Learn a Word-Learning Constraint:

Emergence of the Taxonomic Constraint and its Relationship with Early Word Acquisition

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DAJIE ZHANG

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Dekan/Dekanin: Universitätsprofessor Dr. Heinrich Bedford-Strohm

Erstgutachter/-in: Universitätsprofessorin Dr. Sabine Weinert

Zweitgutachter/-in: Universitätsprofessor Dr. Thomas Lachmann

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DAJIE ZHANG

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Professor Dr. Thomas Lachmann

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Abstract

This research systematically investigated the emergence and development of an assumed word learning constraint - the taxonomic constraint.

The constraint has been proposed to account for young children's rapid noun learning. It has been well demonstrated in children at 2 years of age or older. Only few studies have been conducted with younger infants. The origin and the onset point of the constraint are in debate. The current research sampled infants aged from 9 months to 18 months. It was explored how the constraint that is supposed to facilitate word learning may emerge during this period, where significant changes take place in language and cognitive development. It was investigated whether the evolvement of the constraint interacts with infants' language development.

Two lines of experiments were conducted. First, infants at 9 and 12 months of age were sampled. A series of bottom-up categorization tasks and word-extension tasks were conducted. It was explored whether a precursor of the taxonomic constraint might already be evident at the early stage of language acquisition. Second, infants at 15 and 18 months of age were sampled. A top-down match-to-sample task was conducted. It was investigated whether the taxonomic constraint emerges during this period.

The two lines of experiments have converged to suggest that the assumed taxonomic constraint emerges gradually as young infants acquire language. Shortly after word production begins, a precursor of the constraint is evident. By the time infants begin to more efficiently expand their productive language, they benefit from the taxonomic constraint to learn novel words. The emergence and the development of the constraint seem to be closely related to the status of infants' language development.

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Introduction

Children produce their first words between 8 and 14 months of age. At this time, they add novel words to their productive vocabulary at a slow rate. Around 18 months of age, infants have an average productive vocabulary of 50 words. By 24 months of age, young children typically utter more than 300 words, and at about 30 months of age, the productive vocabulary soars to over 550 words (Bates, Dale, & Thal, 1995; Fenson et al., 1994). Although great individual variations have been revealed in learning rates, learning styles and semantic components of words in early lexical development (Bates et al., 1994; Ganger & Brent, 2004; Goldfield & Reznick, 1990; Gopnik & Choi, 1990; Mervis & Bertrand, 1995; Tardif, 1996), it is consented that a child's word learning rate increases during the second year of life. During this period, nouns compose a high percentage of children's productive vocabulary (Bates et al., 1988; Bloom, 1973; Bornstein et al., 2004; Carey, 1978; Caselli et al., 1995; Dromi, 1987; Fenson et al., 1994; Gentner, 1982; Nelson, 1973; Woodward & Markman, 1998). Although the proportion of nouns in children's lexica varies across languages and vocabulary measures, there are no reported cases in which other kinds of word learning (e.g., verb learning) outstrips noun learning (Au, Dapretto, & Song, 1994; Bornstein et al., 2004; Choi & Gopnik, 1995; Fernald & Morikawa, 1993; Gentner, 1982; Goldfield, 2000; Tardif, 1996). Given that young children have only limited cognitive and social resources, what enables them to learn words, especially novel nouns so efficiently? In particular, a novel noun might have numerous of possible meanings (Quine, 1960). How can a young child readily determine a novel noun's meaning?

Researchers have accounted for the efficient noun learning from different perspectives. Some claim that children just rely on general cognitive abilities to learn novel nouns (Bloom, 2001; Bloom, 2004; Markson & Bloom, 1997). Others believe that social-pragmatic cues (such as joint attention, intonation, non-linguistic gestures, and context) are essential for early word learning (for reviews see Woodward & Markman, 1998; Waxman & Lidz, 2006).

Another attempt to explain young children's success in noun learning is the word learning constraint assumption. It proposes that children rely on a set of default constraints (or biases) on words' meanings to shape their first guess about references and extensions of novel words. By narrowing the hypothesis space, constraints enable young children to acquire words rapidly (Clark, 1991; D'Entremont & Dunham, 1992; Gildersleeve-Neumann, 2002; Golinkoff, Shuff-Bailey, Olguin, & Ruan, 1995; Halberda, 2004; Hollich et al., 2000; Ishida, Kosugi, & Itakura, 2003; Markman, 1989; Markman & Hutchinson, 1984; Merriman & Stevenson, 1997; Regier, 2003; Rey & Berger, 2001; Waxman, 1991; Waxman, Senghas, & Benveniste, 1997; Woodward, 1993).

For example, by 18 months of age, young children are found to demonstrate a taxonomic constraint. They tend to extend a novel label to objects of the same category (Baldwin, 1992; Bauer & Mandler, 1989; D'Entremont & Dunham, 1992; Gelman, Croft, Fu, Clausner, & Gottfried, 1998; Golinkoff et al., 1995; Imai, Gentner, & Uchida, 1994; Kim & Ghim, 1998; Markman & Hutchinson, 1984; Mervis, 1987; Nguyen & Murphy, 2003; Waxman, 1991; Waxman & Hall, 1993; Waxman & Kosowski, 1990; Weinert, 2003). The taxonomic constraint has been assumed to facilitate word learning on the one hand and contribute to early categorization on the other (Booth & Waxman, 2002; Fulkerson, Waxman, & Seymour, 2006; Waxman & Gelman, 1986; Weinert, 2003). For this reason, studies concerning the taxonomic constraint assumption often cut across the two strands of investigation exploring the interaction between early language and conceptual development (Baldwin, 1992; Booth, Waxman, & Huang, 2005; D'Entremont & Dunham, 1992; Gelman et al., 1998; Gentner & Boroditsky, 2001; Hall & Waxman, 1993; Imai et al., 1994; Waxman, 2003; Waxman & Booth, 2003; Waxman & Kosowski, 1990).

Although the taxonomic constraint has been well-demonstrated in children older than 18 months, it is less clear whether the constraint is functional at an earlier stage. Some researchers claim that the word learning constraint is induced from learning experience and emerges no earlier before children have acquired a sizable productive vocabulary (Jones & Smith, 1998; Landau, Smith, & Jones, 1988; Smith, 2000; Smith, Jones, & Landau, 1996). Others believe that the constraint is in place much earlier and have shown that language influences categorization already by nine months of age (Balaban & Waxman, 1997; Fulkerson & Haaf, 2003; Waxman & Markow, 1995). Therefore, how and when the assumed taxonomic constraint emerges and whether its development ties to the progress of language acquisition are still open questions.

The current research intends to systematically investigate the emergence of the taxonomic constraint with respect to infants' early word learning progressions.

1. Precursors to word learning

To learn any word, infants have to (1) discover how to segment words and other linguistic units from the continuous speech stream; (2) identify the relevant conceptual units from their contexts; and (3) establish appropriate mapping between linguistic and conceptual units. None of these tasks is a simple one. To segment a word is difficult as there are, for example, few clear pauses in spoken language and there is an absence of consistent acoustic features indicating word boundaries (Cole & Jakamik, 1980). To identify words' referents is complicated as a referent is often embedded in its environment (e.g., a *dog* in a park), is sometimes abstract (e.g., he is *running*; it's *slopping*), or is rather absent at the time of speaking (e.g., let's go get your *shoes*). On top of these, word learning requires infants to map words to concepts, which means to extend words systematically beyond the individuals with which the words were initially introduced.

In the past decades, studies have provided some insight into how infants solve these fundamental problems of learning language. There is evidence that before word-learning begins in earnest, infants show sensitivity to acoustic cues relevant to language learning, have a basic repertoire of concepts about objects and events, and appreciate some social cues provided by caregivers that will contribute to language learning.

1.1 Early sensitivity to segmentation-relevant acoustic cues

Before infants begin to map words onto objects, they must determine which sound sequences are words. To do so, infants must uncover at least some of the units of their language from the continuous stream of sounds. Despite that words are seldom surrounded by pauses, infants can segment words from fluent speech from about 7 months of age (Jusczyk & Aslin, 1995; Saffran, Senghas, & Trueswell, 2001). How do infants learn the units of their language?

Prior to birth, fetuses can already hear sounds (Fifer & Moon, 1989; Richards, Frentzen, Gerhardt, McCann, & Abrams, 1992). By 37 weeks of gestational age, fetuses response differently to some recurrent maternal speech compared to other sounds (DeCasper, LeCanuet, Busnel, Granier-Deferre, & Maugeais, 1994). Shortly after birth, babies were reported to distinguish between their mother tongue and another language, suggesting that as fetuses they might have taken note of some prosodic features in their native language (Mehler et al., 1988; Moon, Cooper, & Fifer, 1993). Also, it was reported that newborns reacted differently to speech items with or without word boundaries (Christophe, Dupoux, Bertoncini, & Mehler, 1994). Thus, by the time babies are born, they are perceptive to acoustic signals around them, including the prosodic cues inherent in their mother tongue, which may later cue them to extract linguistic units out of the fluent speech stream.

Besides the prosodic cues, fetuses were also reported to response to syllabic information in language stream. For example, by 37 weeks of gestational age, fetuses were reported to distinguish "babi" from "biba" (LeCanuet, Granier-Deferre, & Busnel, 1995). Newborns were also found to discriminate bisyllabic or trisyllabic words (Bijeljac-Babic, Bertoncini, & Mehler, 1993).

Studies on the perception of speech have suggested that some acoustic cues are especially useful for detecting boundaries of linguistic units from fluent speech. Prosodic changes including pausing, stressing, syllable lengthening and changes in pitch contours and rhythm are among such cues (Echols & Marti, 2004; Price, Ostendorf, Shattuck-Hufnagel, & Fong, 1991). It has been found that these cues are particularly salient in the infant-directed speech (Albin & Echols, 1996; Bernstein Ratner, 1986; Fisher & Tokura, 1996a; Fisher & Tokura, 1996b). Compared to adult-directed speech, infant-directed speech consists of shorter sentences, is more repetitive, and uses simpler syntactic constructions (Shatz & Gelman, 1973). The pitch of infant-directed speech is typically higher than that of adult-directed speech, the range of pitch is broader, and the durations of some words are lengthened (Ferguson, 1977; Garnica, 1977). These cues may help infants to segment words and phrases. It has been demonstrated that infants in the first year of life, even newborns, tend to listen longer to infant-directed speech (Cooper & Aslin, 1990; Cooper & Aslin, 1994; Fernald, 1985; Fernald & Kuhl, 1987; Pegg, Werker, & McLeod, 1992; Werker & McLeod, 1989; Werker, Pegg, & McLeod, 1994). The preference may guide infants' attention to those cues in the speech stream that highlight the boundaries of linguistic units and hence ease the parsing task. Studies have shown that young infants are sensitive to these salient cues such as stress, rhythm and intonation in infant-directed speech (Echols & Marti, 2004).

During the second half of the first year of life, infants become more sensitive to the features carrying the most weight in their native language. For instance, different languages have different stress patterns of words, such like a strong/weak word pattern (a trochaic pattern) in English or a weak/strong pattern (an iambic pattern) in French. Nine-month-old infants were found to prefer the predominant stress pattern in their native language while 6-month-old babies do not show such preference (Jusczyk, Cutler, & Redanz, 1993; Turk, Jusczyk, & Gerken, 1995). Similarly, languages are also different in rhythmic classes from each other. Newborns have been found to distinguish two languages from different rhythmic classes (e.g., English and Japanese), but not two languages from the same rhythmic class (e.g., English and Dutch). By 6 months of age, infants can also discriminate their native language from other languages in the same rhythmic class (e.g., English and Dutch). This knowledge is specific to infants' native language, as those learning English are not able to differentiate two unfamiliar languages that both belong to the same rhythmic class as their native language (e.g., German and Dutch) (Nazzi, Bertoncini, & Mehler, 1998; Nazzi, Jusczyk, & Johnson, 2000).

In the second half of the first year, infants also turn to be more sensitive to the sequential and positional cues of phonemes (phonotactic cues) in words in their native language. For instance, by 8 months of age, infants notice that some syllables are more likely to co-occur in their language, and some phoneme combinations are not likely to be word candidates (Johnson, Jusczyk, Cutler, & Norris, 2003; Jusczyk et al., 1993; Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993; Morgan & Saffran, 1995; Saffran, Aslin, & Newport, 1996; Saffran, Newport, & Aslin, 1996; Thiessen & Saffran, 2003). These specified sensitivities indicate that infants do not simply perceive discrete linguistic information, but also gradually learn the regularities of phoneme distribution and combination in their own language, which is very helpful for them to pick out viable words. They may find word boundaries by detecting syllable pairs with low transitional probabilities.

In addition, function words (e.g., *a, the*) are also valuable for infants in detecting word phrases or type of word phrases (e.g., a noun phrase often begins with *a* or *the*). Although function words tend to be unstressed and less salient in natural speech, infants by 11 months of age identify the function words and this influences their comprehension of language (Echols & Marti, 2004; Shafer, Shucard, Shucard, & Gerken, 1998).

While infants are getting more sensitive to cues specific to their own language, they also begin to ignore other cues that are not central to their language. For example, Werker and Tees (1983) found that at 6 to 8 months of age, infants could distinguish phonetic contrasts in different languages. By 8 to 10 months of age, only some of the contrasts in the foreign languages could be distinguished, and by 10 to 12 months of age, infants were largely insensitive of contrasts outside of their native language. Similar findings have also been provided by other researchers (Aslin, Jusczyk, & Pisoni, 1998; e.g., Hayashi, Tamekawa, & Kiritani, 2001; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992).

In sum, infants come to the world with preliminary attentional and perceptional potentials that underpin speech segmentation. At around 7 months of age, infants begin to segment words from fluent speech (Echols & Marti, 2004; Saffran et al., 2001). During the first year of life, their abilities to perceive and process acoustic cues that are essential to segmentation develop and become gradually more specialized to their native language.

1.2 Early visual perception of objects and events

In order to find the right referent of a novel word they hear, infants must be at least able to identify objects and events around them. Due to the immaturities of the optical system (e.g., the relative distance from the cornea to the retina in neonates' eyes is much shorter than that in adults' eyes), the receptoral system (e.g., the fovea cones have very dissimilar size, shape, and structure at birth than they will be later on) and the central visual system (e.g., the primary visual cortex is not fully functioning until around 3 months postnatal age), infants come to the world with extremely poor spatial and chromatic vision (Atkinson, 1984; Chugani, 1998a; Chugani, 1998b; Johnson, 1990; Johnson, 1998; Kellman & Banks, 1998; Slater, 1995). The visual acuity at birth, for instance, is so low that the neonates could be classified as legally blind (Kellman & Banks, 1998; Slater, 1995).

Due to the immaturity of the cortex, in the first few months of life, infants' eyes follow a moving stimulus in a saccadic or step-like manner, as opposed to the smooth pursuit found in adults and older infants. Also, the eye movements always lag behind the movement of the stimulus, rather than predicting its trajectory. Therefore, when a newborn infant visually tracks a moving object, it could be described as performing a series of separate re-orientations as the stimulus leaves the central visual field, behavior characterizing the subcortical control of eye movements (Johnson, 1990). Around 1 month of age, once infants are able to fixate on a stimulus, they often experience a period of obligatory looking, during which they stare fixedly at objects and may have difficulty disengaging their fixation. This obligatory looking gradually disappears at around 4 months of age when babies develop more voluntary control of their visual orientation (Posner & Raichle, 1997), which is essential for disengaging, shifting, and reengaging attention to objects and events.

Between 2 to 4 months of age, the primary visual cortex undertakes substantive developmental changes and the cortical visual pathway becomes functional. Around 2 months of age, infants begin to show periods of smooth visual tracking, although their eye movements still lag behind the movement of the stimulus. Also at about this age they first become sensitive to coherent motion in visual input (Wattam-Bell, 1991). At about 3 months of age, the visual pathways involving the frontal eye fields become functional, which allow infants to begin to make anticipatory eye movements. At about 4 month of age, the binocular vision, which underpins stereopsis, also takes place (Held, 1985).

The onset of the primary visual pathway function, together with the developing optical and receptor systems, provides infants with a foundation for processing visual information about objects and events. The developing optical and neural systems enable infants by 4 months of age to process spatiotemporal information about objects' movement and featural information of objects (e.g., size, shape, color and texture) (Haith & Benson, 1998; Kellman & Banks, 1998).

1.3 Early concepts of objects, actions and events

Some researchers believe that infants are born with some kinds of "core knowledge" about objects, actions and events (Baillargeon, Spelke, & Wasserman, 1985; Baillargeon, 1987; Carey & Xu, 2001; Spelke, 1998; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Wynn, 1998). They assume infants are endowed with fundamental conceptual and relational understandings of objects, such as the understanding of object permanence or the simple causal relations among objects. The core knowledge will serve language learning, as well as be influenced by it (Carey, 2001; Spelke & Tsivkin, 2001).

Other researchers have proposed very different views (Cohen & Cashon, 2006; Cohen, Chaput, & Cashon, 2002; Haith, 1998). They believe that infants' early understanding of objects, events and relations are gradually acquired after birth. Especially during the second half of the first year of life, infants' ability to understand object properties and to detect and comprehend relations among objects improves gradually. In particular, infants begin to integrate and associate different sources of information about objects and events (e.g., featural and spatiotemporal information; visual and auditory information). Infants are not only able to segregate objects and their movements from the background, but more importantly, to gradually understand the actions and events taking place around them and among other objects (Cohen & Cashon, 2001; Cohen & Cashon, 2006; Nelson, Thomas, & de Haan, 2006; Xu, 1999; Younger & Fearing, 1998).

Although the origin of basic conceptual knowledge is in debate, it is consented that by the end of the first year of life, infants already have a rudimentary repertoire of concepts about objects, actions and events (Haith & Benson, 1998).

1.4 Early sensitivity to social cues in language learning situations

In order to learn novel words, infants often have to determine speakers' intentions and goals in order to infer the correct reference of a new word. Studies on this issue have investigated what young children understand about the intentions of others and how they exploit this information in word learning tasks (Woodward, 2003; 2004; 2005; see also Woodward & Markman, 1998, for a review). As the focus of this dissertation is not to explore how infants take advantage of social and pragmatic cues to learn language, the topic will not be discussed in depth here. However, it is worth to mention that different studies have established that by 9 to 12 months of age, infants will spontaneously follow speakers' eye-gaze and gestures, especially pointing. Under favorable conditions, they are willing to use these cues to find the intended focus of speakers in naming situations (Akhtar & Tomasello, 2000; Hirsh-Pasek, Golinkoff, & Hollich, 2000; Woodward, 2003).

1.5 Summary

Infants come to the world with limited perceptual capacities. Around 2 to 4 months of age, the visual and auditory perceptual systems experience substantive developments and infants become better able to observe the world voluntarily. Entering the second half of the first year, supported by the developing physical and neural systems, infants are more capable of obtaining and processing information around them, especially of willingly following, associating and integrating stimuli they perceive. The early auditory and visual perceptual sensitivities, the developing processing capacities supported by the maturation of neural system, the increasing understanding of objects, actions and events in the world, together with other emerging and developing capabilities (e.g., motor abilities, abilities to use social cues) enable infants to perceive, explore, and comprehend the world around them, which set the initial stage of learning language.

2. Taxonomic constraint

2.1 The assumption of the taxonomic constraint

When an adult points to an object and labels it, the new label could refer to the object as a category, a part of the object, the substance of the object, or any property of it such as color, texture, pattern, size, and others. What's more, an object rarely appears alone but often with other objects or events together, such as a dog biting a bone, or a spider spinning its web. How could young children know what a novel word exactly means?

Older children, who are more advanced word learners, may use a range of sources such as syntax, grammatical form class (e.g., count nouns refer to objects, where adjectives refer to properties, and so on.), contrast (e.g., the one not red is 'olive'), morphology, and other cues to narrow down words' meanings. For younger children, these cues remain ambiguous or are rather unavailable (Waxman, 2004; Woodward & Markman, 1998). However, by the end of the second year of life, children can already produce hundreds of words (Fenson et al., 1994). How can these young children acquire new words so efficiently? How do they determine word meanings?

Traditional theories assumed that children rely on general inductive mechanisms to infer a words' meaning (Inhelder & Piaget, 1964). It was proposed that children begin with one exemplar of a novel word and formulate a tentative hypothesis about the word meaning. The hypothesis will then be evaluated against subsequent instances, with consistent ones reinforcing the hypothesis while negative ones causing revisions. However, considering that (a) a given word might have unlimited possible meanings (Quine, 1960); (b) young children learn words quickly and effortlessly (e.g., Mervis, 1987); (c) they make rather few mistakes when learning new words (e.g., Bloom, 2004); and (d) they have restricted ability of formulating and testing hypotheses purposefully and systematically (DeLoache, Miller, & Pierroutsakos, 1998); traditional theories do not seem to be convincing for explaining the achievement of early word learning. Young children must have some solutions of word learning that require no sophisticated, time-taking inductive hypotheses testing.

Markman and her colleagues therefore proposed that children are predisposed to consider only some kinds of hypotheses, or at least to give those hypotheses priority over others (Markman, 1987; Markman, 1989; Markman, 1990; Markman & Hutchinson, 1984). By greatly reducing the hypothesis space, the so called constraints or biases make the inductive problems solvable.

For example, one possibility for a child to narrow down the meanings of a novel word is to honor the *whole-object constraint*, which leads children to assume that a new word refers to an entire object rather than to its parts, its properties or its actions (e.g., Woodward, 1993).

When an adult points to a dog and names it ‘a dog’, the child will think the word refers to the dog as a whole but not its legs, features, or movements.

Supposing the child has assumed that a novel word refers to an entire object, how then will she determine the appropriate extension of the new word? For example, how will she know a newly learned word, say ‘dog’, also refers to other dogs but not to other relational associates (e.g., the doghouse, the bone a dog is chewing, the owner of the dog)? How will she know the word ‘animal’ refers not only to dogs, but also to cats, birds and fish, though not to apples or cars? As mentioned earlier, infants by 12-month of age have a basic understanding of a variety of relations among objects, such as causal, categorical, spatiotemporal, and thematic relations (see Haith & Benson, 1998, for a review). Particularly, young children show great interests in thematic relations among objects (e.g., the dog and the bone, the bird and the nest) (Gelman & Baillargeon, 1983; Inhelder & Piaget, 1964; Nelson, 1977; Smiley & Brown, 1979). Given that, what prevents a child from thinking that ‘dog’ could also refer to the bone? Markman and Hutchinson (1984) assumed that young children limit the referees of a word to objects of “the same kind”. This *taxonomic constraint* (also known as the *taxonomic bias*) leads children to shift their attention to categorical properties of objects when hearing a novel word. This will rule out other associates of the originally named object as possible referents of the novel word.

