes in the child's conceptualization of the domain, a similarity-based sorting task was performed by children of the different ages. We compared the resulting similarity matrices of the children to the adult similarity matrices. A sorting task reveals information about the conceptual knowledge of a semantic domain (Malt et al., 1999)—how people conceptualize the commonalities among the objects non-linguistically – and so the results will allow us to determine whether there is continued evolution in children's non-linguistic grasp of the domain during the age range of interest.

Methods

Materials

The bottles set from Studies 1 and 2 was used.

Participants

Twenty-five children of each age group (ages 8, 10, 12 and 14) participated in the sorting task. None of them had participated in the earlier studies. Their language backgrounds were similar to those of the previous participants. We did not collect sorting data from 5-year-olds since the task was too difficult for them. For the adults, similarity values derived from sorting data of 32 adults were taken from Ameel et al. (2005).

Procedure

For the sorting task, we used instructions similar to the ones used by Ameel et al. (2005) and Malt et al. (1999). First, participants were asked to look through the pictures. Next, they were instructed to put together into piles all the objects that seemed very similar to each other overall. It was stressed that two containers holding similar things, or things that tend to be found together (such as ketchup and mayonnaise), should not be put together unless the containers themselves were alike in an overall way. The participants were also instructed to use as many piles as they wanted, but that they had to use at least two. They were told that they should not make a pile consisting of only one object unless they really could not place the object in one of the existing piles. They were given as much time as they wanted to complete the sorting. In general, the sorting task took about 30 min.

Results and discussion

The data from the sorting task were used to obtain a measure of similarity for each pair of objects and for each age group. Pairwise similarity was recovered by counting for each of the 2628 pairs of objects how many participants of an age group placed that pair of objects in the same pile. A large number of participants placing the two objects in a pile can be taken as indicating high perceived similarity and a smaller number as indicating lower perceived similarity. For each pair of age groups, the object by object matrices of the similarity judgments were then correlated to determine the extent to which the groups agreed on which pairs were more and less similar.

Comparison of perceived similarity. The left panel of Table 7 shows the correlations between the age groups in similarity ratings.

As can be seen, children's correlations with adults across ages gradually increased from 0.61 to 0.75. However, the estimated reliabilities (i.e., split half correlations corrected by the Spearman-Brown-formula) for the different age groups were rather low, except for the adults (0.71, 0.69, 0.75, 0.75 and 0.93, for the 8-, 10-, 12-, 14-year-olds and adults, respectively). We therefore corrected the correlations for unreliability of the data by applying the correction for attenuation formula ($r_{XY} = \frac{r_{XY}}{\sqrt{r_{XX}}*\sqrt{r_{YY}}}$ with r_{XX} the reliability of X and r_{YY} the reliability of Y). This correction indicates what the correlation would be if one could measure X and Y with perfect reliability. The corrected reliabilities are displayed in the right panel of Table 7. The correlations between the sorting data of children of different ages reached values of 1, while the correlations of the age groups with the adult sorting data still showed an increasing trend over age. This finding indicates that the children and adults perceived the commonalities among the objects in a somewhat different way, but the children gradually came to agree with the adults on the similarities among the objects over age. Contrary to what we expected, this finding suggests that the convergence on the adult use of words taking place within this age range is not only due to children learning the adult features and the appropriate weights on them to govern the use of words. Rather, what they see as salient in the objects or how they understand the features also evolves. This process may occur through interactions with the objects, in which children gradually acquire functional knowledge about the objects.

Table 7
Left panel: correlations among age groups in sorting, right panel: correlations in sorting, corrected for unreliability of the data

Age	10	12	14	Adults	Age	10	12	14	Adults
8	.74	.73	.69	.61	8	1	1	.94	.75
10		.75	.71	.67	10		1	.99	.83
12			.77	.76	12			1	.91
14				.75	14				.9

An informal examination of the sorting data of the different age groups suggests that the younger children focused mainly on single dimensions characterizing objects as a whole, for example, size or form, in deciding how to put them into piles. Adults, in contrast, also seemed to use dimensions having to do with a part of the object, for example, the kind of cap or the way in which the object contained its substance. A rectangular object with a push button that was put into a pile of rectangular containers by 8-year-olds was sorted by adults into a pile of objects with a push button. While child sorting seemed to be mainly based on perceptual similarity, adult sorting also appeared to be based on functional similarity and sometimes on a combination of dimensions.