To provide evidence for the taxonomic constraint, studies have investigated how young children organize an object with other objects when the former was named by a novel label versus when it was not labeled (Blanchet, Dunham, & Dunham, 2001; Golinkoff et al., 1995; Imai et al., 1994; Markman & Hutchinson, 1984; Smiley & Brown, 1979; Waxman & Gelman, 1986; Waxman & Hall, 1993; Waxman & Hatch, 1992; Waxman & Kosowski, 1990; Waxman & Namy, 1997). The studies usually applied a *match-to-sample* task. In such a task, children were shown a target object/picture (e.g., a carrot), a thematic match (e.g., a rabbit), and a taxonomic match (e.g., a tomato). Sometimes an irrelevant object/picture (e.g., a book) or a perceptual-similar-only option was also involved as a distracter (D'Entremont & Dunham, 1992; Golinkoff et al., 1995). When the target was labeled with a novel noun, say a *dax*, and the children were asked to find another *dax* among the different options mentioned above, they obviously favored the taxonomic match over others. Children seemed to assume that if the carrot is a *dax*, then the tomato rather than the rabbit or the book would be most likely to be another *dax*. If no novel label was presented and children were simply asked to ‘find another one’, they did not show the special preference for the taxonomic match. In short, young children prefer to extend novel words categorically. The assumed taxonomic constraint leads them to suppose that a novel label refers to objects of the same taxonomic category, but not to the objects that are thematically, spatially or otherwise related to the originally named object.

Although the taxonomic constraint has been well demonstrated in children older than 24 months, only few studies have been conducted with younger children (Graham, Baker, & Poulin-Dubois, 1998; Waxman & Hall, 1993).

For example, Graham and her colleague's investigated the taxonomic constraint in infants younger than 2 years of age. They applied an adapted match-to-sample task with a preferential-looking paradigm[1] (Graham, Baker, & Poulin-Dubois, 1998). Sixteen- to 19-month-old infants (mean age 17.85 months) were randomly assigned to either a novel-label or a no-label condition. Infants were seated in front of two monitors. A target object (e.g., a car) was first presented simultaneously on the two monitors. Infants heard "look at this one" in the no-label condition, and "look at the *dax*" in the label condition. During the interval phase, the monitors were black. Infants heard either "Can you find another one?" or "Can you find another *dax*" respectively. After that, infants were shown a taxonomic match from the same basic-level category on one monitor (e.g., another car) and a thematic match on the other (e.g., a car seat). They heard "where's another one? Find the other one" or "where's the *dax*? Find the *dax*" corresponding to the appropriate condition. Results showed that in the test phase, infants in the novel-label condition looked significantly longer at the taxonomic match than infants in the no-label condition, whereas infants in the no-label condition looked longer at the thematic match than the taxonomic match. Graham and colleagues' study (1998) indicated that the taxonomic constraint is in place by 18 months of age. In addition, infants' taxonomic preference was found to correlate with their language abilities. The larger the vocabulary, the more likely the infants were to look at the taxonomic match in the novel-label condition, and to look at the thematic match in the no-label condition. As the effects of age were statistically controlled, the authors believed that the results suggested a linguistic, rather than an age-related phenomenon.

In consent with this study, with the match-to-sample task Waxman and Hall (1993) found that infants as young as 16-month-old demonstrated the taxonomic bias. Most of these 16-month-old infants could produce less than 50 words and had not yet entered a rapid word learning phase. When provided with a novel word, infants paid much more attention to the taxonomic options than to the thematic ones. However, the word effect was observed in these infants only after the authors have modified the procedures to include demonstrations of the two types of relations (i.e., taxonomic or thematic). Moreover, in order to highlight the differences between the thematic and the taxonomic choices, the authors selected only animate objects as the thematic options and inanimate ones as the taxonomic associates in their study. This

[1] For description and empirical applications of the preferential looking paradigm, see reviews by Slater (1995) or by Hollich et al. (2000).

ontological distinction may have biased infants to extend the novel noun on the basis of inanimateness rather than taxonomic relations. In light of these methodological issues, further research is needed to clarify whether infants indeed honor the taxonomic constraint at this early stage of development.

To summarize, numerous studies have provided evidence that children by 2 years of age demonstrate the taxonomic constraint in word learning contexts. Naming directs children's attention to categorical relations among objects, even though children are aware of and interested in a wide range of other relationships among objects in non-word-learning situations. By substantively reducing the referential scope of a new word, the constraint is supposed to alleviate and contribute to word learning. Given plenty of research on the taxonomic constraint with older children, few studies with infants younger than 2 years of age have been conducted.

2.2 The taxonomic constraint and a facilitative naming effect on early categorization

If naming highlights taxonomic relations, a set of category instances paired with a novel word should serve as an especially effective taxonomic clue. In other words, if children honor the taxonomic constraint, hearing a new word should facilitate categorization (Waxman & Gelman, 1986). In their 1986's study, Waxman and Gelman found that when 3-year-old children were given different exemplars from a global-level category, the introduction of a known English word as well as a novel word helped them to classify the objects. When no labels were provided, children failed to show the same categorization. Similar evidence showing that naming facilitates preschool children's categorization was also provided by Weinert (Weinert, 2003; 2004).

The facilitative effect of language on categorization has not only been found in preschool children, but also in infants. For example, with an object examination task, Waxman and Markow (1995) found that 12-month-old infants benefit from novel nouns to classify different objects. Infants were given a series of objects from the same basic level category (e.g., cars or airplanes) or global-level category (e.g., animals or vehicles) to manipulate, with or without a novel word. On the test trials, infants were shown a new exemplar from the familiar category and an exemplar from a novel category. Like other habituation procedures investigating infants' categorization (e.g., Eimas & Quinn, 1994), the logic of this study was: If infants attended less and less to each next object when given exemplars of the same category, and if infants then attended longer to an out-of-category object than to an object from the familiarized category, this constituted evidence that the infants had categorized. Waxman and Markow's results showed that infants in the novel word condition displayed a greater preference for the out-of-category stimulus than did infants in the no word condition.

The authors believed that naming different objects with the same label invited infants to search for commonalities among objects. This is especially true for objects related at the global-level, for which the commonality would otherwise remain undetected. Novel words appear to help infants to access object categories during familiarization and then to enhance attention to the out-of-category objects during the test phase. In addition, the study also revealed that infants' productive vocabulary status was related to this facilitative word effect on categorization. Infants reported to produce more words were found to reliably benefit from novel nouns to access different basic and global-level categories, whereas those who produced fewer words did not show a consistent tendency.

Balaban and Waxman (1997) extended Waxman and Markow's findings (1995) to even younger children. Using a preferential looking paradigm, 9-month-old infants were familiarized to a series of pictures of basic level animals (e.g., rabbits), either accompanied by a noun phrase ("a rabbit") or by matched tones. On the silent test trials, a new exemplar from the familiar category (e.g., a rabbit) was paired with a novel animal (e.g., a pig). Results revealed that both tones and words enhanced infant's attention during familiarization. However, during the silent test phase, infants in the word condition showed greater attention to novelty than those in the tone condition. Further experiments suggested that the facilitative effect might be caused by language in general, as infants hearing content-filtered words responded in a similar way to infants who were presented with real words. The authors suggested that as young as 9 months of age, infants already have an expectation of linkages between words and categories. This early appreciation of the word-category linkage supports the rapid acquisition of the increasingly sophisticated language and conceptual systems (Waxman, 2003; Waxman & Booth, 2003).

In a more recent study conducted by Fulkerson and Haaf (2003), nine-month-old infants were familiarized to a series of category exemplars (e.g., animals) in an object-examination task. Objects were introduced with a noun phrase, a non-label sound, or no sound. During the test phase, new objects from the familiar category and a novel category (e.g., vehicles) were presented. Although infants demonstrated basic-level categorization in all conditions, they only displayed global-level categorization when noun phrases were introduced. These results extended the findings of Waxman and Markow (1995) to infants of nine-months of age by demonstrating that words facilitate categorization especially at the global-level.

These studies indicated that even before infants produce their first words, they may be able to take advantage of the linkage between nouns and categories. By nine months of age, words seem to prompt infants to classify objects, at least when real words and real objects were presented. More uniquely, words facilitate infants to categorize objects in those situations in which they would not display categorization without linguistic labels (e.g., with global-level object categories) (Fulkerson & Haaf, 2003; Waxman & Markow, 1995).

The fact that words help infants as young as 9 months to access different object categories seems to imply a very early emergence of the taxonomic constraint. However, it remains unclear whether young infants only benefit from linguistic input to *access known* categories (e.g., animals, fruits or vehicles) or whether hearing novel words would promote them to *form new* categories that they have not yet seen before. As previous studies mostly used known categories and sometimes known words as stimuli (Balaban & Waxman, 1997; Fulkerson & Haaf, 2003; Waxman & Markow, 1995), the word effect demonstrated by infants could alternatively be explained by the recognition of familiar categories elicited by (known) words. If children honor the linkage between words and categories, they should be able to take advantage of novel labels to form entirely novel object categories. While this holds true for preschoolers (Markman & Hutchinson, 1984; Weinert, 2003; 2004), little evidence has been provided for infants. Accordingly, it is also unclear at which stage of development the ability of using novel words to form novel categories emerges. One recent study by Booth and Waxman (2002) suggested that this ability may emerge around 14 months of age.

In this study (Booth & Waxman, 2002), artificial objects were used in the categorization tasks. The objects of the same category had similar shapes. Fourteen- and 18-month-old infants were familiarized with a series of exemplars of the same category along with a common function, a common name (a novel label), or non-labeling instructions (the “no-cue” condition). During the test phase, infants in all the three conditions were asked to "find another one", choosing between two novel objects, one from the familiar category (with the similar shape) and the other one not (with a different shape). A familiarity preference (i.e., paying more attention to the in-category exemplar) would indicate successful categorization. It turned out that infants at both ages displayed reliable categorization in the function condition. In the novel-label and no-cue condition, however, infants performed differently. First, in the no-cue condition, when asked to “find another one”, the 18-month-olds displayed a rather high *novelty* preference score[2], whereas the 14-month-old infants performed at chance level. Second, in the novel-label condition, the 18-month-old infants successfully categorized the objects (i.e., displaying the expected familiarity preference), while the 14-month-olds failed to do so. Subsequently, the authors modified the procedures. The same no-cue and novel-label conditions were given to another group of 14-month-olds, with one modification: the function of one of the objects was demonstrated during the familiarization phase. After this cue was added, the 14-month-olds also succeeded in the novel-label

[2] Although the mean novelty preference score of the 18-month-old group (M = .60) seemed to be higher than chance level (.50), it was not reported by the author whether this value is significantly different from .50 (Booth & Waxman, 2002).

condition, but *not* in the no-cue condition. This study seemed to indicate that: First, the impact of novel words on object categorization is restricted in 14-month-old infants. They may still need more cues in addition to the linguistic input alone to form a novel object category. Second, the ability of linking new labels and novel object categories is emerging during this period (i.e., around or by 14 months of age). Although the novel label alone did not facilitate categorization, with an added cue (i.e., the function of the object), the infants succeeded in the categorization task. By contrast, in the no-cue condition where no linguistic label was provided, even the function cue was added, the infants still failed in the task. Thus, linguistic labels do seem to contribute to novel objects' categorization, yet the influence may be still developing at this early stage. As the language development status of the infants was not reported in this study, it was not known whether infants' performances were related to their language abilities (Booth & Waxman, 2002).

In another study, Nazzi and Gopnik (2001) examined infants' ability to form new object categories based on either visual cues alone or novel labels alone. Sixteen- and 20-month-old infants were given an object manipulation task. In the visual cues alone condition, infants played with a set of three objects one by one. Two of them were identical and the third one was different in appearance. Infants were encouraged to manipulate the objects without being given any labels for the objects. During the test phase, the experimenter took one of the identical objects and asked the infants to give him "the object that goes with this one" from the rest two objects. Infants at both ages successfully used visual information to categorize the objects. In the novel label alone condition, the three objects were distinctive in appearance from one another. As infants playing with them, two of the objects were arbitrarily given the same name, while the third one was given another label. The test phase was the same as in the visual cues only condition. This time only the 20-month-olds but not the younger infants succeeded in categorizing the two perceptually distinctive objects based only on their common name. To succeed in the novel label alone condition, infants had to remember which two objects had been named by the same label (although they had distinctive appearances) and differentiate them from the third object named by another new label. This was different compared to the tasks in Booth and Waxman's study (2002), in which infants were provided with perceptual cues as the basis of categorization across all the three experimental conditions (i.e., common function, common name, or no-cue). Nazzi and Gopnik's study (2001) indicated that in a stringent categorization task in which perceptual cues were stripped off, even 16-month-olds were unable to use linguistic cues alone to form a novel object category. It is also worth to mention that in this study, the 20-month-old infants' performances in the novel label alone condition were correlated with their language abilities. Those with greater vocabulary sizes were more likely to succeed in the categorization task.

In summary, it has been hypothesized that if children appreciate the taxonomic constraint, providing them with a common word for a set of distinct objects should facilitate their categorization (Waxman & Gelman, 1986). A number of studies following this hypothesis have found that at least when familiar object categories or known words were used as stimuli, language but not other kinds of auditory input promoted object classification. However, while older children were found to benefit from novel words to form *novel* object categories (Markman & Hutchinson, 1984; Weinert, 2003; 2004), it seems that infants who just begin to learn language at least still have difficulties to do so (Booth & Waxman, 2002). In addition, little has been done to investigate whether the ability of using novel words to categorize novel objects is related to infants' language abilities.

2.3 Different procedures to investigate the taxonomic constraint and their implications

As mentioned in 2.1, studies investigating the taxonomic constraint with children older than 2 years of age usually apply the match-to-sample task. In this kind of "top-down" tasks, children are typically only exposed to a single exemplar of a given category with a linguistic label. After that, they will be asked to choose an object that could also be named with the same label among different options. Thus, children are prompt to extend a novel word to possible members based upon one or few exemplars of a category. The match-to-sample task is a deductive task. It tests children's ability of extending words based on their existent knowledge about language and objects.

As a comparison, studies on the facilitative effect of language on early categorization with young infants usually apply a "bottom-up" model, in which a familiarization or habituation phase is first introduced. During this phase, infants are presented with a series of exemplars of the same category along with the same linguistic label. The assumption behind this kind of models is: If infants hear the same name when given different exemplars of the same category, the label should highlight the consistency of the objects and hence facilitate classification. When infants realize that the objects are more or less the "same", they will attend less and less to the new exemplars of the same category. After that, when presented simultaneously with an exemplar from a novel category and another new exemplar from the familiar category, infants should be more interested in the out-of-category object than the in-category one. If infants attend longer to the former one, then they are assumed to have categorized. Thus, the bottom-up procedures as inductive tasks provides infants chances to learn the linguistic label and the category members during the experiment by exposing them repeatedly to the word-category paring. The bottom-up task has been mainly used in very young infants who have little experience with language and objects.

The top-down word learning task and the bottom-up categorization task taps on different abilities of children at different ages. The former directly tests the taxonomic constraint assumption by examining how children (mostly above 18 months of age) extend novel words. The latter indirectly tests the assumption by exploring whether novel words ease object categorization (mostly in infants younger than one year of age). It is based on the assumption that if children honor the constraint, hearing the same label for a group of objects should facilitate classification of the objects (Waxman & Gelman, 1986).

2.4 Debate on when the taxonomic constraint emerges

Although the taxonomic constraint was originally proposed to explain children's efficient word learning starting around the end of the second year of life, some studies implied that even preverbal infants seem to honor the constraint. It is not yet clear when the taxonomic constraint becomes functional.

Some researchers believe that the word learning constraints are acquired through learning experience itself (Jones & Smith, 1998; Landau et al., 1988; Smith et al., 1996). According to an *attentional learning account* (Smith, 2000), early word learning is similar as other kinds of learning, for which the basic underlying mechanism is association. On this view, infants' first words are acquired without any guiding expectation or constraint. As learning proceeds, some given cues will repeatedly and regularly associate with some contexts. In the similar contexts later, attention will be selectively paid to those cues. Which cues will be picked out depends on the statistical regularity presented in the learning situations.

For example, among English-speaking children's first words, a predominant proportion of nouns (more than 80%) refer to solid object categories organized by shape (Samuelson & Smith, 1999). Accordingly, children learning words are constantly exposed to the association between nouns and the reliable cue 'shape'. Once children having accumulated enough experience (e.g., having learned about 50 count nouns), a qualitative change will occur. Children will form a so called "shape bias", which leads them to expect a new label to refer to those objects having consistent form, regardless of different colors, sizes or textures. This bias will then cue the children to generalize newly learned nouns to objects of the same shape (Gershkoff-Stowe & Smith, 2004; Hupp, 2004; Landau et al., 1988).

According to Smith and her colleagues (Smith, Jones, Yoshida, & Colunga, 2003), the association between cues and contexts is built up automatically. It runs behind the conscious thought, which means it is effortless for young children. Nevertheless, in order to build up a reliable association, children have to first acquire a sizeable productive lexicon (i.e., 50 count nouns). Only after this basic vocabulary is established, such a constraint will emerge and help children to acquire new words rapidly (Jones & Smith, 2002; Smith, 2000).

Smith's research group have demonstrated in a range of experiments that word learning constraints are themselves learned, accordingly context sensitive, and highly adaptive to the language system that children are acquiring (Jones, Smith, & Landau, 1991; Landau et al., 1988; Samuelson & Smith, 1999; Smith, 2001; Smith, Jones, & Landau, 1992; Yoshida & Smith, 2003). Major findings in these studies include: (a) the shape bias appears *after* children have accumulated 50 count nouns in their productive vocabulary, when the children are about 18 months of age or older; (b) in non-word-learning contexts, the shape bias is ineffectual; (c) the shape bias can be induced before children have acquired many words by intensive associative training, which will in turn significantly accelerate the children's common noun acquisition compared to those who have not received the training; (d) children learning different languages show biases specific to the characters of their native languages.

The idea of the attentional learning assumption is in line with the "mass action effect" simulated by the connectionist models (MacWhinney & Chang, 1995; MacWhinney & Leinbach, 1991; Plunkett & Marchman, 1993; Plunkett & Marchman, 1996). The models are constructed based on the function of human neural networks. In such models, the similar associative mechanism is responsible for learning. For example, in a simulation of verb morphology acquisition (Plunkett & Marchman, 1993; 1996), in the early stages, the system appeared to learn each mapping from present to past tense by rote, with no generalization to novel lexical forms and no overgeneralization errors. As instances of present-past tense mapping accumulated, dramatic changes occurred: the rate of learning accelerated markedly, overgeneralization errors started to appear, and the system started to provide a default mapping to novel items. The network behaved as if it had switched from one mode of learning (rote-learning) to another (rule-learning). In sum, rule like behaviors do not arise in the simulated network until the system has acquired enough instances to support those generalizations. When the requisite number of items has been acquired, remarkable changes can take place (see also Cohen, Chaput, & Cashon, 2002).

To summarize briefly, the attentional learning account claims that children start to build their lexicon one word at a time without specific guiding rules. By associative learning, instances representing regularities accumulate quantitatively. At certain time point, qualitative change will occur - constraints or rules will be learned. This will in turn powerfully facilitate future language learning.

Another group of researchers, represented by Waxman and her colleagues, argued forcefully for a very different view. They assert that infants have some expectations linking words and concepts, however general and rudimentary, already at the very onset of word learning (Waxman & Lidz, 2006). In particular, they stated that from the very beginning, words serve as invitations to form object categories. The word learning constraint may emerge much earlier in life (Waxman, 2003; Waxman, 2004). The early tendency of associating nouns and categories has been called the *noun-category bias* or *noun-category linkage* (D'Entremont & Dunham, 1992; Waxman & Hall, 1993). As mentioned in 2.2, infants as young as 9-month-old were shown to benefit from words to access some object categories (Balaban & Waxman, 1997; Fulkerson & Haaf, 2003). As such young infants have extremely limited experiences with language and objects, it is unlikely that they would have *learned* the linkage between words and categories. Therefore, it is possible that the noun-category bias is already in place much earlier in life.

However, as discussed in 2.2, most studies with young infants have used real objects and sometimes real words as stimuli (Balaban & Waxman, 1997; Fulkerson & Haaf, 2003; Waxman & Markow, 1995). The objects such as animals, vehicles and food used in these studies might already be familiar categories for the young infants. The assumption of an early occurrence of the taxonomic constraint is not warranted by these studies. Instead of true classification, the findings could also be interpreted as the recognition of familiar categories or the comprehension of real words. In fact, previous studies seemed to suggest that the ability of using novel labels to form novel object categories is emerging during the second year of life, and it is at least still fragile by 14 months of age (Booth & Waxman, 2002). Also, the ability might be closely related to infants' language learning experiences (Nazzi & Gopnik, 2001)[3].

To date, existent studies could not yet answer: (a) whether preverbal infants could benefit from novel words alone to form *novel* object categories; (b) whether infants younger than 18 months of age are able to extend a novel word taxonomically if only provided with linguistic cues (i.e., novel words). Therefore, it is still an open question how and when the taxonomic constraint emerges. Even less is known whether the emergence of the constraint is related to infants' language learning experiences.

Independent of the categorization studies, some experiments investigating early word learning have demonstrated that infants around 14 months of age just begin to fast map a novel word to a single novel object (not yet the object category), and this only in favorable experimental situations (Hollich et al., 2000; Schafer & Plunkett, 1998; Werker, Cohen, Lloyd, Casasola, & Stager, 1998; Woodward, Markman, & Fitzsimmons, 1994).

For example, Werker and colleagues (1998) tested 8- to 14-month-old infants on their ability to form a word-object linkage in a Switch design. They used a toy dog, a toy truck and pseudowords as stimuli. Infants were habituated to two word-object pairings, and then tested

[3] The correlation between the ability of using novel labels to categorize novel objects and the vocabulary size has been found in children at 20 months of age (Nazzi & Gopnik, 2001). It is yet unknown whether this also holds true for younger infants.

with one trial that maintained a familiar word object pairing and one that involved a familiar word and an object in a new combination, which violated the original pairing. In their study, only 14-month-old infants formed word-object associations and only when the objects were moving, that is, they looked longer to the violation pair than to the familiar pair after habituation. The researchers concluded that the ability to rapidly learn arbitrary associations between words and objects appeared to develop at about 14 months of age. Similar evidence of fast mapping of word-object in children between 12 and 14 months of age comes from Hollich et al. (2000), Schafer and Plunkett (1998) and Woodward et al. (1994). In these studies, infants were often provided with redundant information (e.g., social cues) besides language input in order to help them learning the one word - one object association. Obviously, the ability to connect a novel word to a single object is different from appreciating the linkage between words and categories, yet it may serve as an initial and important step in building associations between words and object categories.

In brief, studies with young infants have implied an early emergence of the taxonomic constraint that has been well demonstrated in older children. However, due to the inconsistency of available studies, whether the taxonomic constraint is functional already before the language learning starts or the constraint is learned through associational experience and only functions at a much later time is an on-going debate. Even less is known about whether the emergence of the taxonomic constraint is related to infants' language learning progressions.

2.5 Summary

The taxonomic constraint assumption has been proposed as one explanation for infants' rapid learning of novel nouns starting toward the end of the second year of life. The constraint is supposed to contribute to novel noun learning on the one hand, and facilitate object categorization on the other.

Many studies have provided evidence that the taxonomic constraint appears by 18 months of age. However, it is yet unclear whether younger children also benefit from the constraint to learn new words and new concepts as older children do. Some researchers claim that the word learning constraint is induced from word learning experience and emerges when children have accumulated a certain amount of productive words (e.g., Smith, 2000). Others believe that the constraint functions much earlier by showing that language influences categorization already by nine months of age (Waxman & Lidz, 2006, for a review).

It is worth to notify that available findings in infants are different from those in older children. From the perspective of word learning, unlike older children, infants younger than 18 months of age have not yet been proved to honor the taxonomic bias in the top-down word learning task (but see Waxman & Hall, 1993, discussed in 2.1). Although infants are able to learn a new label for a single object in certain conditions (Hollich et al., 2000; Werker, Cohen, Lloyd, Casasola, & Stager, 1998), to the best of my knowledge, no study has demonstrated that the young infants could extend newly learned words categorically. From the perspective of concept learning, while preschoolers benefit from novel words to form *novel* object categories (Markman & Hutchingson, 1984; Weinert, 2003), infants at 16 months of age still have difficulties to do so (Nazzi & Gopnik, 2001). Younger infants only found to benefit from novel words to classify novel objects if additional cues (e.g., the function of the objects) were provided in the categorization tasks (Booth & Waxman, 2002). Also, most categorization studies with infants have used real object categories as stimuli that infants might have known before (see 2.2).

In brief, it is unclear how and when the taxonomic constraint becomes functional. Further studies are needed to clarify: (a) whether at the very early stage of language learning infants take advantage of the constraint to acquire novel words on the one hand and to form novel object categories on the other; (b) whether the emergence of the constraint is related to infants' language development.

3. Main research questions, research plan and hypotheses

3.1 Main research questions

From 9 months to 18 months of age, infants' language and cognitive abilities experience substantial changes. At about 9 months of age, infants just begin to understand language and production is yet to start. By 18 months of age, some infants can already utter hundreds of words. If a constraint contributing to early word learning exists, it is likely to emerge during this time. However, little is known about the taxonomic constraint and its relationship with language development between 9 and 18 months of age. To the best of my knowledge, no research has systematically explored how this word learning constraint emerges and how it evolves during this period when considerable changes in language and other cognitive abilities occur. Due to the inconsistency of research, it is not yet clear whether the taxonomic constraint is learned through language acquisition itself and thus appears late, or whether it functions already before language learning even starts. Even less is known about how the constraint evolves along the course of language development.

Previous researches seem to imply that the development of the constraint may correlate with infants' language learning experience. First, infants were found to succeed in the match-to-sample tasks (i.e., to extend a novel word to categorical members in a top-down manner) around the time when they begin to acquire words rapidly (Markman & Hutchinson, 1984; Markman, 1989). Second, in bottom-up object examination tasks investigating naming effect on object categorization, 12-month-old infants with more advanced language abilities were found to be more likely to honor the noun-category linkage (Waxman & Markow, 1995). However, no study has systematically examined whether language abilities are indeed closely related to the emergence of the taxonomic constraint.

The current studies intended to use consistent method to systematically investigate following issues within and across different age groups. It was explored how the taxonomic constraint emerges and whether this is associated with infants' language learning progressions.

The two main questions addressed were:

1. At which stage of early language development does the taxonomic constraint become functional, in a sense of facilitating both novel category formation and novel noun learning?

2. What is essential to the evolvement of the taxonomic constraint? Is the constraint more closely related to infants' age or to their language development?

3.2 Major research plan and hypotheses

Studies were planned to sample infants between 9 months and 18 months of age, during which infants demonstrate considerable changes in language and cognitive abilities. To the best of my knowledge, no study has systematically examined the taxonomic constraint during this period.

Four age groups were sampled: the 9-month-olds (generally regarded as the onset age of word comprehension), the 12-month-olds (onset of word production), the 15-month-olds (transition between first word production and efficient word learning), and the 18- month-olds (onset of efficient word learning). The taxonomic constraint were investigated within and across the different age groups in order to discover during which phase the constraint (or perhaps its precursor) emerges and how this changes and interacts with age and language development. The actual language abilities of each individual infant were measured by a standardized assessment ELFRA-1 (Grimm & Doil, 2000). The preferential looking paradigm was applied across all studies and age groups.

As mentioned earlier, infants younger than 15 months of age are usually considered as having restricted knowledge about objects and concepts. The bottom-up task is often used for the young infants to investigate their categorization and word learning. In this kind of tasks, infants are first exposed to different exemplars of a category, with or without linguistic cues, and subsequently tested on their abilities of categorization or word learning. In so doing, infants are provided chances to get acquainted with a given object category and/or a word. As a comparison, children older than 15 months of age are assumed to have more experiences with different kinds of objects and more advanced conceptual knowledge. Accordingly, the top-down task is often conducted with infants above this age to investigate their language learning or categorization. In this kind of tasks, infants' knowledge acquired before they come to the laboratory will be confronted, without the lengthened learning phase during experiments. Following previous studies, the current research also applied bottom-up tasks with the younger infants (i.e., 9- and 12-month olds), and top-down tasks with older ones (i.e., 15- and 18-month-olds).

Two lines of studies were conducted in parallel to answer the questions proposed in 3.1, one focusing on infants at 12 and 9 months of age (Experiment A), the other on infants at 18 and 15 months of age (Experiment B).

Experiment A:

As mentioned before, if infants honor the taxonomic constraint or a related prelude-like bias, they might be able to benefit from novel words to categorize (novel) objects. At the same time, infants might also be able to quickly learn a new name for different exemplars of the (novel) category. To test these assumptions, both categorization tasks and word learning tasks were conducted.

As discussed in Chapter 2, studies with young infants have mostly used real objects and sometimes real words in the categorization tasks. These were not sufficient to test the assumptions just mentioned above. Consequently, Experiment A (Chapter 5) first adapted the bottom-up categorization task (Balaban & Waxman, 1997) and explored whether young infants' were able to take advantage of *novel* words to categorize both real global-level objects as well as *novel* (i.e., artificial) objects. One reason for using real global-level object categories as stimuli was to bridge and compare the current studies with previous ones. More importantly, the current research focused on the relation between the development of the taxonomic constraint and word learning. Although young infants have been found to profit from words to access both basic- and global-level categories, the global-level categorization has been reported to correlate with infants' language abilities (Waxman & Markow, 1995). Accordingly, global-level object categories were used in Experiment A as well.

At the same time, a word-extension task was introduced in Experiment A. The task has adapted and combined the procedures of the bottom-up categorization task (Balaban & Waxman, 1997) and previous word learning tasks in young infants (e.g., Hollich et al., 2000). It explored whether infants could quickly learn a novel name for an (novel) object category and could extend the novel word to other new in-category members. The word-extension task was designed in parallel with the categorization task in order to enable a comparison between the two tasks. The exact designs and procedures of the task are described in Chapter 5.

As reviewed in Chapter 2, previous studies have demonstrated that: (a) infants by 12 months of age could benefit from novel words to access real object categories (Waxman & Markow, 1995); (b) the ability of taking advantage of novel words to form novel object categories may emerge around 14-months of age (Booth & Waxman, 2002). It is yet not clear whether the ability is functional at the very beginning of word acquisition, although some researchers have proposed that infants honor the linkage between nouns and categories already at the onset of language learning (Waxman & Lidz, 2006).

Consequently, in Experiment A, 12-month-old infants were first sampled. The bottom-up categorization tasks were conducted:

Experiment A-1a: Real global-level object categorization tasks with pseudowords (real objects - novel words categorization);

Experiment A-2a: Artificial object categorization tasks with pseudowords (novel objects - novel words categorization);

as well as the bottom-up word-extension tasks:

Experiment A-1b: Real global-level object word-extension tasks with pseudowords (real objects - novel words extension);

Experiment A-2b: Artificial object word-extension tasks with pseudowords (novel objects - novel words extension).

Corresponding to the research questions proposed in 3.1, it was hypothesized that:

- **a.** By 12 months of age, infants are able to benefit from novel words to access real global-level object categories as well as to form novel object categories in bottom-up tasks. They are able to learn the novel words and to extend them to new categorical members.
- **b.** Infants' performance is more related to their language development status than to their age.

When Experiment A-1 and A-2 positively support these hypotheses, younger infants at 9 months of age would subsequently be sampled and the same tasks would be conducted again.

In short, in Experiment A, young infants were planned to be tested with the bottom-up categorization tasks and word-extension tasks with pseudowords. The stimuli consisted of both real global-level object categories and created artificial categories. Infants' performances on these tasks were examined with respect to their language abilities.

Experiment B:

To investigate the taxonomic constraint, studies with older children have used the top-down match-to-sample task. Only limited evidence has been provided that infants younger than 2 years of age honor the taxonomic constraint in top-down word learning contexts (Graham et al., 1998; Waxman & Hall, 1993). Even less was known whether the emergence of the constraint is related to infants' language development. Nonetheless, infants by 15-month-old were reported to be able to perform the top-down word learning tasks. Therefore, Experiment B (Chapter 6) was conducted with infants at 15 and 18 months of age with a modified match-to-sample task presented with the preferential looking paradigm. Infants were confronted with different global-level object categories. They were expected to extend different novel words categorically, as would be predicted by the taxonomic constraint assumption. In order to analyze the language ability effect, performances were compared across language groups within and between the two age groups.

Corresponding to the research questions proposed in 3.1, it was hypothesized that:

a. By 18 months of age, infants demonstrate the taxonomic constraint by extending novel words categorically in top-down word learning tasks.

b. The appreciation of the taxonomic constraint is more related to infants' language development status than to their age.

4. Pilot study

The pilot study was a replication of the study done by Balaban and Waxman in 1997, in which real objects and real words were used as stimuli in a bottom-up task testing 9-month-old infants' categorization (see 2.2). The pilot study explicitly replicated experimental details (i.e., materials, design and procedure) of Balaban and Waxman's study. It was asked whether the findings in English-learning infants were replicable in German-learning infants, that is, whether 9-month-old German infants could also take advantage of real words to access real object categories.

Following Balaban and Waxman's study, it was hypothesized that infants in the Word, but not in the Tone condition, would show categorization. During the test phase, infants in the Word condition were expected to attend more to the out-of-category exemplars than to the new in-category ones. In other words, they should demonstrate a higher novelty preference score than those in the Tone condition.

4.1 Method

Participants

41 healthy 9-month-old infants (21 girls) from the region of Bamberg in southern Germany participated in the pilot study (mean age 279 days; *SD* = 19). Infants were recruited by mail and subsequent phone calls[4]. Two additional infants were excluded, due to fussiness (1) or experimenter error. German was the primary language spoken at home for all infants.

Materials

Replicating Balaban and Waxman (1997), the visual stimuli were simple drawings of pigs, rabbits, birds, and dinosaurs (see Figure 1 for examples). Animals in each category varied in form. Within the same category, each exemplar had a different solid body-color. Pig and rabbit were set as paired categories, so were bird and dinosaur. Body-color was matched for each pair of categories. Pigs and rabbits were outlined in black while birds and dinosaurs were outlined in darker colors than their body-colors. All figures presented in the test phase had orange body-color and were outlined in black. All animals were about 25cm in height and were presented against a white background.

[4] In all experiments in the current research, subjects were recruited from the region of Bamberg by the same way. This will not be restated in the following text.

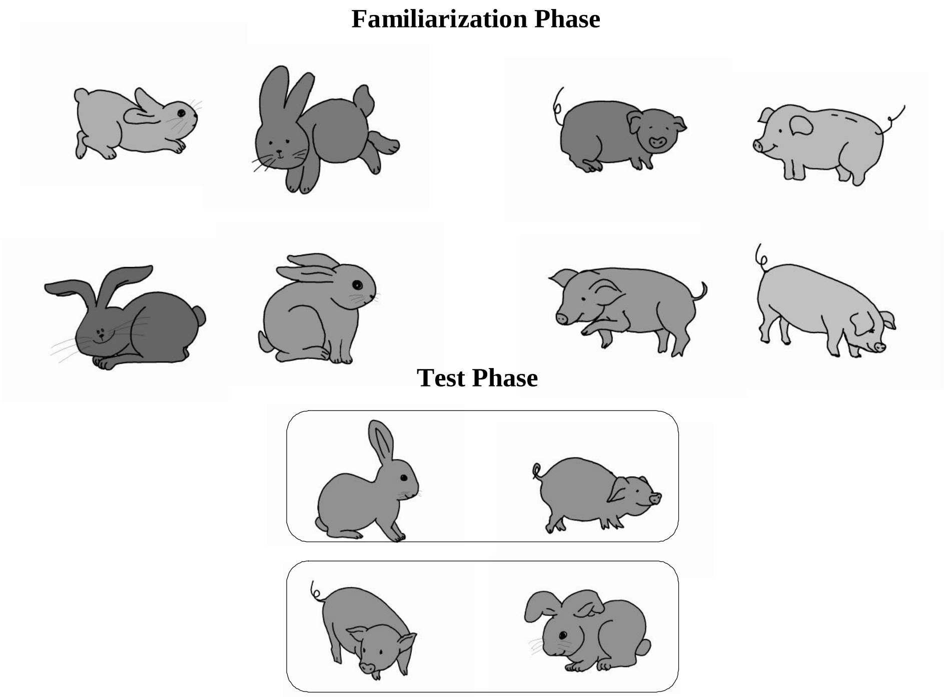

Figure 1. Examples of familiarization and test phase pictures used in the pilot study (pig - rabbit pair)

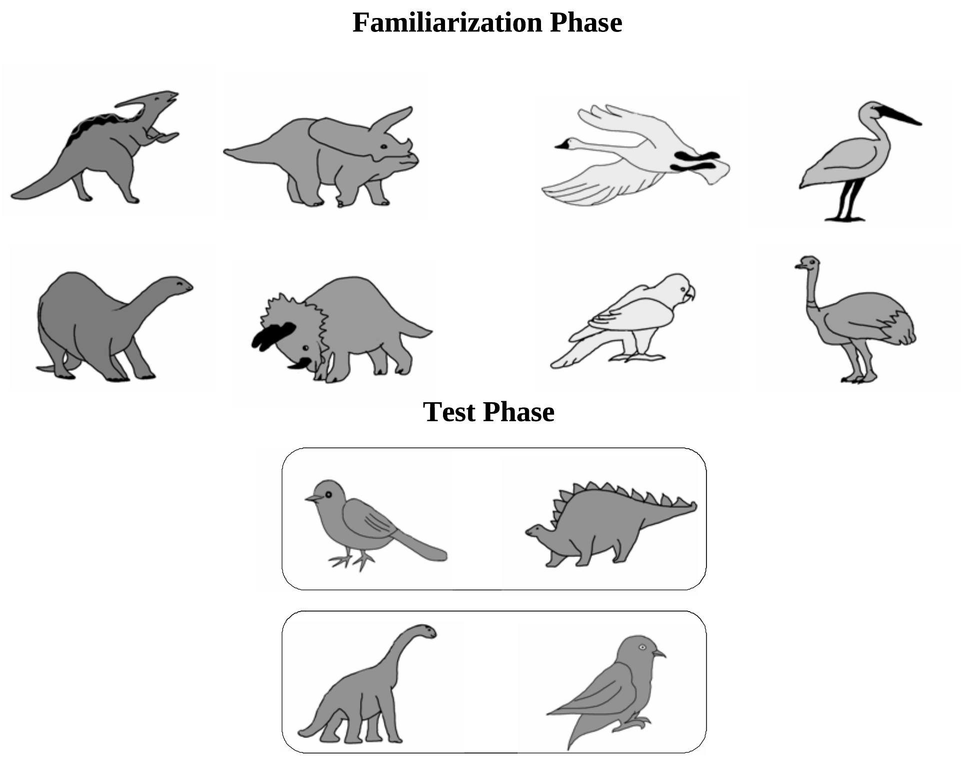

Figure 1 (continued). Examples of familiarization and test phase pictures used in the pilot study (dinosaur - bird pair)

Depending on the condition, the audio stimuli consisted of noun phrases or tone sequences. For the "Word condition", appropriate German noun phrases were produced by an adult female using infant-directed speech (e.g., "ein Schwein", which means "a pig"). The four noun phrases were digitized by computer. For the "Tone condition", four sine wave tone sequences were created also by the computer, each matching to the corresponding noun phrase in duration of each syllable. For the two-syllable German noun phrase "ein Schwein", a 500-300 Hz tone sequence was created. For the three-syllable noun phrases "ein Hase" (a rabbit), "ein Dino" (a dinosaur), and "ein Vogel" (a bird), the tone sequences of 500-400-300 Hz, 500-300-500 Hz, and 400-500-500 Hz were created respectively. The words and the tones were also matched in loudness and were 60dB loud at the position of the infant's head[5].

All stimuli were presented by PowerPoint.

In the observation room a cabinet was concealed with light-gray-colored curtains. Inside the cabinet three 19-inch flat monitors were visible to the infant. Two loudspeakers were hidden below the left and right monitors and a digital video camera was fixed above the middle monitor. All apparatus were connected and controlled by computers in an adjacent room.

Design

Replicating Balaban and Waxman (1997), the categorization task consisted of a familiarization phase and a test phase.

During the familiarization phase, infants viewed nine successive trials on the central monitor. Each slide presented a different exemplar from a single category (e.g., a pig). Three different presentation orders of the nine slides were randomly assigned to the subjects. Six of the nine slides were presented with an audio stimulus. The remaining three trials were presented in silence. The silent slides were trials 2, 4, 7; or 2, 5, 7; or 3, 5, 8.

Infants were randomly assigned to be familiarized with one of the four categories, as well as randomly assigned to either the Word or the Tone condition. In the Word condition, the six auditory trials were presented along with the appropriate noun phrase (e.g., "ein schwein"). In the Tone condition, the six trials were presented along with the corresponding sine wave tone sequence described above.

[5] In the pre-test, some infants appeared to be startled when hearing an auditory stimulus louder than 60dB. Therefore, the volume of 60dB was selected for the experiments in this work

During the test phase, infants viewed two silent trials. On each trial, a new member of the familiar category (e.g., another pig) and a member from a novel category (e.g., a rabbit) were presented on the left and the right monitor. Infants familiarized with pigs or rabbits saw the pig - rabbit test pictures and those familiarized with birds or dinosaurs viewed the bird - dinosaur pairs. Different exemplars were presented on each test trial. The members from the novel category were presented on the right monitor on one test trial and on the left monitor on the other test trial. Order of the left-right presentation was counterbalanced across subjects.

Procedure

During the experiment, infants sat on their parent's lap 1.20m away from the central monitor. Parents were asked to look only at their child but not to the monitors and not to draw the infant's attention in any way.

At the onset of the experiment, an animated penguin appeared on the central monitor against a blue background, accompanied with a pleasant bell ring for 3s to attract infant's attention. This was immediately followed by the familiarization phase. During the familiarization phase, each slide was presented for 10s. The interval between two trials was either 3 or 4s, randomly. On the six auditory trials, the onset of the sound was synchronized with the onset of the picture.

The test phase started 3s after the last trial of the familiarization phase. Infants viewed two silent trials. Each of them was presented for 15s. The intertrial interval was 3s.

An experimenter stayed in a room next to the observation room during the whole experiment. After starting the PowerPoint presentation, she controlled the camera to track and record the eye movement of the infant for later coding.

Data Analysis

Infant's visual fixations were all coded offline, using a video analysis software *Interact*. With Interact, the eye movements of the subject was recorded every 40ms, i.e., 25 snapshots in a single second. Coders were only required to distinguish at which monitor (i.e., left, middle, right, or none) the subject was looking. As three-monitor system was used for stimuli presentation, the directions of the eye movements were easily and clearly to judge. Two observers coded the video separately. One of them was completely blind of the design and purpose of the experiment. Twenty-five percent of all subjects were coded by both observers and the interrater reliability was .98 (Cohen's Kappa coefficient).

In all the experiments included in the current research, coding reliabilities were always strictly controlled before any data would be submitted to statistical analyses. Coders were university students who were unaware of the design and purpose of the experiment[6]. They were all well trained on coding and were frequently cross-controlled by coworkers. For each single experiment, at least 15 percent of the subjects were randomly selected for double-coding, ranging from 15 to 50 percent, with 30 percent on average. Coders were assigned based solely on availability. If interrater agreement was ever lower than .95, a third coder was asked to recode the video excerpts causing big discrepancies and the possible coder errors were always corrected based on self- or cross-coder recheck. In this way, no coded data would be accepted for data analysis if the interrater reliability was lower than .95. In practice, the agreements were almost always higher, staying at about .97. Consequently, the coder reliability will not be reported separately in the following experiments.

Preliminary analysis revealed no significant effect or interaction with gender or the presenting order of the nine familiarization slides. Therefore gender and slide-order were not included as variables in subsequent analysis.