Thus, even for children well past the early years of semantic development, conceptual knowledge is not fully developed yet. As long as children do not understand the objects in the same way as adults do, they will not arrive at adult word use. These results suggest that later lexical development is not purely lexical; it also involves conceptual changes.

One might wonder whether, in accordance with the Sapir–Whorf hypothesis, the developmental changes in sorting are caused by the refinements in the meanings of the words, rather than causality working in the other direction. However, the dissociation Malt et al. (1999) and Ameel et al. (2005) found between naming patterns and similarity judgments for adult speakers of different languages—with similarity judgments more closely shared across speakers of the languages than naming patterns—indicates that naming and similarity are partly independent from each other. This finding argues against word learning being the source of changes in the sorting pattern.

General discussion

Summary of the results

Although it may seem that learning the meaning of common nouns should be relatively easy for young children (Gentner, 1982), and perhaps is of little interest (Bloom, 2000, 2001), Study 1 revealed substantial evolution in the use of nouns labeling familiar household objects well past the first years of language acquisition, even up to at least the age of 14. Children gradually converged on the adult naming pattern. This gradual convergence involved a small increase in total vocabulary words for the domain across ages. Once a new word entered the vocabulary, however, its meaning was not fully understood yet. The entities (belonging to the new category) gradually moved from the child's over-extended categories into the new (under-extended) category. Over age, over-extended words (e.g., *fles*) narrowed and under-extended words (e.g., *bus*) broadened. These results suggest that later lexical development is characterized by reorganization of lexical categories that continues well after the entry of new words into the vocabulary has triggered new partitions of semantic space. This conclusion deviates from Clark's (1973, 1995a) suggestion that reorganization of existing categories takes place at the time that the new words enter into the vocabulary. Contrary to Bloom (2000, 2001), refinements of meaning should be considered an important process in later semantic development.

In Study 2, we investigated the nature of the learning that takes place during later lexical development. We found that children gradually learned to attend to the adult set of features and assign them the appropriate weights, as evidenced by the increasing proportion of variance explained by the optimal set of adult predictors over age. In contrast to Clark's (1973) and Nelson's (1974) views, children aged 5 through 14 did not attend to either fewer or more features than adults when naming objects. Instead, children attended to different features from adults, in line with Mervis' (1987) view. The results of Study 2 further suggested that one general set of features was not sufficient to account for all the reorganizations in later semantic development, as even the naming pattern of adults could not be fully explained by the features used here. Besides the mastery of a main feature set, achieving full convergence with adult use may also require mastery of language-specific idiosyncrasies represented by specific combinations of features or by specific values on the main features not captured in the present feature set and obtained through experience with the naming of individual objects.

Finally, Study 3 revealed substantial differences in the way that the children and adults perceived the commonalities among the objects. This finding indicates that later semantic development for common nouns is not purely lexical in nature, but also entails further development of the underlying conceptualization of the stimulus domain.

Category heterogeneity and lexical development

An interesting finding was that some lexical categories started off broad and narrowed later on, while for other categories the opposite pattern was found. This difference in development may be explained by the degree of heterogeneity of the categories. It may take children more time to acquire the full adult representation of the meaning of heterogeneous categories, containing a wide range of very different exemplars (such as the *bus* category) than it does for more homogeneous categories, and therefore heterogeneous categories start off narrow relative to their end-state. Heterogeneous categories are less likely to be captured by a clear set of (adult) features - as confirmed by the lower proportion of variance (64%) of the adult naming of objects as *bus* explained by the optimal feature set derived from the feature generation task. Instead, more of the knowledge of what adult speakers call *bus* (e.g., conventional knowledge of the naming of these objects) may need to be learned through specific object-word pairings which must accumulate over time. On the other hand, more homogeneous categories containing exemplars that are very similar to each other may be more likely to be captured by a single set of features. A category name the meaning of which can be grasped by a clear set of features may be more easily applied to objects than other category names. Therefore, homogeneous categories may start out broader. Over time, as the meanings of other (more heterogeneous) category names are further refined, the homogeneous categories may narrow down in favor of the heterogeneous categories.