4.2 Results

<u>Familiarization phase</u>

The looking time for the auditory and the silent trials in the familiarization phase were first examined. As shown in Table 1, infants watched significantly longer during the auditory trials than during the silent trials. An analysis of variance with the difference of the average looking time between auditory and silent trials as dependent variable, with condition (i.e., Word or Tone) and familiarization category (i.e., pig, rabbit, birds, or dinosaurs) as between-subjects factors revealed no significant effect or interaction. The result replicated the findings of other researchers that sound per se attracts infants' attention (e.g., Balaban & Waxman, 1997; Baldwin & Markman, 1989).

The familiarization phase was further grouped into three blocks, each including three trials. The first block consisted of trials 1 to 3. The last block consisted of trials 7 to 9. An analysis of variance was conducted with average looking time of each block as dependent variable, with block as within-subjects factor, and with familiarization category and condition as between-subjects factors. The main effect of block was significant, $F(2, 66) = 5.22$, $p < .01$; the main effect of condition approached significance, $F(1, 33) = 3.47$, $p < .07$; the interaction

[6] Except the author herself who coded most of the videos. These were randomly controlled by other coders.

between block and condition also approached significance, $F(2, 66) = 2.64$, $p < .08$. No more significant effect or interaction was found.

Table 1

Average looking times for auditory and silent trials during familiarization in the pilot study

		Looking time (s)		
		Auditory Trials	Silent Trials	$t_{(40)}$
Pilot Study	*M*	7.44	6.57	3.69***
(N = 41)	*SD*	1.83	1.64	

*** $p < .001$

More specifically, only infants in the Word condition (N = 20) were familiarized by significantly reducing their looking time across blocks, $F(2, 32) = 6.34$, $p < .005$, with average looking times of 7.63s ($SD = 1.73$), 6.67s ($SD = 2.24$), and 6.03s ($SD = 2.49$) from the first to the third blocks, respectively. Test of within-subjects factor contrast of block displayed a significant linear decrement, $F(1, 16) = 12.93$, $p < .002$. On the contrary, infants in the Tone condition (N = 21) did not appear to be familiarized, $F(2, 34) = .266$, $p > .77$, with average looking times of 7.65s ($SD = 1.24$), 7.46s ($SD = 1.81$), and 7.40s ($SD = 1.77$) from the first to the third block, respectively (Figure 2). Although infants looked on average longer in the Tone ($M = 7.51$, $SD = 1.32$) than in the Word condition ($M = 6.78$, $SD = 1.85$) across the nine familiarization trials, only those in the word condition were familiarized.

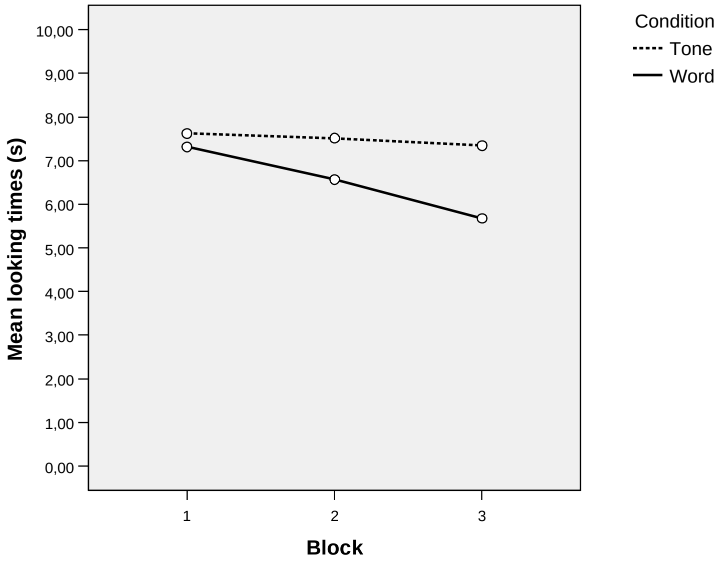

Figure 2. Pilot study looking times averaged over three trials of each block, during the familiarization phase for subjects in the Word and the Tone condition. Data were averaged across familiarization category (i.e., pig, rabbit, birds, and dinosaurs) and trial type (auditory or silent).

In sum, infants looked on average longer in the auditory than in the silent trials during the familiarization phase. They looked in general longer in the Tone condition than in the Word condition. This was due to the fact that, although started with similar lengths of watching during the first trials, only infants in the Word condition were familiarized - reducing their looking time linearly in later trials. Those in the Tone condition, on the contrary, looked about equally long across all trials without identifiable decrement.

Test Phase

A novelty preference score for each individual infant was calculated: the looking time of the infant to the stimuli from the novel category was divided by the total looking time to both test stimuli during the two test trials.
An analysis of variance with novelty preference score as dependent variable, and with condition and familiarization category as between-subjects factors was conducted. The only significant effect found was condition, $F(1,33) = 6.35$, $p < .02$, showing a clearly higher novelty preference in the Word than in the Tone condition. The mean novelty preference score in the Tone condition was .52 ($SD = .06$), which was not significantly different from chance level (.50), $t(20) = 1.21$, $p > .24$; in the Word condition, however, the mean novelty

preference score was .57 (*SD* = .09), which was significantly higher than chance level, $t(19) = 3.85$, $p < .001$, indicating a reliable novelty preference. No more significant effect or interaction was found.

Additional analysis of actual looking times revealed a compatible data pattern. First, the overall looking time during the test phase for both conditions was examined. The overall looking times did not differ significantly between conditions, $t(39) = 1.52$, $p > .14$. In the Tone condition, the mean overall looking time was 21.05s (*SD* = 5.80). In the Word condition it was 18.41(*SD* = 5.26).

Further analysis revealed that infants spent much shorter time to look at the familiar category in the Word condition, $t(19) = 4.01$, $p < .001$. They looked on average 10.52s (*SD* = 3.16) to the novel category, but only 7.87s (*SD* = 2.86) to the familiar category. On the contrary, infants in the Tone condition spent about equal time to watch both the familiar (*M* = 10.18, *SD* = 3.13) and the novel category (*M* = 10.87, *SD* = 3.18), $t(20) = 1.29$, $p > .21$.

In sum, as hypothesized, in the categorization task with real words and real object categories (i.e., pig, rabbit, dinosaur, and bird) as stimuli, 9-month-old infants displayed a significantly greater novelty preference in the Word than in the Tone condition.

4.3 Discussion

The pilot study successfully replicated the findings of Balaban and Waxman (1997) that 9-month-old infants benefited from real nouns to access real object categories, albeit a few differences.

Familiarization phase

During the familiarization phase, just like in other studies (Balaban & Waxman, 1997; Fulkerson & Haaf, 2003), it was replicated that both linguistic labels and non-linguistic tones improve infants attention. That is, in general, infants watched longer in the auditory than in the silent trials – their attention was improved both by the tones and the words.

Unlike B&W, it was found that infants' overall looking time across blocks was longer in the Tone than in the Word condition, as a result of different familiarization progressions and outcomes. While B&W did not find any familiarization effect in their study, infants in the pilot study were clearly familiarized in the Word condition, although those in the Tone condition did not[7]. It is worth to highlight that during the first three trials, infants' looked about equally long (*M* =7.63, *SD* = 1.73 in the Word condition; and *M* = 7.65, *SD* = 1.24 in the Tone condition; $t(39) = .05$, $p > .96$). After that, however, only infants in the Word condition quickly reduced their looking time whereas those in the Tone condition did not. Accordingly, during the second block, the difference between conditions became greater but not yet significant ($t(39) = 1.24$, $p > .22$); and during the third block, infants in the Word condition watched significantly less (*M* = 6.03, *SD* = 2.49) than those in the Tone condition (*M* = 7.40, *SD* = 1.77), $t(39) = 2.04$, $p < .05$.

In sum, during the familiarization phase, although both tones and real words attracted infants' attention, only real words, but not the tones, promoted infants' familiarization. Nevertheless, as infants in the Tone condition looked generally longer, they had enough or even more time to learn the categorical resemblances of the presented objects.

<u>Test Phase</u>

During the test phase, the 9-month-old infants displayed an apparent novelty preference in the Word condition but performed at chance level in the Tone condition. The difference between conditions was as expected significant.

The analysis of actual looking time showed that the novelty preference in the Word condition was indeed caused by the longer looking time to the out-of-category exemplars (about 10.50s) than to the new in-category exemplars (less than 8s). As a comparison, infants in the Tone condition seemed to treat both categories as "new", as they looked about 10s at each one, which was about the same length as in the Word condition at the novel-category. This was not surprising, as the in-category exemplars during the test phase were indeed *new* pictures. Infants had not seen them during the familiarization phase. If a non-linguistic tone sequence did not facilitate categorization, infants might simply perceive all the exemplars, both in the familiarization and in the test phase, as many unrelated new objects. This was also reflected in their looking pattern during the familiarization phase in the Tone condition.

[7] In B&W's study (1997), the stimulus in the Tone condition was a single-frequency tone (i.e., 400Hz), whereas in the pilot study multi-frequency tone sequences were used. This variation might have made the tones more interesting to infants in the pilot study. This could be one reason why infants looked overall longer in the Tone condition. Nevertheless, the longer attention during familiarization in the Tone condition did not appear to contribute to infants' categorization.

Across three blocks, infants in the Tone condition spent similar lengths of time to watch the objects with no observable reduction. Their interest to the objects remained high.

In all the four experiments of Balaban and Waxman (1997), infants were never familiarized, neither in the Word nor in the Tone condition. Maybe also due to this reason, only one of their four experiments revealed a significant novelty preference in the Word condition, with tripled sample size as the other three. Nevertheless, all their four experiments showed that in the Word condition, infants' attention to the novel category was still significantly greater than in the Tone condition. They argued that, it is not always necessary or viable to show a significant novelty preference in such categorization tasks, but more importantly, to show the difference between words and non-words, with the former seeming to facilitate categorization.

4.4 Summary

The pilot study confirmed that real nouns, but not their matched tones, help 9-month-old German infants to access real object categories.

The categorization task adapted from Balaban & Waxman's study (1997) is easy to execute and has been proved to be well functioning with very young infants. Therefore, the basic model of the task in the pilot study was applied for later studies with young infants (Experiment A).

Specifically, the task consisted of a familiarization phase with 9 trials, among which 6 were presented with an auditory stimulus (i.e., a noun phrase or its matched tone sequence), and the other 3 were shown in silence. Different exemplars from a single category were presented during this phase. After that, the test phase with 2 different trials was presented, each showing simultaneously a new exemplar of the familiarized category and an exemplar from a novel category. An experiment always involved a Tone condition and a Word condition. With this basic procedure, visual and auditory stimuli were varied across different experiments.

Acknowledging the good function of the apparatus in the lab and the viability of the experimental paradigm in the pilot study, the research plan proposed in Chapter 3 were consequently executed.

5. Experiment A

Experiment A first sampled 12-month-old infants. The bottom-up categorization and word-extension tasks were executed. The visual stimuli included either real global-level object categories or created artificial categories. It was asked:

a. Whether by the time of producing their first words, infants benefit from novel words to access real global-level object categories as well as to form completely novel categories.
b. Whether the Infants are able to learn the novel words and to extend them to new in-category members.
c. Whether the performance is related to infants' language abilities.

To answer these questions, the following experiments were planned:

Experiment A-1: with real global-level object categories

Experiment A-1a: real objects - pseudowords - <u>categorization</u>

Experiment A-1b: real objects - pseudowords - <u>word extension</u>

Experiment A-2: with artificial object categories

Experiment A-2a: novel objects - pseudowords - <u>categorization</u>

Experiment A-2b: novel objects - pseudowords - <u>word-extension</u>

It was hypothesized that 12-month-old infants are able to take advantage of novel words to access real global-level object categories and to form novel object categories and the novel words could be rapidly associated with the novel category and then be extended to new in-category members. Infants' performance should be closely related to their language development status.

If 12-month-old infants succeed in the tasks, younger, language less advanced 9-month-old infants would be sampled and given the same tasks again.

5.1 Experiment A-1: Real global-level object categorization and word-extension[8]

5.1.1 Method

The categorization task and the word-extension task were designed and conducted in parallel. Therefore, the two tasks are described and compared together.

Participants

55 healthy 12-month-old infants (27 girls) participated in Experiment A-1a (mean age 377 days; range 358 days to 397 days). Two additional infants were excluded due to fussiness or technical malfunction. German was the primary language spoken at home for all infants.
Another 56 12-month-old infants (29 girls) participated in Experiment A-1b (mean age 375 days; range 360 days to 395 days). Five additional infants were excluded due to fussiness (4) or parent interference (1). Fifty of the 56 infants were monolingual German. The other six were bilingual, for whom one of the languages spoken at home was German. These six infants were assigned to the Tone condition.

Materials

The visual stimuli were true-color pictures of four-leg animals and fruits (Figure 3[9]). All figures were about 25cm in height and were presented against a white background.
The auditory stimuli were again a word phrase and its matched tone sequence. For the Word condition, a German pseudoword phrase, “ein Jaloß” (means “a Jaloß”), was produced by an adult female using infant-directed speech. The phrase was digitized by computer and was 1.14s long. For the Tone condition, a 400-300-500 Hz sine wave tone sequence was created by computer, matching to the noun phrase in duration of each syllable. The phrase and the tone sequence were matched in loudness and were 60dB at the position of the infant’s head.

[8] Some data of this experiment have been presented by: Zhang, D. & Weinert, S. (2007, March). *The noun-category linkage and its relationship with early lexical development in 12-month-old German infants*. Poster presented at the biennial meeting of the Society for Research in Child Development: Boston, MA, USA.

[9] Figures were partly copied from CorelDRAW® Graphics Suite 11(2002), Disc 4, Objects.

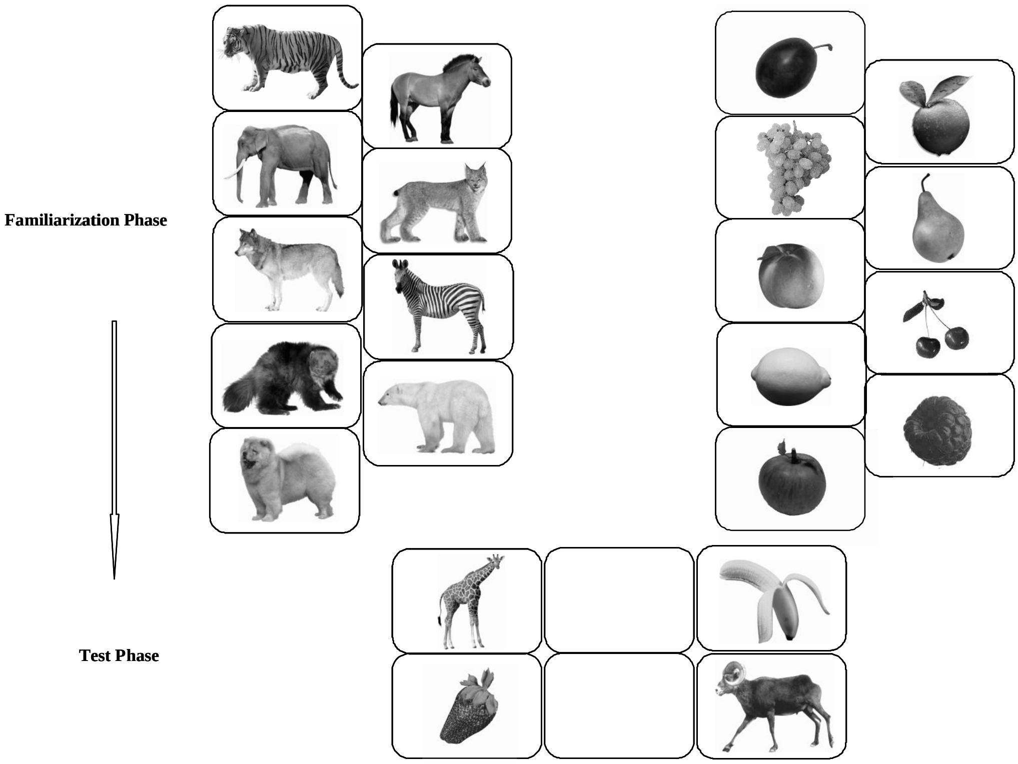

Figure 3. Visual stimuli presented in Experiment A-1

Design and Procedure

The design and procedure of the categorization task (Experiment A-1a) was the same as that in the pilot study. Only the visual and auditory stimuli were replaced with those described above.

Infants were randomly assigned to be familiarized either with animals (N = 28, of which 14 were in the Tone condition) or with fruits (N = 27, of which 14 were in the Tone condition).

In Experiment A-1b, infants were also randomly assigned to be familiarized either with animals (N = 28, half in the Tone condition) or with fruits (N = 28, half in the Tone condition).

The only difference between the categorization and the word-extension task (Experiment A-1b) was the auditory stimulus during the test phase. In Experiment A-1a, the test phase was presented in silence. In Experiment A-1b, however, at the onset of both test trials infants heard the same stimulus as in the familiarization phase, either the tone sequence or the pseudoword noun phrase. No more difference exists between the two tasks.

This only difference between the two tasks was crucial to the experiment design. As mentioned in the pilot study, if the novel word facilitates object categorization, in Experiment A-1a, infants should display a higher novelty preference score at test in the Word than in the Tone condition. On the contrary, in Experiment A-1b, if infants were able to extend the just-learned novel word, but not the tone, to new members of the familiarized category, they should look longer at the new in-category exemplars named by that word during the test phase. Accordingly, they were expected to display a higher familiarity preference in the Word than in the Tone condition.

Parents were asked to fill out a language development questionnaire ELFRA-1 (Grimm & Doil, 2000, a standardized language assessment developed for German infants. The assessment is similar to MCDI (Fenson et al., 1993)) after the experiment.

5.1.2 Results

Language Assessment

Both receptive and productive language data of the infants obtained with ELFRA-1 are listed in Table 2.

In ELFRA-1, the language scale includes: I. “Sprachproduktion” (language production), and II. “Sprachverständnis” (language comprehension).

Scale I is further divided into I(a). “produktiver Wortschatz” (productive vocabulary) and I(b). “Produktion von Lauten und Sprache” (production of sounds and language).

Scale II is further divided into II(a). “rezeptiver Wortschatz” (receptive vocabulary) and II(b). “Reaktion auf Sprache” (reaction to language).

The values reported in Table 2 are the raw data of scale I and II, under the column “production” and “reception”, respectively.

Table 2

Experiment A-1 (categorization and word-extension task with global-level object categories)

Infants’ productive and receptive language measured by ELFRA-1

	Experiment A-1a (N = 55)		Experiment A-1b (N = 56)		**Total** (N = 111)	
	Reception	Production	Reception	Production	Reception	Production
M	55.89	10.76	52.73	11.80	54.30	11.28
SD	35.60	6.16	30.40	7.40	32.97	6.80
Min.	7	2	6	1	6	1
Max.	138	29	151	41	151	41
50 Percentile	55	10	52	10.50	52	10

<u>Familiarization phase</u>

Auditory and silent trials

In both Experiment A-1a and A-1b, Infants watched significantly longer during the auditory trials than during the silent trials.

In Experiment A-1a, the average looking time during the auditory trials was 8.21s (*SD* = 1.15) and during the silent trials was 7.25s (*SD* = 1.61); $t(54) = 5.17$, $p < .0005$. No significant effect or interaction was found across conditions or types of the familiarization figure (i.e., fruit or animal).

In Experiment A-1b, the average looking times during the auditory trials was 8.15s (*SD* = 1.35) and during the silent trials was 7.09s (*SD* = 1.78); $t(55) = 5.45$, $p < .0005$. No significant effect or interaction was found across conditions or types of the familiarization figure.

Looking time across three blocks

In Experiment A-1a, children did not significantly reduce their looking time linearly from the first to the third block in either condition (Table 3). An analysis of variances with average looking time as dependent variable, with block as within-subjects factor, and with type of familiarization figure and condition as between-subjects factor revealed no significant main effect or interaction. Infants in both conditions were not familiarized regardless whether they were presented with animals or fruits.

In Experiment A-1b, infants were also not familiarized in either condition, regardless of familiarization categories (Table 4). As the familiarization phase were identical in Experiment A-1a and A-1b, it was not surprising to find the same data patterns in this phase.

In brief, no familiarization effect was found in Experiment A-1, neither in the Tone nor in the Word condition, regardless of familiarization categories (animal or fruit).

Table 3

<u>Experiment A-1a</u> (categorization task with global-level object categories)

Average looking times (*SD*) at animals and fruits in the Tone and in the Word condition over familiarization blocks

Familiarization Figures	Condition	Familiarization Block 1	2	3
Animals	Tone	8.20	8.28	8.18
	N = 14	*(1.26)*	*(1.09)*	*(1.39)*
	Word	7.94	7.10	7.48
	N = 14	*(1.33)*	*(1.59)*	*(2.03)*
	Subtotal	8.07	7.69	7.83
		(1.28)	*(1.47)*	*(1.74)*
Fruits	Tone	7.67	8.01	7.80
	N = 14	*(1.50)*	*(1.82)*	*(1.58)*
	Word	7.73	8.27	7.99
	N = 13	*(1.18)*	*(1.16)*	*(1.27)*
	Subtotal	7.70	8.14	7.89
		(1.33)	*(1.50)*	*(1.42)*
	Total	7.89	7.91	7.86
	N = 55	*(1.31)*	*(1.49)*	*(1.58)*

Table 4

Experiment A-1b (word-extension task with global-level object categories)

Average looking times (*SD*) at animals and fruits in the Tone and in the Word condition over familiarization blocks

		Familiarization Block		
Familiarization Figures	Condition	1	2	3
Animals	Tone	8.00	8.15	8.37
	N = 14	*(1.74)*	*(2.58)*	*(2.58)*
	Word	8.46	8.15	7.36
	N = 14	*(1.09)*	*(.86)*	*(1.42)*
	Subtotal	8.23	8.15	7.87
		(1.44)	*(1.89)*	*(2.11)*
Fruits	Tone	7.59	7.48	7.86
	N = 14	*(1.48)*	*(1.22)*	*(1.21)*
	Word	7.40	7.17	7.53
	N = 14	*(1.50)*	*(1.49)*	*(1.74)*
	Subtotal	7.49	7.33	7.70
		(1.46)	*(1.35)*	*(1.48)*
	Total	7.86	7.74	7.78
	N = 56	*(1.49)*	*(1.68)*	*(1.81)*

Test Phase

An analysis of variance with novelty preference score (see 4.2) as dependent variable and with 4 between-subjects factors was run. The 4 independent variables were:

1. Condition (Word or Tone);
2. Task (categorization or word-extension);
3. Type of familiarization figure (animal or fruit); and
4. Productive language group (high or low).

   According to their productive language, infants were split into two subgroups. The cutting point was the 50th percentile of their productive language scores (i.e., 10 words, see Table 2).

   For Experiment A-1a, the high-language ability group consisted of 31 infants with a mean productive language score of 14.35 (*SD* = 5.81), ranging 10 to 29. The low-language ability group consisted of 24 infants with a mean score of 6.13 (*SD* = 2.27), ranging 2 to 9. The language scores were significantly different between two groups, $t(40.93) = 7.21$, $p < .0005$.

   For Experiment A-1b, the high-language ability group consisted of 31 infants with a mean productive language score of 16.10 (*SD* = 7.33), ranging 10 to 41. The low-language ability group consisted of 25 infants with a mean score of 6.44 (*SD* = 2.10), ranging 1 to 9. The language scores were significantly different between two groups, $t(35.97) = 6.99$, $p < .0005$.

   All together, there were 49 subjects in the low productive language group and 62 in the high group.

The analysis revealed a significant main effect of type of familiarization figure, $F(1,95) = 47.18$, $p < .0001$. Infants familiarized with animals displayed an overall mean novelty preference score of .45 (*SD* = .11), and those familiarized with fruits .61 (*SD* = .12).

The analysis also revealed a significant two-way interaction between task and productive language group, $F(1,95) = 6.00$, $p < .02$. A three-way interaction among condition, task, and productive language group approached significance, $F(1,95) = 3.01$, $p < .09$. No more effect or interaction was significant.

Note that although the main effect of type of familiarization figure was significant, it did *not* interact significantly with any other factors. It appears that the 12-month-old infants have a robust high preference for the figures in the animal category. In order to clarify this effect and to better explain the data already obtained, a separate post-hoc preference test was execute.

An independent group of fifteen 12-month-old infants were recruited for this purpose. Infants were directly shown the two test phase trials in Experiment A-1, yet only in silence. It turned out that when only watching the test phase pictures, infants spent 63 percent of overall looking time to look at the animal category, ranging from 48 to 84 percent, $SD = .10$. The natural (or baseline) preference for the animal category was confirmed.

Going back to the results shown before, it turns out that infants familiarized with fruits had on average a similar preference score (.61) to the baseline preference (.63). Those familiarized with animals, however, had on average a higher preference for the fruit (.45) than the baseline preference (1-.63 = .37) during the test phase, $t(55) = 5.06$, $p < .0005$. Actually, across conditions, tasks, and language groups, the mean novelty preference score was never lower than .37. Except one score being .37, all others ranged from .41 to .49. This finding will be discussed later in 5.1.3.

Although above mentioned analysis of variances revealed a significant two-way and a three-way interaction, it has to be admitted that the cell size for comparison was sometimes as small as 3 or 4, which was rather not meaningful for further explanation.

The small and unbalanced cell sizes were primarily caused by the variable "productive language group". While subjects could be randomly and evenly assigned to other factors (i.e., condition, task, type of familiarization figure), it was not practicable to do so in advance with respect to the language abilities. As a result, it happens that sometimes only 3 or 4 low- or high-language subjects appeared in one cell, while sometimes more than 10 in another.

Due to this reason, a data collapsing was needed so that the cell sizes would reach a statistically meaningful level (i.e., no less than 5). According to the above analysis, only "type of familiarization figure" did not interact with any other factors. Although the natural preference for the animal category was significant, this remained stable across experimental factors. In other words, it did not interfere significantly with the effects or interactions of other variables. The effects induced by other factors (i.e., condition, task, productive language group) were about equal for infants familiarized with animals as well as with fruits. Therefore, data along this variable dimension (i.e., type of familiarization figure) were converted and collapsed.

The novelty preference score (P) was converted to a new *novelty preference score compared to group mean* (P_m) for each subject in Experiment A-1. For infants familiarized with the fruit category, $P_m = P - .61$; and for those familiarized with the animal category, $P_m = P - .45$. For instance, if an infant who was familiarized with fruits in Experiment A-1 had a novelty preference score (P) of .61, the converted score (P_m) would be 0, indicating theoretically no preference compared to the group mean. If an infant who was familiarized with animals also displayed a P value of .61, however, the converted score P_m would be .16, which would indicate a preference, theoretically, for the novel category, i.e., the fruit.

By this conversion, the effect of the factor *type of familiarization figure* was teased out. As a result, the cell sizes of ANOVA for other variables (i.e., condition, task, and productive language group) would increase. This factor reduction was only run since the reduced factor (type of familiarization figure) did not interact with any other variables in any way.

Subsequently, a new ANOVA was run, with P_m as dependent variable, with condition, task, and productive language as independent factors. It revealed a significant interaction between task and productive language group, $F(103) = 6.28$, $p < .01$. The three-way interaction of the factors also approached significance, $F(103) = 3.33$, $p < .07$. Since data have been collapsed across the type of familiarization figure, the current cell sizes of the analysis range 11 to 17 (Table 5).

As shown in Figure 4, in Experiment A-1a, the categorization task, the interaction between condition and productive language group was significant, $F(51) = 4.16$, $p < .05$. Infants in the high-language ability group displayed an expected much higher novelty preference (indicated by P_m) in the Word ($M = .08$, $SD = .09$) than in the Tone condition ($M = .00$, $SD = .12$), $t(29) = 2.04$, $p < .05$.

Those in the low-language group, as a contrast, displayed a much lower P_m in the Word condition, $M = -.06$, $SD = .08$. This score was significantly lower than 0, $t(11) = -2.53$, $p < .03$, indicating a familiarity preference. In the Tone condition, the mean P_m was -.03, $SD = .09$. The difference between conditions did not reach significance for the low-language group.

In Experiment A-1b, the word-extension task, infants in both language groups did not show a P_m significantly different from zero, in neither the Tone nor the Word condition. However, comparing Experiment A-1a and A-1b, while all infants in the Tone condition performed at about chance level (i.e., $P_m = 0$) across tasks and language groups (Table 5), in the Word condition, the two language groups displayed opposite data patterns. Specifically, infants in the high-language ability group showed an expected much higher P_m in the categorization than in the word-extension task, $t(30) = 2.83$, $p < .01$. Those in the low-language group, however, showed a significantly lower P_m in the categorization than in the word-extension task, $t(21) = 2.32$, $p < .03$.

These results account for the significant interaction between task and productive language group, and the three-way interaction among condition, task, and productive language group mentioned above.

Table 5

Average P_m score (*SD*) in Experiment A-1 across animal and fruit categories compared between tasks and conditions for high- and low-language groups. Scores significantly different from 0 are flagged.

		Condition			
		Tone		Word	
Task	Language group	*M*	N	*M*	N
Categorization	Low	-.03 (*.09*)	12	**-.06*** (*.08*)	12
	High	.00 (*.12*)	16	**.08**** (*.09*)	15
Word-extension	Low	-.01 (*.16*)	14	.02 (*.09*)	11
	High	-.02 (*.12*)	14	-.03 (*.12*)	17

* $p < .05$

** $p < .01$

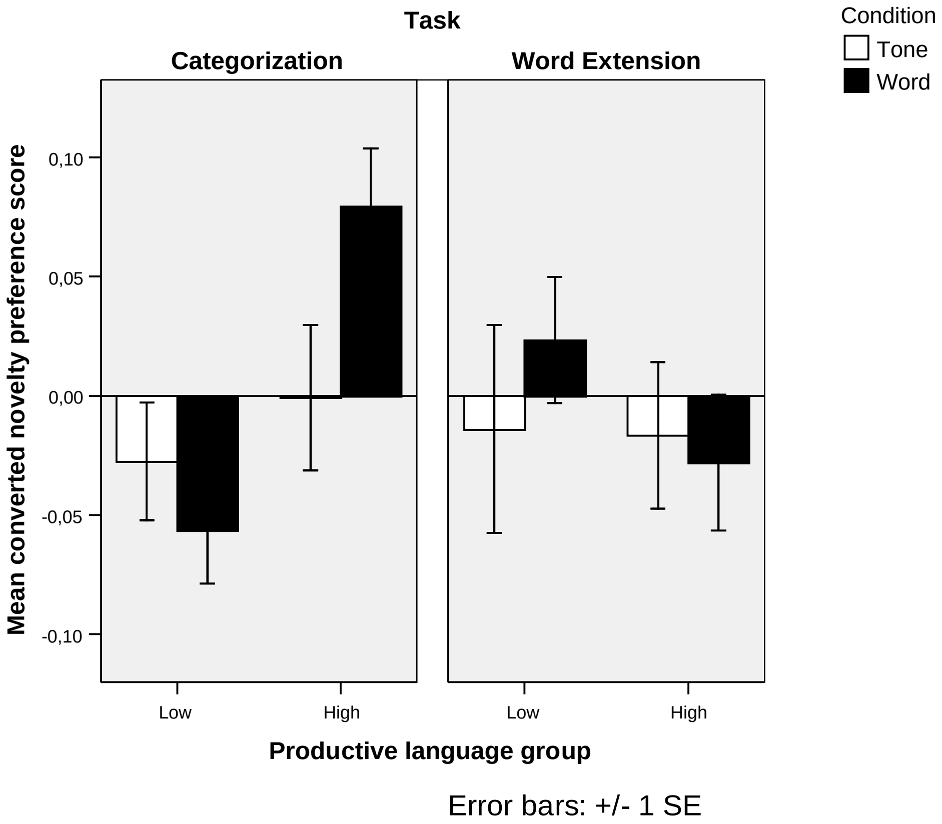

Figure 4. Experiment A-1 converted novelty preference score (P_m) compared between tasks, conditions, and productive language groups.

5.1.3 Discussion

Experiment A-1 used both the categorization and the word-extension task to examine whether 12-month-old infants profit from a novel noun to access global-level object categories; and, whether they could at the same time learn the novel word and extend it to new exemplars of the same category.

It was hypothesized that infants in the categorization task (Experiment A-1a) would show a higher <u>novelty</u> preference in the Word than in the Tone condition while those in the word-extension task (Experiment A-1b) should display a higher <u>familiarity</u> preference in the Word than in the Tone condition. The high- and low-language ability groups were expected to be different in their performances.

With the initial analysis of variances, some cell sizes turned out to be too small. Subsequently, the variable “type of familiarization figure” was teased out by data conversion and collapsing. A new analysis of variances was then run. The overall result was consistent with the hypotheses. First, similar to the previous study using object examination tasks (Waxman & Markow, 1995), infants with higher language ability displayed expected object categorization in the Word but not in the Tone condition. Second, the infants also demonstrated an expected much higher novelty preference in the categorization than in the word-extension task in the Word condition. Third, infants with lower language ability, as a contrast, displayed a reversed data pattern.

<u>Familiarization phase</u>

Unlike the pilot study, during the familiarization phase, infants were not familiarized in either condition, in spite of the familiarization category. Since the results during the test phase appeared differently between the two language groups, the data of the familiarization phase was submitted to an analysis of variances again. Similarly, the dependent variable was the mean looking time of block. The within-subjects factor was block, and the between-subjects factors were productive language group, condition, and type of familiarization figure. As the familiarization phases were identical in Experiment A-1a and A-1b, task was not included as a factor in this analysis. The analysis revealed no significant main effect or any interaction. Therefore, no familiarization effect was found in either language group.

The absence of a familiarization effect might be caused by the materials used for Experiment A-1. As shown in Figure 3, the exemplars were perceptually very different from each other in both the animal and the fruit categories. Infants might find all the pictures interesting and attractive and maintained a high attention all along, although some of them might have noticed the categorical consistence of the objects. At the same time, infants heard a pseudoword instead of a real word in the pilot study. The novel word might have maintained infants' attention. Consequently, infants in the Word condition also did not reduced their attention linearly across blocks.

However, as reported by Balaban and Waxman (1997), even infants do not show a familiarization effect, they still have the potential to categorize the objects they see. This was manifested in Experiment A-1a with language more advanced infants during the test phase.

Test Phase

In Experiment A-1, an *a priori* effect appeared. Infants preferred the animal to the fruit category, which was confirmed by a separate post-hoc baseline preference test. For infants familiarized with the fruit category, their novelty preference score (.61) was similar to the baseline score (.63). For those familiarized with the animal category, their overall novelty preference score (.45) was significantly higher than the baseline score (.37).

It was not known why infants in this group *generally* displayed a much higher novelty preference score than the baseline level (.37). Presumably, the exemplars of the animal category, however interesting and attractive, were not so colorful as the exemplars in the fruit category presented in the test phase. After viewing many relative dull colored animals during the familiarization phase, the bright intensive colored fruits might appear to be a strong contrast for the infants, hence attracted more of infants' attention compared to the baseline level. Nevertheless, the overall inclination to the animal category was still salient, as the average preference score was .45 for the novel category (fruit), which was significantly lower than chance level (.50), $t(55) = 3.60$, $p < .001$.

In the initial analysis of variances with all the 4 factors, interactions have been revealed. However, due to unbalanced subject distribution in cells and some extremely small cell sizes, the result was not meaningful for further explanation. Given that the main effect of "type of familiarization figure" did not interact with any other variables in the analysis, it was accordingly nullified by data conversion based on the corresponding mean score of each subgroup (i.e., animal or fruit). The converted preference score P_m was free of the influence of "type of familiarization figure". As this factor was eliminated, the cell sizes for a renewed analysis of variances increased.

Similar to the previous studies with object-examination procedure (Fulkerson & Haaf, 2003; Waxman & Markow, 1995), in the categorization task, infants with more advanced language abilities displayed a predicted higher novelty preference during the test phase in the Word than in the Tone condition. That is, the novel word, but not the tone, has facilitated infants to access the global-level object categories. However, those with lower language abilities did not do so. In fact, they presented a significant familiarity preference in the Word condition.

This result implied that infants with limited productive language ability might not have an effective bias to link nouns and object categories together. As having been reported by other researchers, in categorization tasks with preferential looking paradigm, when infants have not yet categorized the objects, they tend to first show a familiarity preference at test, as if they are in the initial stage of processing the stimuli and need more time to check and study the familiarization category (Hunter & Ames, 1988; Slater, 1995). This seemed also to be the case for low-language ability infants In Experiment A-1a. The introduction of the novel word during the familiarization phase caused them to devote more time to look at the familiar category at test, indicating that they had not yet categorized the objects but might be in a transitional period of processing the category.

The P_m scores for infants in both the high- and the low-language ability group in the Tone condition were about 0. The tone sequence in Experiment A-1 did not seem to affect the object categorization.

Experiment A-1b itself did not reveal any significant novelty or familiarity preference. Infants in both language groups had the P_m scores about 0, in both the Tone and the Word condition. No interaction was found significant.

However, in Experiment A-1b, infants in the higher language group in the Word condition displayed a much lower novelty preference compared to that in Experiment A-1a. This might indicate that the reappearance of the noun phrase during the test phase inhibited infants to look longer at the novel category, since it was not the category named by the pseudoword. Without hearing the noun phrase again, infants would have displayed a significant novelty preference, as evident in the categorization task in Experiment A-1a.

In order to succeed in the word-extension task, infants have to at least differentiate the two categories, determine which of the two new objects belongs to the category that was named by the jus-learned word, and inhibit to look at the not-named but novel category. Accordingly, this task was more demanding than the categorization task.

Note also that in the Tone condition, the P_m scores for the high-language ability infants did not differ between tasks. The difference was only evident in the Word condition. Given the significant novelty preference in the categorization task, the “no-preference” in Experiment A-1b in the Word condition might well indicate a significant word effect. However, without a clear familiarity preference, it can not be concluded that the infants can extend the novel word categorically. The result could also merely be a random effect, as the P_m in the Word condition was not significantly different from zero, just as in the Tone condition in the same task.

For infants in the lower language ability group, in the Tone condition, the difference between tasks was also not significant. The P_m scores were about 0 in both tasks. In the Word condition, however, the infants displayed an opposed data pattern compared to their language more advanced peers. They showed a significant *familiarity* preference in the categorization task in Experiment A-1a, and a comparatively higher novelty preference in the word-extension task. This was exactly opposite to the hypothesized data pattern.

Comparing Experiment A-1a and A-1b, the results implied that the low-language ability infants might have an immature but emerging understanding of the relation between nouns and object categories. On the one hand, the novel word brought out a reversed data pattern compared to the one shown by language more advanced infants. On the other hand, the word elicited a distinguishable effect than the non-linguistic tone in the object categorization context. The infants with lower language ability were probably experiencing a transitional period. At first, they distinguished words and non-words when confronted with categorization tasks. As language learning proceeds, they might also gradually learn the linkage between nouns and categories, as their language more advanced peers did.

5.1.4 Summary

Consistent with previous study (Waxman & Markow, 1995), Experiment A-1 demonstrated that infants at 12 months of age with higher language ability benefited from a novel word to access global-level object categories. The novel word, but not the tone, appeared to have focused infants' attention on categorical properties of the objects and hence facilitated categorization.

Comparing to their performance in the categorization task in the Word condition, the infants looked much more at the familiar category in the same condition in the word-extension task, indicating at least a tendency of word-learning. However, further studies may be necessary to demonstrate unquestionable novel word learning.

Experiment A-1 demonstrated a significant difference of performance between high- and low-language groups. While the high-language ability group displayed a data pattern consistent with the hypotheses, the low-language ability group showed an exactly opposite data pattern. It seemed that infants in the low-language ability group were experiencing a transitional phase of learning the noun-category linkage. The linguistic label, in contrast to the non-linguistic tone, clearly influenced on these infants' categorization, although not in the same way as on the infants with more advanced language ability. Experiment A-1 showed that whether infants honor the linkage between words and real global-level object categories was not determined by their age. Rather, the advance of language learning was essential.

As stated in Chapter 3, if infants honor the taxonomic constraint, they might be able to benefit from novel words to categorize novel objects, and might also be able to extend the novel words categorically. As previous researches with infants have used mostly real object categories, whether young infants could benefit from a novel word to form a novel category or whether they could also lean the novel word and then extend it to new category members are still open questions (see 2.2 and 2.4). Therefore, Experiment A-2 created artificial object categories and executed the similar categorization and word-extension tasks with 12-month-old infants.

5.2 Experiment A-2: Artificial object categorization and word-extension[10]

In Experiment A-2, two artificial object categories were created: the curvilinear and the rectilinear categories. Infants in 5.2.1 were randomly assigned to be familiarized with one of the categories and tested with either the categorization or the word-extension task. In 5.2.2, in order to analyze the language ability effect on infants' performance, more subjects were added and were given the same tasks as in 5.2.1. In 5.2.3, another group of 12-month-old infants were sampled to examine whether the figures used in Experiment A-2 were distinguishable to the infants.

It was hypothesized that in the categorization task, infants should display a significantly higher novelty preference in the Word than in the Tone condition. In the word-extension task, they should show a significantly higher familiarity preference in the Word than in the Tone condition. Infants with different language abilities were expected to perform differently on the tasks.

5.2.1 Artificial object categorization and word-extension with both the rectilinear and the curvilinear categories

5.2.1.1 Method

Participants

34 healthy 12-month-old infants (17 girls) participated in Experiment A-2a (mean age 377 days; range 364 days to 396 days). Two additional infants were excluded due to parental interference. German was the primary language spoken at home for all but one infant, whose first language was Polish. This infant was assigned to the Tone condition.

32 healthy 12-month-old infants (13 girls) participated in Experiment A-2b (mean age 377 days; range 358 days to 397 days). Four additional infants were excluded due to parental interference (3) or experimenter error (1). German was the primary language spoken at home for all infants.

[10] Some data of this experiment have been presented by: Weinert, S. & Zhang, D. (2005, July). *Word-category linkage in 12-month-old infants*. Paper presented at the X International Congress for the Study of Child Language: Berlin, Germany. See also: Zhang, D. & Weinert, S. (2007, March). *The noun-category linkage and its relationship with early lexical development in 12-month-old German infants*. Poster presented at the biennial meeting of the Society for Research in Child Development: Boston, MA, USA.

Materials

The visual stimuli were simple drawings of bug-like artificial creatures. Two kinds of these figures were created[11]. One was the curvilinear category. The other was the rectilinear category. Figures were different from each other in a variety of body parts. All figures in the curvilinear category were outlined with smooth curvilinear lines; whereas all in the rectilinear category were outlined with protrude rectilinear lines (Figure 5). The figures were delineated in black and within the same category each was filled with a different solid body-color. The body-color was matched between the two categories. Figures presented in the test phase had the same color. All figures were about 25cm in height and were presented against a white background.

[11] Similar figures have been first created by students in a research seminar held by Professor Sabine Weinert at the University of Bielefeld. Experiment A-2 adapted the basic components of those figures with variations of body parts' details.