The degree of heterogeneity of categories can be quantified by the ratio of the average distance in an

MDS solution (Ameel & Storms, 2006) between the members within a category to the average distance between the members within the whole semantic domain (in this case, the bottles set). The advantage of using distances derived from an MDS solution instead of raw similarity data is twofold: (1) a scaling algorithm looks for a limited set of relevant underlying psychological dimensions that account for similarities among the stimuli as accurately as possible (Borg & Groenen, 1997), and (2) all stimuli receive an optimally scaled value on these underlying psychological dimensions, increasing the reliability of MDS-derived distances compared to raw similarity data. Members of heterogeneous categories vary substantially and they will be scattered over the MDS representation. Homogeneous categories, on the other hand, consist of members that are very similar to each other. Hence, in an MDS representation, they will cluster together. The more heterogeneous a category, the higher the ratio of within-category distance to within-domain distance. We derived an MDS solution from the adult similarity matrices used in Study 3. We calculated the measure of heterogeneity for the four categories *fles, bus, pot* and *brik*. The resulting values were, respectively, 0.56, 0.72, 0.50, and 0.16. When comparing these values to the percentages of variance explained by the optimal set of adult predictors for each of the categories (respectively, 0.82, 0.64, 0.75, and 0.89), there is a negative relation between the degree of heterogeneity of a category and the extent to which a category can be captured by a single set of features: The more heterogeneous, the less variance explained by the optimal feature sets ($r = -0.88$; $p < .10$). This correlation is only based on 4 categories, preventing us from drawing a strong conclusion, but it is supportive of our suggestion.

Furthermore, heterogeneous categories may be more interrelated with contrast categories (categories at the same level of abstraction and belonging to the same immediate superordinate as the target category) than homogeneous categories, which may be better isolated from one another (Ameel & Storms, 2006). Categories that are more closely related to contrast categories may be harder to learn, since the set of features that discriminates members of the category from members of the contrast categories may be more complex. The extent to which features of a category discriminate the category from its contrast categories can be quantified using the exemplar by feature applicability matrices obtained in Experiment 2 to determine the difference in average applicability of a category's features to members versus non-members. The smaller the difference, the more interrelated the category is to its contrast categories and, hence, the worse the feature set can discriminate between members and non-members. For each exemplar in a category, we averaged the applicability scores across the features belonging to the optimal set of adult feature predictors for the corresponding category (Fig. 3 illustrates this procedure: for each row, the average was computed across the feature columns). Next, we computed two mean applicability scores: one for members and another for non-members of the category. The absolute differences in averaged applicability between members and non-members for *fles, bus, pot* and *brik* were, respectively, 0.70, 0.48, 0.91 and 1.92. A comparison of these values to the percentages of variance explained by the optimal set of adult predictors for each of the categories (respectively, 0.82, 0.64, 0.75, and 0.89), reveals a negative relation between the degree of interrelatedness of a category and the extent to which a category can be captured by a single set of features: The more interrelated to contrast categories (i.e., the lower the difference in feature applicability between members and non-members), the less variance is explained by the optimal feature sets ($r = .81$; $p < .10$). This pattern supports the argument that some categories will tend to follow a narrow-to-broad learning trajectory because discerning relevant features will be difficult and much item-specific learning must take place[4].

Why referential terms aren't really so easy to learn

In children's early vocabularies, nouns greatly outnumber verbs, and regardless of the language, children learn nouns before verbs (Gentner, 1982). Gentner (1978, 1982, 2005) suggests that simple nouns, comprising concrete and proper nouns, are faster to be acquired than verbs because simple nouns refer to real-world entities and their meanings are constrained by the nature of the physical world. For verbs, in contrast, the mapping between language and the physical world is less transparent, because verbs express relationships among the entities in the physical world.