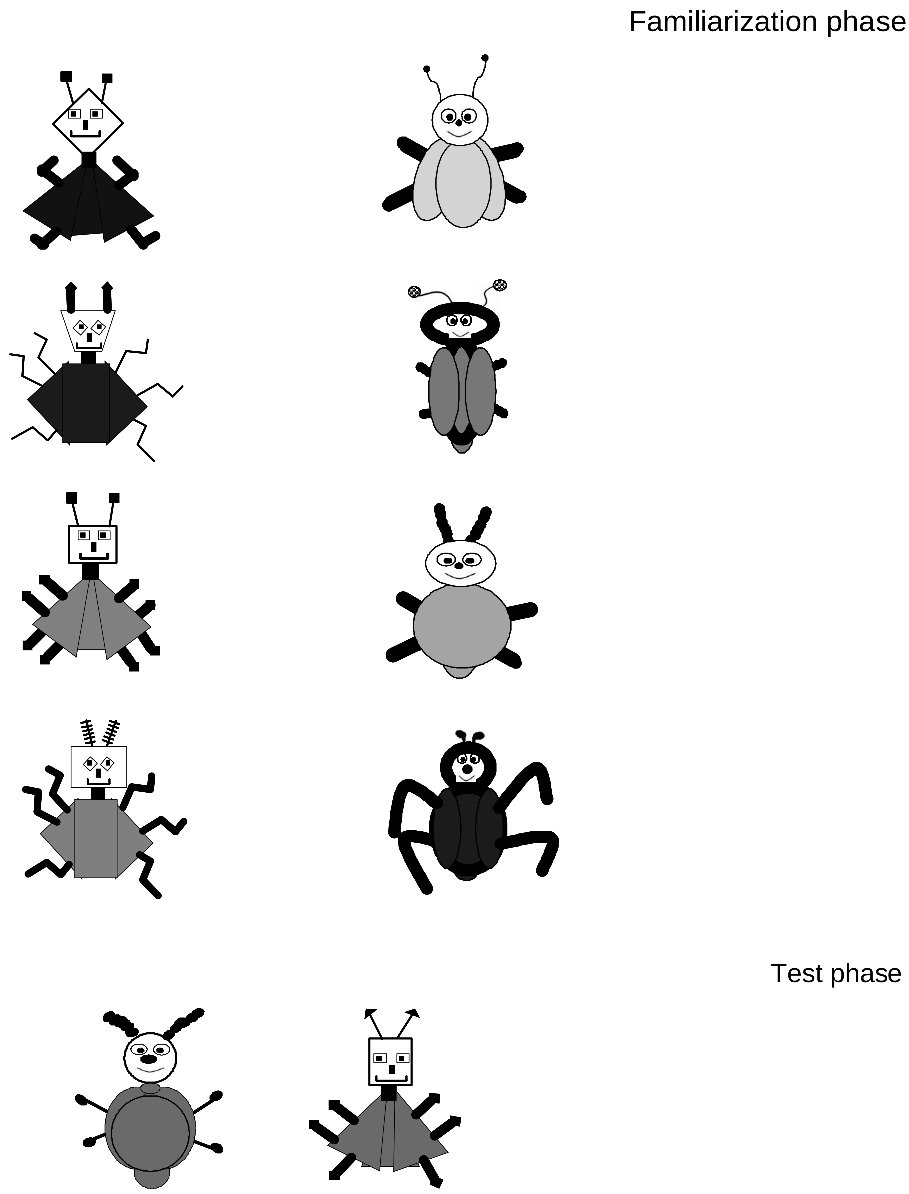

Figure 5. Some exemplars of the rectilinear and the curvilinear categories used in the familiarization and the test phase in Experiment A-2.

The auditory stimuli were a pseudoword phrase and its matched tone sequence. For the Word condition, a German noun phrase, “eine Plabel” (means “a Plabel”), was produced by an adult female using infant-directed speech. The phrase was digitized by computer and was 1.08s long. For the Tone condition, a 500-500-400 Hz sine wave tone sequence was created also by computer, matching to the noun phrase in duration of each syllable. The word and the tone were matched in loudness and were 60dB at the position of the infant’s head.

Design and Procedure

The design and procedure of the categorization (Experiment A-2a) and the word-extension task (Experiment A-2b) was the same as that in Experiment A-1. Only the visual and auditory stimuli were replaced with those described above.

Again, half of the infants were familiarized with rectilinear figures and the other half with curvilinear figures. Infants were randomly assigned to either the Word or the Tone condition.

Same as in Experiment A-1, it was hypothesized that if the novel word facilitated novel object categorization, in Experiment A-2a, infants should display a higher novelty preference score at test in the Word than in the Tone condition. On the contrary, in Experiment A-2b, if infants were able to extend the novel word, but not the tone, to new members of the just-learned category, they should look longer at the new in-category exemplars named by that word. Accordingly, they were expected to display a higher familiarity preference in the Word than in the Tone condition.

Parents were asked to fill out ELFRA-1 after the experiment.

Baseline preference test

As Experiment A-1 has revealed an *a priori* effect, in Experiment A-2, a baseline preference test was first conducted. Again, 15 infants were separately recruited for this purpose. Subjects were only presented with the two silent test phase trials in Experiment A-2. It showed that infants reliably preferred the curvilinear figures to the rectilinear ones. They spent on average 60 percent of their total looking time at the curvilinear figures, ranging .25 to .74, SD = .12. The value was significantly higher than chance level (.50), $t(14) = 3.10$, $p < .01$.This baseline preference score .60/.40 was used to explain the results obtained during the test phase.

5.2.1.2 Results

Language Assessment

Both receptive and productive language data of the infants obtained with ELFRA-1 are listed in Table 6.

Familiarization phase

Auditory and silent trials

In both Experiment A-2a and A-2b, Infants watched again significantly longer during the auditory trials than during the silent trials.

In Experiment A-2a, the average looking time during the auditory trials was 8.12s (*SD* = 1.63) and during the silent trials was 7.60s (*SD* = 2.03); $t(33) = 2.79$, $p < .01$. No significant effect or interaction was found across conditions or types of the familiarization figure (i.e., rectilinear or curvilinear).

Table 6

Experiment A-2 (categorization and word-extension task with artificial categories)

Infants' productive and receptive language measured by ELFRA-1

	Experiment A-2a (N = 34)		Experiment A-2b (N = 32)		**Total** (N = 66)	
	Reception	Production	Reception	Production	Reception	Production
M	54.12	10.76	46.97	9.28	50.69	10.05
SD	36.00	5.96	36.97	4.44	36.65	5.33
Min.	2	2	7	2	2	2
Max.	140	29	138	22	140	29
50 Percentile	48	10	36	9	42	10

In Experiment A-2b, the average looking times during the auditory trials was 7.69s (*SD* = 1.57) and during the silent trials was 6.76s (*SD* = 2.21); $t(31) = 4.16$, $p < .0005$. No significant effect or interaction was found across conditions or types of the familiarization figure.

Looking time across three blocks

An analysis of variance with block as within-subjects factor, and with task (categorization or word-extension), type of familiarization figure, and condition as between-subjects factors revealed a reliable effect of block, $F(1,58) = 34.62$, $p < .0005$ (Table 7 and 8).

A significant effect of type of familiarization figure was also evident, $F(1,58) = 5.70$, $p < .02$. On average, infants in the familiarization phase attended longer to the curvilinear figures (*M* = 8.15, *SD* = 1.41) than to the rectilinear figures (*M* = 7.19, *SD* = 1.87), suggesting that infants preferred the curvilinear category to the rectilinear category.

The main effect of condition was not significant, $F(1,58) = 2.31$, $p > .10$. In the Tone condition, mean looking time during the familiarization phase was 7.98s (*SD* = 1.51), while in the Word condition 7.38s (*SD* = 1.86). In other words, infants in both conditions had statistically the same opportunity to learn the familiarization categories.

The interaction between condition and type of familiarization figure approached significance, $F(1, 58) = 3.31$, $p < .075$. Closer examination showed that infants familiarized with rectilinear figures looked somewhat longer in the Tone condition ($M = 7.87$, $SD = 1.61$) than in the Word condition ($M = 6.55$, $SD = 1.92$), $t(31) = 2{,}12$, $p < .04$. For infants familiarized with curvilinear figures, the looking time during the familiarization phase was not significantly different between conditions.

Table 7

Experiment A-2a (categorization task with artificial categories)

Average looking times (*SD*) at rectilinear and curvilinear categories in the Tone and in the Word condition over familiarization blocks

Familiarization Figures	Condition	Familiarization Block 1	2	3
Rectilinear	Tone	9.13	8.15	7.57
	N = 8	*(1.26)*	*(1.74)*	*(2.15)*
	Word	7.60	6.38	6.71
	N = 9	*(1.84)*	*(2.55)*	*(1.49)*
	Subtotal	8.32	7.21	7.12
		(1.73)	*(2.33)*	*(1.82)*
Curvilinear	Tone	8.86	8.62	7.80
	N = 8	*(1.67)*	*(1.49)*	*(1.58)*
	Word	8.74	8.23	8.23
	N = 9	*(1.08)*	*(1.59)*	*(1.71)*
	Subtotal	8.80	8.41	7.82
		(1.34)	*(1.51)*	*(2.25)*
	Total	8.56	7.81	7.47
	N = 34	*(1.54)*	*(2.02)*	*(2.05)*

Table 8

Experiment A-2b (word-extension task with artificial categories)

Average looking times (*SD*) at rectilinear and curvilinear categories in the Tone and in the Word condition over familiarization blocks

		Familiarization Block		
Familiarization Figures	Condition	1	2	3
Rectilinear	Tone N = 8	8.52 *(1.16)*	6.99 *(2.18)*	6.86 *(2.23)*
	Word N = 8	6.83 *(1.83)*	5.69 *(2.71)*	5.98 *(2.34)*
	Subtotal	7.68 *(1.72)*	6.33 *(2.46)*	6.42 *(2.25)*
Curvilinear	Tone N = 8	8.73 *(1.25)*	7.07 *(1.75)*	7.05 *(1.89)*
	Word N = 8	9.36 *(0.80)*	7.79 *(1.64)*	7.72 *(2.21)*
	Subtotal	9.04 *(1.06)*	7.43 *(1.68)*	7.38 *(2.01)*
	Total N = 32	8.36 *(1.57)*	6.88 *(2.15)*	6.90 *(2.16)*

Test Phase

Across conditions and tasks, infants familiarized with the rectilinear figures displayed an overall mean novelty preference score (*P*) of .58 (*SD* = .10), which was not significantly different from the baseline value (.60), $t(32) = .92$, $p > .37$. Infants familiarized with the curvilinear figures displayed a mean *P* score of .42 (*SD* = .10), which was also not significantly different from the baseline value (.40), $t(32) = 1.04$, $p > .31$. That is, across conditions and tasks, the overall *P* scores in both groups were comparable to their corresponding baseline values.

In order to better represent the data, the *P* scores were transformed to a *novelty preference score compared to baseline value* (P_B). For infants familiarized with rectilinear figures, $P_B = P - .60$. For infants familiarized with curvilinear figures, $P_B = P - .40$.

An analysis of variance with P_B as dependent variable and with three between-subjects factors was run. The 3 independent variables were:

1. Condition (Word or Tone);
2. Task (categorization or word extension); and
3. Type of familiarization figure (rectilinear or curvilinear)

The language ability was deliberately not included as a variable in this analysis, since otherwise the individual cell size would be too small (< 5) to make sense. Further analysis related to language abilities was conducted later with added subjects in 5.2.2.

The analysis revealed a significant interaction between task and condition, $F(1,58) = 6.47$, $p < .01$; and a significant three-way interaction among task, condition and type of familiarization figure, $F(1,58) = 5.58$, $p < .02$. No more effect or interaction was found significant (Figure 6).

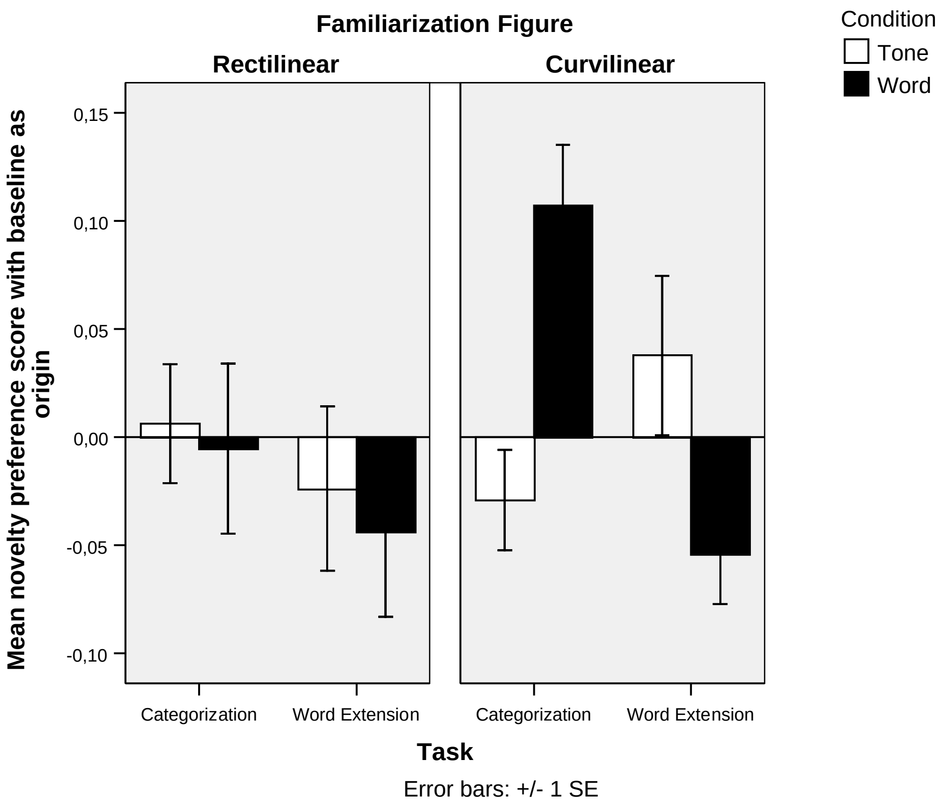

Figure 6. Experiment A-2 converted novelty preference score (P_B) for infants familiarized with rectilinear and curvilinear categories compared between tasks and conditions.

Note that unlike Experiment A-1, the variable *type of familiarization figure* significantly interacted with other factors in Experiment A-2. In other words, the effects induced by *condition* and *task* were different for infants familiarized with different categories. As a result, the data collapse in Experiment A-1 was not viable for Experiment A-2.

For infants familiarized with curvilinear figures, just as hypothesized, the interaction between task and condition was significant, $F(1,29) = 15.99$, $p < .0005$. In the categorization task, infants displayed a significantly higher novelty preference in the Word than in the Tone condition, $t(15) = 3.68$, $p < .002$. They showed a reliable novelty preference compared to baseline value in the Word condition. In the Tone condition, no significant preference appeared (Table 9). In the word-extension task, on the contrary, infants displayed a significant greater familiarity preference in the Word than in the Tone condition, $t(14) = -2.10$, $p < .05$. They showed a reliable familiarity preference compared to baseline value in the Word condition. In the Tone condition, again, no significant preference was observed.

Table 9

Average P_B score (*SD*) in Experiment A-2 in both tasks and conditions for infants familiarized with rectilinear and curvilinear figures. Scores significantly different from 0 are flagged.

		Condition			
		Tone		Word	
Familiarization figure	Task	*M*	N	*M*	N
Rectilinear	Categorization	.01 (*.08*)	8	-.01 (*.12*)	9
	Word-extension	-.02 (*.11*)	8	-.04 (*.11*)	8
Curvilinear	Categorization	-.03 (*.07*)	8	**.11**** (*.08*)	9
	Word-extension	.04 (*.10*)	8	**-.05*** (*.07*)	8

* $p < .05$

** $p < .01$

As shown in Table 9 (lower part with curvilinear category), in the Tone condition, the preference scores did not differ significantly between tasks, $t(14) = 1.53$, $p > .15$. In the Word condition, however, the mean P_B score was significantly higher in the categorization task than in the word extension task, $t(15) = 4.34$, $p < .001$.

In brief, just as hypothesized, infants familiarized with curvilinear figures in the Word condition displayed a significant novelty preference in the categorization task, and a significant familiarity preference in the word-extension task. In the Tone condition, no significant preference was observed.

For infants familiarized with rectilinear figures, however, no significant interaction was found between task and condition. As obvious in Table 9 (upper part with rectilinear category), infants always performed at baseline level across conditions and tasks. This accounts for the three-way interaction among type of familiarization figure, condition and task.

5.2.2 Language related analysis with added subjects only familiarized with the curvilinear category

Experiment A-2a and A-2b contained limited subjects and a comparison between language groups was not suitable. In 5.2.2, more subjects were sampled. They were given exactly the same tasks again as in 5.2.1.

By far, only enough infants have been obtained to be familiarized with the curvilinear figures. This has first been done as clear results have been displayed with the curvilinear category (5.2.1). Ongoing studies are sampling more infants who are familiarized with the rectilinear category.

32 healthy 12-month-old infants were added to Experiment A-2. Infants were randomly assigned to the tasks and the conditions. Involving the 33 infants tested before (i.e., in Experiment A-2a and A-2b those who were familiarized with the curvilinear categories only), the mean age of all the 65 infants (33 girls) was 376 days, ranging 358 to 397 days. Four other infants were excluded due to fussiness. German was the primary language spoken at home for all but three infants, who were assigned to the Tone condition.

The tasks and procedures were the same as in 5.2.1, with the exception that infants were only familiarized with the curvilinear figures.

<u>Language Assessment</u>

Both receptive and productive language data of the infants obtained with ELFRA-1 are listed in Table 10.

32 infants with productive language score lower than 10 (i.e., the 50th percentile) were labeled as low productive language group, the other 33 were labeled as high group.

Familiarization phase

Auditory and silent trials

Again, Infants watched significantly longer during the auditory trials than during the silent trials. The average looking time during the auditory trials was 8.18s (SD = 1.32) and during the silent trials was 7.54s (SD = 1.78); $t(64) = 4.10$, $p < .0005$. No significant difference was found across conditions and tasks.

Looking time across three blocks

An analysis of variances with block as within-subjects factor, and with task and condition as between-subjects factors revealed a reliable effect of block, $F(2,122) = 14.39$, $p < .0005$ (Table 11). No more effect or interaction was significant.

Table 10

Experiment A-2 (with added subjects familiarized only with the curvilinear category)

Infants' productive and receptive language measured by ELFRA-1

	Categorization (N = 32)		Word-extension (N = 33)		**Total** (N = 65)	
	Reception	Production	Reception	Production	Reception	Production
M	54.41	9.94	59.12	12.03	56.80	11.00
SD	34.04	4.49	35.69	8.68	34.70	6.96
Min.	11	2	13	5	11	2
Max.	138	22	151	41	151	41
50 Percentile	52	10	55	9	52	10

Test Phase

To be consistent with previous analysis, the novelty preference score (P) was again transformed to P_B ($P_B = P - .40$).

An analysis of variance with P_B as dependent variable and with 3 between-subjects factors was run. The 3 independent variables were:

1. Condition (Word or Tone);
2. Task (Experiment A-2a or Experiment A-2b); and
3. Productive language group (high or low)

The analysis revealed a significant interaction between task and condition, $F(1,57) = 12.83$, $p < .001$; and a significant interaction between task and productive language group, $F(1,57) = 5.62$, $p < .02$. No more effect or interaction was found significant (Figure 7).

As shown in Table 12, in both language groups, in the categorization task, the P_B score was, as hypothesized, significantly higher in the Word than in the Tone condition, $t(31) = 2.07$, $p < .05$; and in the word-extension task, the P_B score was significantly lower in the Word than in the Tone condition, $t(30) = 3.38$, $p < .002$.

However, the interaction between task and condition was stronger with the high-language group, $F(1,29) = 10.81$, $p < .003$. For the low-language group, the interaction approached significance, $F(1,28) = 3.46$, $p < .07$.

Table 11

Experiment A-2 (with added subjects familiarized only with the curvilinear category)

Average looking times (*SD*) in the Tone and the Word condition over familiarization blocks in categorization and word-extension tasks

		Familiarization Block		
Task	Condition	1	2	3
Categorization	Tone	8.63	8.01	8.02
	N = 17	*(1.38)*	*(1.85)*	*(1.62)*
	Word	8.53	7.99	7.40
	N = 16	*(1.15)*	*(1.54)*	*(2.41)*
	Subtotal	8.58	8.00	7.72
		(1.25)	*(1.68)*	*(2.03)*
Word-extension	Tone	8.23	7.16	7.00
	N = 16	*(1.46)*	*(1.79)*	*(2.00)*
	Word	8.95	8.11	7.50
	N = 16	*(1.08)*	*(1.28)*	*(2.11)*
	Subtotal	8.59	7.63	7.25
		(1.32)	*(1.60)*	*(2.04)*
	Total	8.59	7.82	7.49
	N = 65	*(1.27)*	*(1.64)*	*(2.03)*

The significant interaction between task and productive language group was due to the fact that, across conditions, the P_B score for the low-language ability group was greater in the categorization task than in the word-extension task; and for the high-language group, the score was greater in the word-extension task than in the categorization task (Table 12, right-most 2 columns).

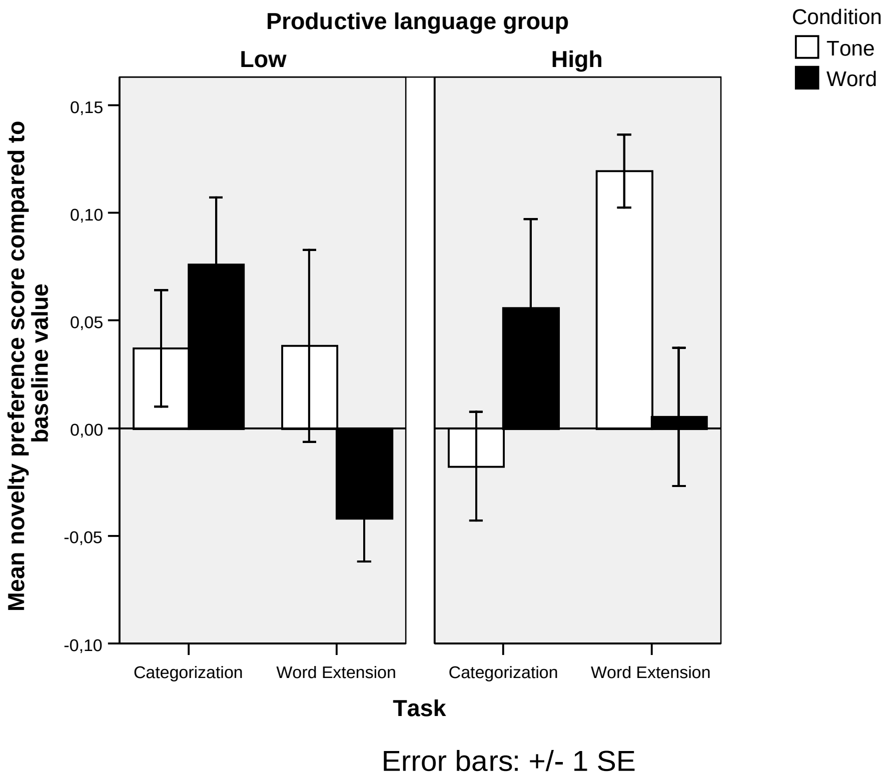

Figure 7. Experiment A-2 converted novelty preference score (P_B) for infants (familiarized with the curvilinear category) in the high- and low-productive language groups compared between tasks and conditions.