Our results, however, revealed that the learning trajectory for nouns is more extended than these observations might suggest. Substantial evolution in word use was observed even up to at least the age of 14. We suggest that Gentner's relational-referential distinction as an explanation for the difference in rate of acquisition between nouns and verbs may account for the very early years of language acquisition characterized by fast mapping, but it may not account for later lexical development, characterized by gradual reorganizations of existing categories. The early meanings attached to nouns are very limited. If children, for example, learn the word *bottle*, they quickly attach some meaning to the word and start using the word *bottle* for objects.

[4] To test a possible relation between category heterogeneity and word frequency, we looked at word frequency values for *fles*, *bus*, *pot* and *brik*, taken from the Dutch version of the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993). However, no clear relation was found.

They may name some objects correctly, but they may also use the word for many objects named differently by adults. So, it may be true that the first grasp of noun meanings is more quickly established than the first grasp of verb meanings, but this does not imply that the full meanings of nouns are quickly grasped, without need for further evolution. Past the early years of language acquisition, a different kind of learning may need to take place to refine the initial meanings. Other factors besides the relational-referential dimension may play a role in this later process of refinement.

We suggest that the fuzziness and complexity of the boundaries of the categories referred to by common nouns is one of the reasons why it is so hard to fully learn the meanings of common nouns. For most nouns, there exist borderline cases situated at the boundaries of the categories that are not consistently given the name. For example, a carpet is not always considered to be *furniture*. Similar examples were found in our stimulus set: an object with a less prominent push button (compared to typical *bus* objects) containing a beauty product was almost as often called *fles* as *bus*. Such borderline cases, which may receive different names on different occasions of exposure or when considered from different perspectives (Clark, 1997), make it difficult to learn the meanings of common nouns. Further, the evidence for cross-linguistic variability in naming patterns together with the finding that a single set of features cannot fully account for adult naming suggests the need for language-specific learning of word-object pairings that cannot be captured through the main feature set. These idiosyncracies take time to be fully mastered, since they can only be learned through real-world interactions with the objects and through experience with the linking of words to these objects.

Developing a theory of later lexical development

The first challenge for developmental psychology has been to understand how children begin to make sense of the words of their native language. Except for a few studies showing extended learning periods for verb meanings (Bowerman, 1974; Clark & Garnica, 1974; Gentner, 1978; Gropen et al., 1991; Pye et al., 1996) and spatial prepositions (Clark, 1980; Clark & Clark, 1977), little attention has been paid to lexical development taking place after children have established a working grasp of the words covering much of a semantic field. Our data, however, demonstrate a manifest need to understand later lexical development as well.

A number of lexical principles or constraints have been proposed that assist children in learning early word meanings (e.g., Clark, 1987; Markman, 1987). Golinkoff, Mervis, and Hirsh-Pasek (1994) distilled a set of six principles, some new and some reflecting past theorizing, to account for how children map their first words onto objects. They offered a developmental framework in which the principles were organized into two tiers. The principles of the first tier are foundational to word learning in the sense that they help word learning to begin. The second tier represents the principles that make the vocabulary spurt possible (via *fast mapping*). The three principles of the first tier allow children to understand that (a) words have a 'stands for' relation to what they label (the principle of *reference*), (b) words do not refer to a single exemplar, as do proper names, but to categories of objects (the principle of *extendibility*), and (c) words refer to objects over actions or events and to whole objects as opposed to an object part or attribute (the principle of *object scope*). As children get more experienced in word learning, the principles of the first tier become insufficient to account for the word learning process, and children refine their learning strategies with the second tier. The first strategy or principle of the second tier is the principle of *conventionality*, the assumption that, in order to communicate successfully, words used to refer should match the words used by others in the language community (Clark, 1983). Second, while under the first tier principle of extendibility, children mainly extend object labels on the basis of shape, the principle of *categorical scope* states that label extension is based on taxonomic category membership. Finally, the principle of *novel name-nameless category* (N_3C) biases the child to map a novel word onto a nameless object referent, rather than onto an already named object (Clark, 1983; Markman, 1989). Golinkoff et al.'s (1994) framework is a powerful model to explain how word learning slowly begins by the end of the first year and how children turn into expert word learners within a year's time.

What role, if any, should such principles play in a theory of later lexical acquisition? We suggest that once children have established a working grasp of words, the first tier principles will make little contribution to further refinements of the word meanings. The second tier principles are more likely to be partly responsible for the learning that takes place during later lexical development. The principle of *conventionality* (Chouinard & Clark, 2003; Clark, 1987, 1993) may contribute to the gradual convergence towards the adult naming pattern, as children notice discrepancies from adult word use or receive explicit feedback about discrepancies and strive to conform to the adult usage. The principle of *categorical scope* may explain gradual reorganizations of the sort we observed between 5 years and adulthood, to the extent that these reorganizations can be predicted by the main sets of features defining the scopes of the different categories. However, given the fuzziness and complexity of the lexical category boundaries, the categorical scope principle will not always predict the correct name. For example, typical *bus* objects contain beauty or cleaning products and have a push button on top, but there are also *bus* objects without a push button, as illustrated in Fig. 7. Based on the categorical scope principle, these objects would be called *fles* rather than *bus*. To learn to name these objects correctly, children need to go beyond the categorical scope principle and learn to appreciate the specific featural relations that hold among the objects (and that are not included in the main set of features defining the scope of the category *bus*), and how these features map onto the names.

Finally, the N_3C principle may have a limited but important role in later lexical development. For familiar household objects, most objects may have already been named by 5 or 6 years. However, in many other domains, a child's vocabulary is likely to be still growing with the help of the N_3C principle. In addition, our data provided some evidence compatible with the notion that acquisition of new vocabulary words helps trigger refinement of existing lexical categories, and so N_3C will indirectly contribute to this refinement. However, they also demonstrate that extended reorganization of the existing lexical categories goes on beyond the point of entry of the new words, and so other principles or mechanisms such as fine-grained application of conventionality in order to match usage to the adult pattern may be needed to fully account for this process.

How formal modeling can contribute to understanding lexical development

To our knowledge, developmental psychologists have not often used formal models in evaluating development of word meaning. Evidence has mainly come from descriptive diary studies (e.g., Clark, 1995a; Mervis', 1987). By applying a regression model to later lexical development, the present paper makes a unique contribution to the developmental literature. The model allowed us to test competing theories that account for children's discrepancies to adult word use in terms of differences in featural knowledge. The linear regression model is only one type of featural model in which naming patterns were predicted from one or more feature predictors. No claims were made about other (feature-based) categorization models that might be applied to naming. We hope that our attempt to implement developmental theories in a regression model gives the impetus to apply other formal models to the domain of lexical development in the future.

Conclusion

We found substantial evolution in the use of common nouns well past the early years of language acquisition. Gradual convergence to adult naming was achieved through addition of new words to the vocabulary as well as through extended reorganizations of existing categories. In line with Mervis' (1987), children gradually learn to attend to the adult-like features and gradually assign them the appropriate weight. Our data highlight the importance of understanding later lexical development in order to develop a complete view of word learning. Neither featural theories of early language acquisition nor lexical principles can simply be assumed to apply to language acquisition at a later age, but need to be evaluated with respect to later lexical development. Word learning during later lexical development needs to be considered as a different learning process than that which takes place during early lexical development.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jml.2007.01.006.

References

Ameel, E., & Storms, G. (2006). From prototypes to caricatures: geometrical models for concept typicality. *Journal of Memory and Language, 55*, 402–421.

Ameel, E., Storms, G., Malt, B. C., & Sloman, S. A. (2005). How bilinguals solve the naming problem. *Journal of Memory and Language, 53*, 60–80.

Andersen, E. S. (1975). Cups and glasses: learning that boundaries are vague. *Child language, 2*, 79–103.

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database [CD-ROM]*. Philadelpha: University of Pennsylvania, Linguistic Data Consortium.