This significant interaction was partly attributed to the evidence that infants in the high-language ability group displayed a very high novelty preference in the Tone condition in the word-extension task. The reappearance of the tone sequence during the test phase seemed to have promoted the infants to look much longer to the *novel* category. When the noun phrase reappeared at test, however, infants significantly inhibited this novelty preference shown in the Tone condition, spending comparably much longer time to look at the familiar category named by the word.

To sum up, with added subjects, sixty-five 12-month-infants were familiarized with the curvilinear category and tested with either the categorization or the word-extension task. In general, similar to the results in 5.2.1, infants in the categorization task displayed an expected much higher novelty preference in the Word than in the Tone condition, and in the word-extension task a much lower novelty preference in the Word than in the Tone condition. This overall data pattern was not significantly different between high- and low-language groups, although the interaction between task and condition was greater for the higher language ability group than the lower one.

Table 12

Average P_B score (*SD*) in Experiment A-2 with added subjects for infants familiarized only with curvilinear figures. Scores significantly different from baseline value are flagged.

		Condition					
		Tone		Word		**Total**	
Productive language group	Task	*M*	N	*M*	N	*M*	N
Low	Categorization	.04 (*.07*)	7	**.08*** (*.10*)	10	**.06*** (*.09*)	17
	Word-extension	.04 (*.12*)	7	-.04 (*.06*)	8	-.00 (*.10*)	15
High	Categorization	-.02 (*.08*)	10	.06 (*.10*)	6	.01 (*.09*)	16
	Word-extension	**.12***** (*.05*)	9	.01 (*.09*)	8	**.07**** (*.09*)	17
Total	Categorization	.00 (*.08*)	17	**.07*** (*.10*)	16		
	Word-extension	**.08**** (*.09*)	16	-.02 (*.08*)	16		

* $p < .05$, ** $p < .01$, *** $p < .001$

5.2.3 Figure differentiability test

This test examined whether infants could differentiate the individual exemplars within each of the two categories used in Experiment A-2. A demonstration that infants can easily discriminate the different figures within a category would strengthen the hypothesis that word helps infants to *categorize* distinguishable objects; and that infants extend a newly learned word to *new* members of the appropriate category.

5.2.3.1 Method

Participants

20 healthy German 12-month-old infants (11 girls) participated in the experiment (mean age 376 days; range 364 to 395 days). One additional infant was excluded due to fussiness. German was the primary language spoken at home for all infants.

Materials

The 22 figures used in Experiment A-2 were used as visual stimuli. The auditory stimulus was the tone sequence used in Experiment A-2. All equipments were the same as in previous experiments.

Design and procedure

Each infant viewed three familiarization-test blocks during the experiment. The interval between blocks was 3 seconds. Each block consisted of a single 15-second familiarization trial followed by two 8-second test trials. On the familiarization trial, one of the figures from the rectilinear or the curvilinear category was presented on the central monitor. The first test trial started 3 seconds after the familiarization. The familiar figure and a new figure from the same category were presented one on the right and one on the left monitor. The left-right position of the new figure was counterbalanced across blocks and subjects. The second test trial began one second after the first, and the two figures were shown again but in reversed left-right positions.

All nine trials (i.e., three blocks each consisting of three trials) were presented with the same tone sequence to draw infant’s attention. The onset of the sound was synchronized with the onset of the picture.

Every infant viewed a different presentation sequence so that across subjects each figure within a category was presented about equally often as familiarization figure and had about equal opportunity to be compared with other members of the same category during the test phase. Every infant viewed two different blocks from one category (e.g., curvilinear), which were intermediated with one block of another category (e.g., rectilinear). The category presented first was counterbalanced across subjects.

5.2.3.2 Results

A novelty preference score for each infant was calculated. Infants' looking time to the new exemplars across all test trials was divided by the total looking time during the test phases. The mean novelty preference score was .53 (*SD* = .07, ranging from .42 to .71), which was significantly higher than chance level (.50), $t(19) = 1,99$, $p < .03$, one-tailed. Mean total looking time to the new exemplars was 20.60s, *SD* = 3.77; and to the familiar exemplars 18.29s, *SD* = 4.04. That is, infants looked significantly longer at the novel exemplars than at the familiar ones, $t(19) = 1.95$, $p < .03$, one-tailed. In the test phases, 15 of the twenty infants looked longer at the novel exemplars than at the familiar ones.

The result demonstrates that 12-month-old infants can easily distinguish the different figures used in Experiment A-2. After just a single 15-second exposure to any individual figure, infants discriminated it from another exemplar of the same category.

5.2.4 Discussion

5.2.4.1 Overview

Experiment A-2 introduced a novel word and two artificial object categories. Results of 5.2.1 and 5.2.2 consistently demonstrated that 12-month-old infants can benefit from the hypothesized noun - object category linkage. When familiarized with their preferable object category, infants successfully displayed expected novel object categorization and novel word learning in the Word condition. Result of 5.2.3 showed that infants perceived the members of each artificial category as well different from each other. The finding strengthens the argument that the novel word facilitates *categorization* by highlighting the commonalities among *different* members of the same category. In addition, the novel word was also rapidly associated with the novel category. When hearing the word again, infants were able to extend the word to *new* in-category members.

The expected word effect did not appear when infants were familiarized with the less preferred rectilinear category. Infants familiarized with this category performed at baseline level across tasks and conditions.

For infants familiarized with the curvilinear category, the predicted interaction between task and condition was significant. Both high- and low-language ability groups showed expected data pattern. Yet the interaction was stronger in infants with higher productive language ability.

In brief, the predicted word effect manifested in both the categorization and the word-extension tasks when infants were familiarized with their preferable category. The result indicated that infants began to honor the noun-category linkage to learn novel words and to form novel object categories. However, this was still fragile and subject to infants' intrinsic preference. The word effect was obscured in the tasks when infants were familiarized with a less favorable category.

5.2.4.2 The successful novel-object-categorization and novel-word-learning with the curvilinear category.

In 5.2.1, when infants were familiarized with the curvilinear category, they displayed a significant *novelty* preference in the Word but not in the Tone condition in the categorization task, indicating successful novel object categorization. In the word-extension task, the data pattern reversed. Infants in the Word condition showed a significant *familiarity* preference in the Word but not in the Tone condition, implying novel word-learning.

During the familiarization phase, infants in both the Tone and the Word conditions were familiarized to the same extent. They significantly reduced their looking time linearly as the familiarization phase progressed. Both group had about the same length of time to learn the category resemblance during familiarization. However, only in the Word condition, infants showed the predicted novel object categorization and novel word learning at test.

The results were remarkable since the young infants learned both the novel word and the novel category within very limited time and with no redundant cues (e.g., social pragmatic cues) besides perceptual commonalities and linguistic input. As the word and categories were both new to the infants, the results indicated genuine novel word learning and novel object categorization but not the recognition of a known word or a familiar object category.

In 5.2.2, the result of 5.2.1 was confirmed with additional subjects. Infants also displayed predicted much higher novelty preference in the categorization task and lower novelty preference in the word-extension task in the Word condition. This was the case for both the high- and low-language ability groups in 5.2.2.

In the word-extension task, infants in the high-language ability group did not demonstrate a significant familiarity preference in the Word condition. Instead, they displayed a very high novelty preference in the Tone condition (Table 12). In the Word condition, this significant novelty preference was inhibited. Infants did not prefer the novel category, which was not named by the reappeared label during the test phase.

The result suggested that the infants treated words and non-words distinctively in such tasks. The novel word might have highlighted the commonalities of the different objects, hence promoted infants to form a novel category. At the same time, the word has been associated with the category. When hearing the word again, infants refrained from looking at another *new* category that was not being named by the word.

The non-linguistic tone, on the contrary, was not found to facilitate novel object categorization. The high-language ability infants performed at baseline level in the categorization task in the Tone condition.

The non-linguistic tone might have merely lured infants to look at "something *different"*. During the familiarization phase, all the nine exemplars presented were different for the infants (see 5.2.3). If the tone was not regarded as a "category identifier", each time when it appears, it might simply signify that something different was coming. In other words, in the Tone condition, infants might perceive each of the objects during the familiarization phase as well as in the test phase as divergent and unique without forming a category. This might explain the result that they did not show categorization in the Tone condition.

It was interesting why the infants displayed a significant novelty preference in the Tone condition in the word-extension task. If the tone only directed infants' attention to "something different", given that all the test phase exemplars were different from those in the familiarization phase, infants would have looked similarly long at both the out-of-category exemplars and the in-category ones. However, they looked more at the out-of-category exemplars. Thus, they must have perceived the out-of-category members as "more different", why?

Bronson (1974) has proposed a *retinal adaptation* interpretation that may account for this finding. According to his assumption, when infants were exposed to a series of exemplars during the familiarization phase, a population of retinal cells was adapted to a salient property of the stimuli (i.e., the curvilinear contour). When the property changed (i.e., the rectilinear contour), a new population of retinal cells was activated. This made the more different stimulus detectable. In other words, to perceive the rectilinear figures as more different from the previous curvilinear figures do not require object categorization, but can be simply attributed to the function of optical systems.

If the rectilinear figures were perceived as "more different" during the test phase, and if the reappeared non-linguistic tone would engage infants to look at "something different", then infants in the Tone condition in the word-extension task should pay more attention to the out-of-category exemplars. When the tone sequence did not reappear during the test phase, nothing elicited them to attend to figures that were "more different". Accordingly, infants just performed at baseline level in the Tone condition in the categorization task.

Whether this interpretation is correct may require further examination. Nevertheless, the significantly different effects of linguistic and non-linguistic labels on categorization and word-extension tasks were evident. In Experiment A-2, the non-linguistic tone was not found to help infants' novel object categorization. It was also not regarded as the label for the category by the infants. As a contrast, the pseudoword phrase promoted infants to form a novel category and infants could extend the word to other new in-category members.

5.2.4.3 The different effects of language ability in Experiment A-1 and A-2

In Experiment A-1, infants in the higher productive language group demonstrated expected performances on the categorization and the word-extension tasks. The lower group did not. In Experiment A-2, however, both language groups succeeded. In the Word condition, they all demonstrated a predicted much higher novelty preference score in the categorization task than in the word-extension task. What caused this difference?

One possibility might be that the commonalities of the artificial categories shown in Experiment A-2 were perceptually more obvious and easier to detect. The objects in each global-level category presented in Experiment A-1 looked more heterogeneous (Figure 3). Each exemplar in the animal category, for instance, had very different body parts (e.g., tail, long or short neck, with or without trunk/horn), color, texture (i.e., with or without fur), and position (i.e., towards left or right). The exemplars in the artificial category, as a comparison, all faced up straight ahead, had the same texture, and were self-colored (i.e., each figure had only a single solid color). Admittedly, these criteria are from the adult perspective. Whether the infants perceived the perceptual features as heterogeneous or homogeneous is an open question. It may be possible, for example, that infants only paid attention to some specific features of the exemplars, such as all having legs or eyes, and ignored the others.

Nonetheless, to succeed in the categorization and word-learning tasks, infants had to group perceptually different exemplars as a unit according to their categorical commonalities. They also had to connect this with a common label. During the test phase, they must identify which of the two new members was in-category and which one was not. Here, the more divergent the stimuli within a category, the more difficult the task would be. In this case, whether infants could exploit the consistent label as a cue for extracting the categorical commonalities would be important for their success in the task.

Evidence has been provided that the language effect on categorization tasks was especially significant with global-level categories, for which the categorical commonalities would be less detectable without the help of linguistic labels (Fulkerson & Haaf, 2003; Waxman & Markow, 1995). In line with these findings, the tasks involving global-level object categories might be more demanding on infants' language ability and their appreciation of the connection between nouns and categorical commonalities. Consequently, only the high-language ability group succeeded in Experiment A-1. On the other hand, when the objects might be perceptually easier to classify, both high- and low-language ability groups did well. However, even for perceptually more homogeneous categories, the expected interaction between condition and task was greater with the high-language ability infants than with the low-language ones. The effect of language ability on categorization and novel word learning still can not be ignored.

5.2.4.4 The ambiguous result from infants familiarized with the rectilinear category

It is an open question, why after being familiarized with the rectilinear category, infants displayed neither the expected categorization nor word learning. In both the Word and the Tone conditions, they always performed at baseline level. It seemed that infants' attention was preoccupied by their natural preference, regardless of what they had heard during the familiarization phase.

It has been demonstrated that at 12 months of age, infants' intrinsic interest plays a steadfast role in their looking preference, in spite of linguistic and social cues provided in the word learning context (Hollich et al., 2000; Pruden, Hirsh-Pasek, Golinkoff, & Hennon, 2006). However, the result with the rectilinear category seems still difficult to explain considering of the findings with global-level categories in Experiment A-1. In that study, although the infants (i.e., the high-language ability group) also had a high preference for the animal category, they displayed categorization and a tendency of word learning in the Word condition after being familiarized with *both* categories (i.e., animal and fruit).

One explanation to the difference between Experiment A-1 and A-2 could be that: During the familiarization phase, infants had never learned the association between the novel word and the rectilinear category. As they disliked the rectilinear figures, they tended to look away and ignore the auditory stimulus. Indeed, their average looking time to the rectilinear figures during the familiarization phase was significantly shorter than to the curvilinear ones (see 5.2.1.2). If infants had not paid attention to the word-objects paring in the first place, their looking preference during the test phase would simply be influenced by their intrinsic preference and have little to do with the experience during the familiarization phase. As a comparison, in Experiment A-1, infants spent similar amount of time to look at the animal and the fruit categories during the familiarization phase (see 5.1.2). They had similar chances to learn the word-objects paring for both categories. Consequently, the word effect was evident for both categories in Experiment A-1. It is reasonable that at this young age, infants would only benefit from novel words to categorize objects if they are interested in those objects they are looking at (e.g., animals, fruits, curvilinear figures). Otherwise, learning is unlikely to take place (e.g., with rectilinear figures) in such a short experimental (unnatural) situation.

Another possible explanation for the results with the rectilinear category could be the account of asymmetrical categorization (Furrer & Younger, 2005; Mareschal, Quinn, & French, 2002; Quinn, 2004; Younger & Fearing, 1999). Unexpected asymmetries in category learning in young infants have been reported by these cited studies. For example, in Mareschal and colleagues' study (2002), when 3- to 4-month-old infants were shown different photographs of either cats or dogs, they formed the CAT category included novel cat photographs but excluded dog photographs. However, the DOG category included novel dog photographs and *included* cat photographs. It was an asymmetry in the exclusivity of the categories formed. Detailed computational analysis of the frequency distribution of the pictures' features revealed that almost all cats were legitimate exemplars of the DOG category whereas most dogs were *not* legitimate exemplars of the CAT category. In other words, the perceptual features of the DOG category embraced those of the CAT category. The authors suggested that this formed the basis of an account of the exclusivity asymmetry (Mareschal, French, & Quinn, 1998). According to this account, for the 12-month-old infants in the current study, the rectilinear category might perceptually include the curvilinear category. Thus, across tasks and conditions, infants performed at baseline level after familiarized with the rectilinear figures, as they might assume the curvilinear figures belonging to the rectilinear category. However, this explanation is subject to examination as there is no evidence yet whether the perceptual features of the rectilinear category would include those of the curvilinear category. In addition, the result with the rectilinear category might also be a consequence of the complex interactions of different factors. The significant natural preference, the *novel* object category and the *novel* word, and the limited sample size might have affected one another, which overcast the possible word effect. It might be possible that with expanded sample size, different data pattern would appear with the rectilinear category. Ongoing study is running to clarify the ambiguities remained in Experiment A-2.

5.2.4.5 A prelude of the taxonomic constraint

Experiment A-2 demonstrated that 12-month-old infants were able to take advantage of a novel word to categorize novel object categories and they could extend the just-learned word to new in-category members. Does this suggest that the taxonomic constraint is in place by 12 months of age? One has to be cautious before drawing such a conclusion.

First, the expected categorization and word-extension has not been demonstrated with the rectilinear category. Although this might change if more subjects are sampled, it indicated the appreciation of the link between words and object categories is at least still fragile at the early stage of language learning. It can be obscured by other factors such as infants' intrinsic interest or the difficulties inherent in a given task.

Second, in order to introduce completely novel categories and a novel word to young infants, Experiment A-2 only used a "bottom-up" procedure. The "top-down" procedure that has often been used to investigate the taxonomic bias in older children (see Markman & Hutchinson, 1984) was not conducted. In the top-down word learning task, children are usually presented with just one "object-novel noun" pairing, and then are expected to choose among a few options and to extend the novel noun categorically. In Experiment A-2, young infants were shown the novel category with a series of different exemplars, accompanied with a novel noun phrase. The infants were provided with the opportunity to learn the arbitrary linkage between the linguistic label and the concept. In Experiment A-2, infants have succeeded in the bottom-up task, showing the task is sensitive and suitable for detecting young infants' ability of linking words and categories at the very beginning of language acquisition. However, the author was aware that the bottom-up task was different from a top-down inductive task. The latter shall be tried in very young infants in the future to examine the taxonomic constraint.

Third, in Experiment A-2, no global-level artificial category was created. It was considered that an introduction of a novel global-level category might require a much longer time in the experiment, which might not be ideal for such young infants.

In short, the tasks in Experiment A-2 were still different from those often used in studies on the taxonomic constraint in older children. Accordingly, the obtained evidence was not sufficient for a conclusion that 12-month-old infants have the specific bias equivalent to the taxonomic constraint shown by older children.

Nevertheless, Experiment A-2 demonstrated that as early as 12 months of age, infants appreciate the linkage between nouns and object categories. In this study, infants learned a new label for a new category, and the novel label helped them to form the novel category. Already at this early stage of language acquisition, infants showed at least a *prelude* of the taxonomic constraint.

Importantly, Experiment A-2 demonstrated that although non-linguistic tone also attracted infant's attention, infants did not map it to an object category and the tone sequence did not appear to help them to form novel categories. In contrast, with the help of language, infants easily detected the linkage between the novel label and the novel object category. They took advantage of the linkage to learn a novel word and to form a new category at the same time. However, at this early stage of language learning, the appreciation of the noun-category linkage may be still fragile and can be overridden by infants' natural preference.

5.2.5 Summary

Experiment A-2 provided evidence that infants took advantage of certain bias to acquire new words and new concepts by the time they producing their first words. They showed the bias to discriminate language and non-language input when learning new object categories. This was especially apparent with language more advanced infants. Already at this initial stage of language acquisition, infants appreciated the mutual linkage between linguistic and categorical structures. This might be a precursor of the emerging taxonomic constraint.

The hypothesized word effect has been demonstrated in both Experiment A-1 and A-2 with 12-month-old infants. Do infants who just start to comprehend language also honor the noun-category linkage? Experiments were conducted in 5.3 and 5.4 to explore this question.

5.3 Experiment A-1-0: 9-month-old infants global-level object categorization and word-extension task with the animal category

Experiment A-1 demonstrated that infants at 12 months of age with more advanced productive language honored the noun-category linkage. They benefited from a novel word to access global-level object categories. They also seemed to be able to learn the novel label for the categories. Experiment A-1 also revealed a significant difference of performance between high- and low-language ability groups. While the high-language ability group displayed a data pattern consistent with the hypotheses, the low-language ability group showed an exactly opposite data pattern. This supported the assumption that whether infants honor the linkage between nouns and real global-level object categories is not determined by their age. Rather, the advance of language learning is essential.

If the younger 9-month-old infants, who just start to comprehend words, would perform similar as the low-language ability 12-month-old infants in the same tasks, it would strongly support the assumption stated above. Therefore, Experiment A-1-0 gave the same tasks in Experiment A-1 to 9-month-old infants to further examine the viability of the assumption. To save subjects, only the animal category was used.

It was hypothesized that the 9-month-old infants would perform similarly as the 12-month-old infants in the low-language ability group.

5.3.1 Method

<u>Participants</u>

32 healthy 9-month-old infants (17 girls) participated in the categorization task (mean age 285 days, ranging 272 to 302 days). Seven additional infants were excluded due to non-alertness (1) or fussiness (6).

By far, only 22 healthy 9-month-old infants (16 girls) have participated in the word-extension task (mean age 287 days, ranging 275 to 302 days). The study is on-going and will sample more subjects. Two additional infants were excluded due to fussiness for this study.

German was the primary language spoken at home for all infants.

<u>Material, Design and Procedure</u>

Materials and tasks were the same as in Experiment A-1. For both the categorization and the word extension tasks, infants were randomly assigned to either the Word or the Tone condition. Due to the low birth-rate in the region of Bamberg, obtaining subjects turned out to be difficult. To maintain reasonable cell sizes for analyses, all sampled infants were only familiarized with the animal category.

Parents were asked to fill out ELFRA-1 after the experiment. The author was aware that ELFRA-1 is only appropriate for infants older than 12 months of age. However, by the time the experiment was conducted, no other suitable language assessment was available for infants younger than 12 months. Accordingly, the checklist was only taken as a reference to infants' language development status. At the beginning, some parents expressed frustration when trying to fill out the whole language scale. Subsequently, all parents were only asked to finished I(a) and II(a) (see 5.1.2).

Baseline preference test

As in Experiment A-1, a baseline preference test was also conducted. 20 9-month-old infants were separately recruited for this purpose. Subjects were only presented with the two silent test phase trials in Experiment A-1. It revealed that infants reliably preferred the animals to the fruits. They spent on average 61 percent of their total looking time at the animals, ranging .43 to .81, SD = .10. The value .61 was significantly higher than chance level (.50), $t(19) = 4.94$, $p < .001$. The preference for the animal category was confirmed in the 9-month-old infants.

5.3.2 Result

Familiarization phase

Auditory and silent trials

Infants in both tasks watched significantly longer during the auditory (M = 7.31, SD = 1.60) than during the silent trials (M = 6.23, SD = 2.06), $t(53) = 4.71$, $p < .001$. No significant difference was found across tasks and conditions.

Looking time across three blocks

An analysis of variance with average looking time of each block as dependent variable, with block as within-subjects factor, and with condition as between-subjects factor revealed no significant main effect or interaction. The average looking times from the first to the third blocks was 7.25s (SD = 1.99), 6.82s (SD = 1.90), and 6.78s (SD = 2.12), respectively; F(2,

104) = 1.57, $p > .21$. Thus, infants were not familiarized in either the Word or the Tone condition.