Berlin, B. (1978). Ethnobiological classification. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and categorization* (pp. 9–26). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Bloom, L. (1973). *One word at a time: The use of single-word utterances before syntax*. The Hague, The Netherlands: Mouton.

Bloom, P. (2000). *How children learn the meanings of words*. Cambridge, MA: MIT Press.

Bloom, P. (2001). Precis of ''How children learn the meanings of words. *Behavioral and Brain Sciences, 24*, 1095–1103.

Booth, A., Waxman, S. R., & Huang, Y. T. (2005). Conceptual information permeates word learning in infancy. *Developmental Psychology, 41*(3), 491–505.

Borg, I., & Groenen, P. (1997). *Modern Multidimensional Scaling: Theory and applications*. New York: Springer-Verlag.

Bowerman, M. (1974). Learning the structure of causative verbs: a study in the relationship of cognitive, semantic and syntactic development. *Papers and Reports on Child Language Development, 8*, 142–178.

Carey, S. (1978). The child as word learner. In M. Halle, J. Bresnan, & G. A. Miller (Eds.), *Linguistic theory and psychological reality* (pp. 264–293). Cambridge, MA: MIT Press.

Chouinard, M. M., & Clark, E. V. (2003). Adult reformulations of child errors as negative evidence. *Journal of Child Language, 30*, 637–669.

Clark, E. V. (1973). What's in a word? On the child's acquisition of semantics in his first language. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 65–110). New York: Academic Press.

Clark, E. V. (1980). Here's the "top": Nonlinguistic strategies in the acquisition of orientational terms. *Child Development, 51*, 329–338.

Clark, E. V. (1983). Meanings and concepts. In P. H. Mussen (Series Ed.), & J. H. Flavell, & E. M. Markman (Vol. Eds.), *Handbook of child psychology,* Vol. 3: *Cognitive development* (pp. 787–840). New York: John Wiley.

Clark, E. V. (1987). The principle of contrast: a constraint on language acquisition. In B. MacWhinney (Ed.), *Mechanisms of language acquisition* (pp. 1–33). Hillsdale, NJ: Lawrence Erlbaum Associates.

Clark, E. V. (1990). On the pragmatics of contrast. *Journal of Child Language, 17*, 414–431.

Clark, E. V. (1993). *The lexicon in acquisition*. Cambridge University Press.

Clark, E. V. (1995a). Later lexical development and word formation. In P. Fletcher & B. MacWhinney (Eds.), *The handbook of child language* (pp. 393–412). Oxford: Blackwell.

Clark, E. V. (1995b). Language acquisition: the lexicon and syntax. In J. L. Miller, & P. D. Eimas (Eds.), *Handbook of perception and cognition (2nd ed)*, Vol. 11: *Speech, language and communication (pp. 303–337)* (Gen. Eds., E. C. Carterette & M. P. Friedman). New York: Academic Press.

Clark, E. V. (1997). Conceptual perspective and lexical choice in acquisition. *Cognition, 64*, 1–37.

Clark, E. V. (2004). How language acquisition builds on cognitive development. *Trends in Cognitive Sciences, 8*(10), 472–478.

Clark, H. H., & Clark, E. V. (1977). *Psychology and language: An introduction to psycholinguistics*. New York: Harcourt Brace Jovanovich.

Clark, E. V., & Garnica, O. K. (1974). Is he coming or going? On the acquisition of deictic verbs. *Journal of Verbal Learning and Verbal Behavior, 13*, 559–572.

Clark, E. V., & Sengul, C. J. (1978). Strategies in the acquisition of deixis. *Journal of Child Language, 5*, 457–475.

De Groot, A. M. B. (1993). Word-type effects in bilingual processing tasks: support for a mixed-representational system. In R. Schreuder & B. Weltens (Eds.), *The bilingual lexicon* (pp. 27–51). Amsterdam: John Benjamins Publishing Company.

Gentner, D. (1978). On relational meaning: the acquisition of verb meaning. *Child Development, 49*, 988–998.

Gentner, D. (1982). Why nouns are learned before verbs: linguistic relativity versus natural partitioning. In S. Kuczaj (Ed.), *Language development*. *Language thought and culture* (Vol. 2, pp. 301–334). Hillsdale, NJ: Lawrence Erlbaum.

Gentner, D. (2005). The development of relational category knowledge. In L. Gershkoff-Stowe & D. H. Rakison (Eds.), *Building object categories in developmental time* (pp. 245–275). Hillsdale, NJ: Erlbaum.

Golinkoff, R. M., Mervis, C. B., & Hirsh-Pasek, K. (1994). Early object labels: the case for a developmental lexical principles framework. *Journal of Child Language, 21*, 125–155.

Gropen, J., Pinker, S., Hollander, M., & Goldberg, R. (1991). Syntax and semantics in the acquisition of locative verbs. *Journal of Child Language, 18*(1), 115–151.

Hampton, J. A. (1979). Polymorphous concepts in semantic memory. *Journal of Verbal Learning and Verbal Behavior, 18*, 441–461.

Haryu, E., & Imai, M. (2002). Reorganizing the lexicon by learning a new word: Japanese children's interpretation of the meaning of a new word for a familiar artifact. *Child Development, 73*(5), 1378–1391.

Hunn, E. (1977). *Tzetal folk zoology: The classification of discontinuities in nature*. New York: Academic Press.

Huttenlocher, J., & Smiley, P. (1987). Early word meanings: the case of object names. *Cognitive Psychology, 19*(1), 63–89.

Kroll, J. F. (1993). Accessing conceptual representations for words in a second language. In R. Schreuder & B. Weltens (Eds.), *The bilingual lexicon* (pp. 53–82). Amsterdam: John Benjamins Publishing Company.

Malt, B. C., & Sloman, S. A. (2003). Linguistic diversity and object naming by non-native speakers of English. *Bilingualism: Language and Cognition, 6*, 47–67.

Malt, B. C., Sloman, S. A., & Gennari, S. (2003). Universality and language-specificity in object naming. *Journal of Memory and Language, 49*, 20–42.

Malt, B. C., Sloman, S. A., Gennari, S., Shi, M., & Wang, Y. (1999). Knowing versus naming: similarity and the linguistic categorization of artifacts. *Journal of Memory and Language, 40*, 230–262.

Markman, E. M. (1987). How children constrain the possible meanings of words. In U. Neisser (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization* (pp. 255–287). Cambridge, England: Cambridge University Press.

Markman, E. M. (1989). *Categorization and naming in children*. Cambridge, MA: MIT Press.

McRae, K., de Sa, V. R., & Seidenberg, M. S. (1997). On the nature and scope of featural representations of word meaning. *Journal of Experimental Psychology: General, 126*, 99–130.

Mervis, C. B. (1987). Child-basic object categories and early lexical development. In U. Neisser (Ed.), *Concepts and conceptual development: ecological and intellectual factors in categorisation* (pp. 201–233). Cambridge: Cambridge University Press.

Nelson, K. (1974). Concept, word, and sentence: Interrelations in acquisition and development. *Psychological Review, 81*, 267–285.

Pye, C., Loeb, D. F., & Pao, Y. Y. (1996). The acquisition of breaking and cutting. In E. V. Clark (Ed.), *The proceedings of the twenty-seventh annual child language research forum* (pp. 227–236). Stanford: Center for the Study of Language and Information.

Rescorla, L. A. (1980). Overextension in early language development. *Journal of Child Language, 7*, 321–335.

Rosch, E. (1975). Cognitive representations of semantic categories. *Journal of Experimental Psychology: General, 103*, 192–233.

SAS Institute Inc., *SAS STAT ® Users's Guide 8*, Cary, NC: SAS Institute Inc., 1999. 3884 pp.

Sloman, S. A., Malt, B. C., & Fridman, A. (2001). Categorization versus similarity: the case of container names. In U. Hahn & M. Ramscar (Eds.), *Similarity and categorization* (pp. 73–86). Oxford: Oxford University Press.

Waxman, S. R. (2002). Early word learning and conceptual development: everything had a name, and each name gave birth to a new thought. In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development* (pp. 102–126). Oxford UK: Blackwell Publishers.