Test Phase

An analysis of variance with novelty preference score (*P*) as dependent variable and with condition and task as between-subjects factors was run. The interaction between task and condition approached significance, $F(1,50) = 2,22$, $p < .14$, No significant main effect was found (Figure 8.).

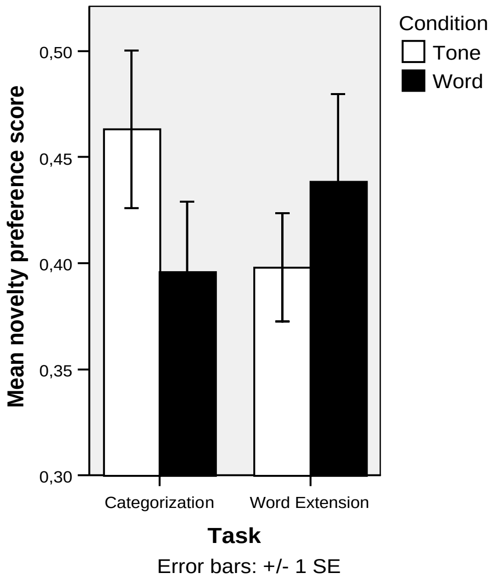

Figure 8. Experiment A-1-0 nine-month-old infants' novelty preference score in the categorization and word-extension tasks with animal-category compared between Word and Tone conditions.

The 9-month-old infants tended to display a higher *familiarity* preference in the Word than in the Tone condition in the categorization task, but a reversed trend in the word-extension task. However, due to the broad individual differences (*SD*) and probably still limited sample size (especially in the word-extension task), the preference scores were not significantly different between conditions in either task (Table 13). The scores were also not significantly different between tasks in either condition.

Table 13

Average novelty preference score (*SD*) in Experiment A-1-0 in both tasks and conditions for 9-month-old infants familiarized with animals. Score significantly different from baseline value (.39) is flagged.

	Condition						
	Tone		Word				
Task	*M*	N	*M*	N	***t***	*df*	*p*
Categorization	**.46**$^{+}$ (*.15*)	16	.40 (*.13*)	16	1.35	30	.19
Word-extension	.40 (*.08*)	11	.44 (*.14*)	11	.84	20	.41

$^{+}$ $p < .07$

With ELFRA-1, data was obtained on whether the infant could produce any word (based on raw data of I(a), see 5.1.2) . Among the 54 subjects, 19 were reported to produce at least one word (M = 2.2, SD = 1.07, ranging 1 to 4). Accordingly, these infants were labeled as high-vocabulary group and the other 35 as low-vocabulary group.

An analysis of variance with P_B (novelty preference score compared to baseline value, $P_B = P - .39$.) as dependent variable, with condition, task, and productive vocabulary group as between-subjects factors was run. The interaction between task and condition approached significance, $F(1,46) = 3{,}24$, $p < .08$. The interaction between condition and vocabulary group also approached significance, $F(1,46) = 3{,}31$, $p < .08$. The three-way interaction among the three factors tended to approach significance, $F(1,46) = 2.14$, $p < .15$. No significant main effect was found (Figure 9).

It has to be notified that in this analysis, due to limited sample size and uneven distribution of vocabulary groups, 3 of the cells related to the high-vocabulary group had a subject number equal to or less than 5. The result must be explained with caution.

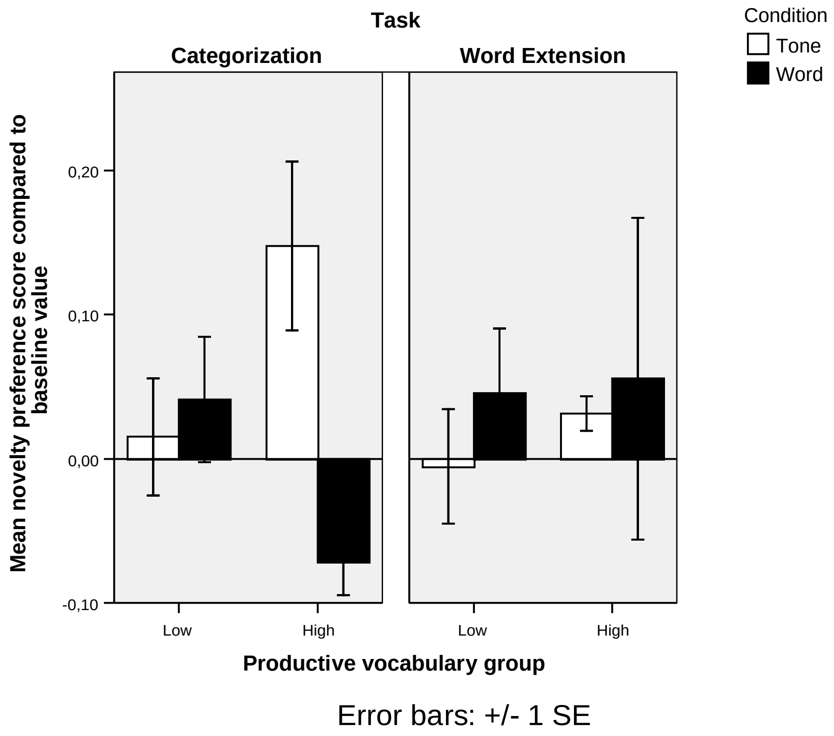

Figure 9. Experiment A-1-0 nine-month-old infants' converted novelty preference score (P_B) in the categorization and word-extension tasks with animal category compared between conditions and productive vocabulary groups.

As shown in Figure 9, the high-vocabulary group in the categorization task displayed a significantly high novelty preference in the Tone condition, $M = .15$, $SD = .15$, $t(6) = 2.53$, $p < .05$ (test value = 0); and a significant familiarity preference in the Word condition, $M = .07$, $SD = .05$, $t(4) = 3.14$, $p < .04$. The difference between conditions was significant, $t(7.70) = 3.50$, $p < .01$. The P_B scores in other cells were not significantly different from baseline value.

5.3.3 Discussion

Experiment A-1-0 revealed an interesting data pattern. The 9-month-old infants as a whole did not honor the noun-category linkage as the 12-month-old infants with high-productive language ability did. Instead, their performances were similar to the low-language ability 12-month-old infants (see Figure 4). They tended to display a familiarity preference in the categorization task in the Word condition, and a novelty preference in the Tone condition. In the word-extension task, no significant preference has been found. This data pattern was especially salient in the high-vocabulary 9-month-old infants. They displayed a novelty preference in the Tone condition but a familiarity preference in the Word condition in the categorization task.

As mentioned earlier, the analysis involving language ability has to be interpreted with caution due to the small sample size. Especially with the high-vocabulary group, although their novelty preference in the categorization task in the Tone condition was significant, the variation among subjects was large (i.e., SD = .15, n = 7), which might indicate an artifact. Comparably, the performance in the Word condition was more homogeneous (i.e., SD = .05, n = 5). With just 7 or 5 subjects in each condition respectively, the reliability of the data may be questionable. However, the data pattern might convey meaningful insights. This will soon be discussed again in 5.4.3.

Given the possible vocabulary group differences, the overall data pattern of Experiment A-1-0 suggested that the 9-month-old infants did not appreciate the linkage between nouns and object categories as older infants with more advanced language abilities did.

5.4 Experiment A-2-0: 9-month-old infants artificial object categorization and word-extension with curvilinear figures

Experiment A-2 has demonstrated that 12-month-old infants could rapidly learn a novel label for a novel object category and the label but not the non-word tone helped them to form a novel category. Experiment A-2-0 gave 9-month-old infants the same tasks as in Experiment A-2a and A-2b, but with the curvilinear category only.
If infants at the onset of language comprehension honor the noun-category linkage, they should be able to form a novel category with the help of the novel word but not with the tone sequence; and they should be able to extend the novel word to new in-category members.

5.4.1 Method

Participants

32 healthy 9-month-old infants (15 girls) participated in the categorization task (mean age 287 days, ranging 262 to 314 days). Two additional infants were excluded due to parental interference (1) or fussiness. German was the primary language spoken at home for all infants.
Another 32 healthy 9-month-old infants (15 girls) participated in the word-extension task (mean age 288 days, ranging 274 to 315 days). One additional infant was excluded due to parental interference. German was the primary language spoken at home for all but one infant, whose first language was Polish and was assigned to the Tone condition.

Material, Design and Procedure

Materials and tasks were the same as in Experiment A-2. For both the categorization and the word extension tasks, infants were randomly assigned to either the Word or the Tone condition. All children were familiarized with the curvilinear category.
Parents were asked to fill out I(a) and II(a) on ELFRA-1 (see 5.1.2) after the experiment.

Baseline preference test

As in Experiment A-2, a baseline preference test was also conducted. 20 9-month-old infants were separately recruited for this purpose. Subjects were only presented with the two silent test phase trials in Experiment A-2. It revealed that infants reliably preferred the curvilinear figures to the rectilinear ones. They spent on average 61 percent of their total looking time at the curvilinear figures, ranging .34 to .83, *SD* = .15. The value was significantly higher than chance level (.50), $t(19) = 3.41$, $p < .003$. This baseline preference .39 (i.e., 1-.61) was used to explain the results obtained later during the test phase.

Figure differentiability test

Eight additional healthy 9-month-old infants (2 girls) were sampled for this test. The procedure was the same as in 5.2.3, except that only the figures from the curvilinear category were presented. The result showed that infants reliably differentiate the figures from each other. The mean novelty preference score was .56 (*SD* = .06, ranging .52 to .67), which was significantly higher than chance level (.50), $t(7) = 3.15$, $p < .02$. All the 8 infants looked on average longer at the novel exemplars than at the familiar ones at test. The result proved that the infants can easily distinguish the different figures of the curvilinear category.

5.4.2 Result

Familiarization phase

Auditory and silent trials

Infants in both tasks watched significantly longer during the auditory (M = 8.30, SD = 1.46) than during the silent trials (M = 7.74, SD = 1.86), $t(63) = 3.79$, $p < .001$. No significant difference was found across tasks and conditions.

Looking time across three blocks

An analysis of variance with average looking time of each block as dependent variable, block as within-subjects factor, task and condition as between-subjects factors displayed a significant main effect of block, $F(2, 120) = 6.00$, $p < .01$. Test of within-subjects factor contrast of block displayed a significant linear decrement ($F(1, 60) = 7.56$, $p < .01$). The average looking times from the first to the third blocks was 8.51s (*SD* = 1.66), 7.93s (*SD* = 1.76), and 7.90s (*SD* = 1.82), respectively. Post hoc comparisons showed that the difference between the first two blocks was significant ($t(63) = 3.52$, $p < .002$), but between the second and the third was not ($t(63) = .16$, $p > .87$). No other effect or interaction was found significant.

Test Phase

To be consistent with Experiment A-2, the novelty preference score (*P*) was transformed to P_B, with $P_B = P - .39$.

An analysis of variance with P_B as dependent variable and with condition and task as between-subjects factors was run. The main effect of condition approached significance, $F(1,60) = 3.89$, $p < .06$, showing a generally higher novelty preference in the Tone than in the Word condition. The mean P_B score in the Tone condition was .02 (SD = .10); and in the Word condition, -.02 (SD = .08). No more effect or interaction was found (Figure 10).

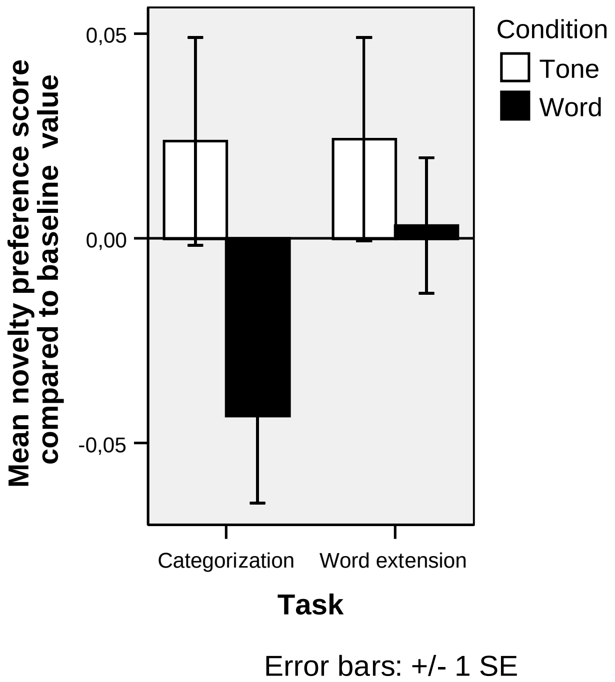

Figure 10. Experiment A-2-0 nine-month-old infants' converted novelty preference score (P_B) in the categorization and word-extension tasks with curvilinear category compared between Word and Tone conditions.

Closer examination shows that in the categorization task, the difference of the novelty preference score between conditions was significant, $t(30) = 2.02$, $p < .05$. Opposite to the 12-month-old infants in Experiment A-2a, however, the 9-month-olds showed a significant *familiarity* preference in the Word condition (Table 14). In the word extension task, the difference of the novelty preference score between conditions was not significant.

Table 14

Average P_B score (*SD*) in Experiment A-2-0 in both tasks and conditions for 9-month-old infants familiarized with the curvilinear category. Score significantly different from baseline value (.39) is flagged.

	Condition					
	Tone		Word			
Task	*M*	N	*M*	N	***t***(30)	*p*
Categorization	.02 (*.10*)	16	**-.04**$^+$ (*.09*)	16	2.02	.05
Word-extension	.02 (*.10*)	16	.00 (*.07*)	16	.71	.49

$^+$ $p < .06$

With subscale I(a) from ELFRA-1, data was again obtained on whether the infant could produce any word. Among the 64 subjects, 20 were reported to produce at least one word. One child was reported to have 28 productive words and 149 receptive words at this young age. Except this outlier, the rest 19 children had a mean I(a) score of 2.16, *SD* = 1,34, ranging 1 to 7. Accordingly, the 20 infants were labeled as high-vocabulary group and the other 44 as low-vocabulary group.

An analysis of variance with P_B as dependent variable, with condition, task, and productive language group as between-subjects factors was run. The main effect of condition was significant, $F(1,56) = 5.85$, $p < .02$. The interaction between task and condition approached significance, $F(1,56) = 3{,}81$, $p < .06$. The three-way interaction among the three factors was significant, $F(1,56) = 6.45$, $p < .02$, (Figure 11).

Again, due to limited sample size and uneven distribution of vocabulary groups, 3 of the cells related to the high vocabulary group had a subject number equal to or less than 5. The result must be explained with caution.

Figure 11 displayed a similar pattern as in Figure 9. The high-vocabulary group in the categorization task displayed a tendency of novelty preference in the Tone condition, *M* = .08, *SD* = .12. However, as only 4 subjects were in this cell, and the individual variance was again large, the score was not significantly different from 0, $t(3) = 1.26$, $p > .29$. In the Word condition, infants displayed a more homogeneous tendency of familiarity preference, *M* = -

.11, $SD = .07$, $t(3) = 2.91$, $p < .06$. The difference between conditions was significant, $t(6) = 2.58$, $p < .05$. The P_B scores in other cells were not significantly different from baseline value.

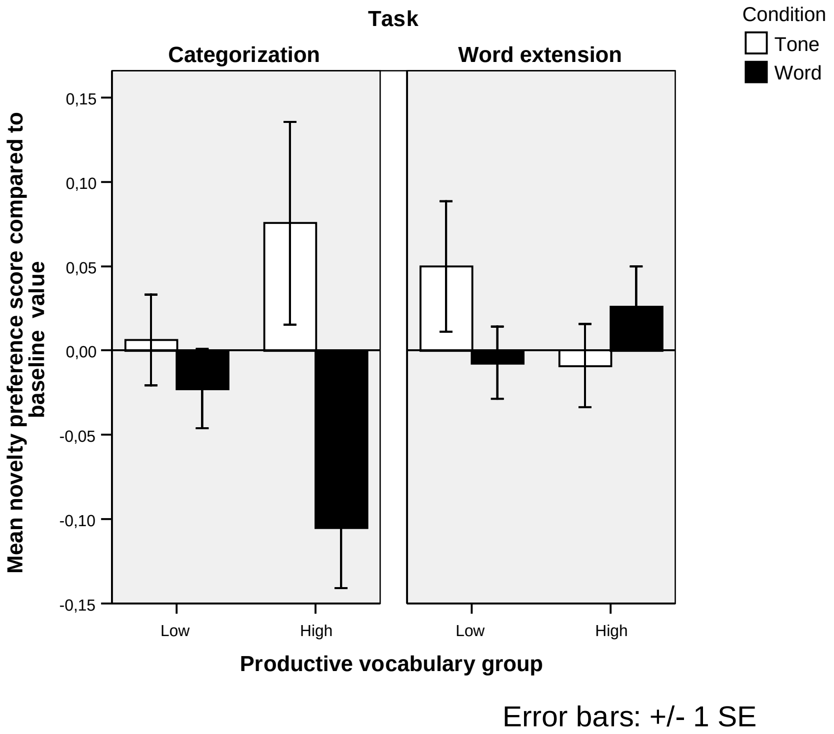

Figure 11. Experiment A-2-0 nine-month-old infants' converted novelty preference score (P_B) in the categorization and word-extension tasks with curvilinear category compared between conditions and productive vocabulary groups.

5.4.3 Discussion

In Experiment A-2-0, 9-month-old infants were given the same categorization and word extension tasks as in Experiment A-2. However, the infants performed quite differently compared to the 12-month-old infants.

In the categorization task, the 9-month-old infants displayed a significant familiarity preference in the Word condition. In the word extension task, no reliable word learning was found. Infants did not benefit from the noun-category linkage to learn a new word or to form a novel category.

The data pattern in Experiment A-2-0 was similar to the one in Experiment A-1-0, and was again similar to the performance of the low-language ability 12-month-old infants in Experiment A-1. Importantly, the analyses involving language ability as a factor in both Experiment A-1-0 and A-2-0 revealed consistent data patterns. In particular, the familiarity preference in the categorization tasks in the Word condition seems to be robust in the high-vocabulary 9-month-old infants. In the Tone condition, the novelty preference was once significant but with great individual differences. In the same aged low-vocabulary infants, in contrast, no reliable preference in any condition or task was found.

The results yielded important implications. First, by the time infants starting to produce any word, language has a special effect on their attention in the categorization tasks. Second, at the early stage of language learning, infants' do not reliably honor the linkage between words and categories but this seems changing. Third, the language influence on categorization is related to infants' language development status but has little to do with their age.

Combining the findings from both the 12-month-old and 9-month-old infants, a developmental trend seems to fold out. First, infants who just started to comprehend words did not appear to differentiate the linguistic labels and the non-linguistic tones in categorization tasks. Second, infants who just started to produce their first words did discriminate words and non-words. However, during this period, words did not consistently facilitate their categorization but sometimes *hindered* their performances. Interestingly, the non-linguistic tones sometimes seemed to show a facilitative effect on their categorization. Third, infants having more advanced ability in productive language (12-month-old high-language ability group) showed a bias to reliably discriminate words and non-words. These infants were able to take advantage of the noun-category linkage to learn novel words and to form novel object categories.

The most interesting groups were the high-vocabulary 9-month-old infants and the low-language ability 12-month-old infants. They appeared to be experiencing a transitional period of learning the noun-category linkage.

The high-vocabulary 9-month-old infants performed similarly in both Experiment A-1-0 and A-2-0. This was again very similar to the performance of the low-language 12-month-old infants in Experiment A-1. Although the infants were very different in age, they both tended to devote more time to look at the familiar category in the Word condition in the categorization tasks. As discussed before, when infants are still in the initial stage of processing the object category, they tend to show a familiarity preference at test in the categorization task (Balaban & Waxman, 1997; Hunter & Ames, 1988; Roder, Bushnell, & Sasseville, 2000; Schilling, 2000; Slater, 1995). Since they did not have a mature appreciation of the linkage between nouns and categories, novel nouns did not promote them to categorize objects. However, words did seem to direct infants' attention *towards* categories, making them to spend considerably more time to examine the familiar category during the test phase. This behavior may indicate that infants were aware of the concurrence of a serious of objects and a common label. They might be processing the possible meaning of the novel word and its connection to the group of objects.

In the novel word - artificial object category task (Experiment A-2), the low-language ability 12-month-old infants displayed an expected data pattern. In the categorization task, they tended to show a higher novelty preference in the Word than in the Tone condition. In the word-extension task, they tended to show a higher familiarity preference in the Word than in the Tone condition. The interaction between condition and task approached significance (5.2.2). The high-vocabulary 9-month-old infants did not show this pattern in this task. Presumably although the 9-month-old high-vocabulary infants had started to produce words, their general cognitive capacities were still restricted, which might attenuate the task difficulty for them. A support for this assumption came from the result of the familiarization phase in Experiment A-2-0. Although the 9-month-old infants were in general familiarized with the curvilinear figures, the decrement of looking time was much less than displayed by the older infants (see 5.2.1.2). The 9-month-olds only significantly reduced their looking time from the first to the second block, but not further from the second to the third block. The restricted familiarization effect might be caused by the general lower cognitive capacity of the infants, which had also consequence on their performance during the test phase.

Taken together, when infants did not reliably honor the linkage between nouns and categories, their performances were also not stable, suggesting a developmental period. For the low-language ability 12-month-olds, as the noun-category bias was still forming, they some times succeeded in categorization and word-learning tasks, sometimes failed, depending on the relative difficulty of the task. For the high-vocabulary 9-month-olds, the noun-category bias was also forming. Yet due to their inferior processing abilities, a relative easier task for the 12-month-olds might be still demanding for them. Thus, they displayed similar performances on both Experiment A-1-0 and A-2-0.

In short, for infants just starting to produce words, the presence of novel nouns had evident consequences on their performances in categorization tasks. Whether they would display a noun-category bias was task dependent. This suggested that the infants might still in a transitional period of learning the linkage between nouns and categories.

Another interesting finding in 5.3 and 5.4 was the effect of the non-word tones. With the high-vocabulary 9-month-old infants, the tones sometimes seemed to facilitate their categorization. Some researchers have reported that at the early stage of language learning, both words and non-word sounds are able to facilitate infants' categorization in some circumstances. Infants' acceptance of tones as labels for categories will decrease as they develop (Fulkerson & Haaf, 2003; Namy & Waxman, 1998; Roberts & Jacob, 1991; Woodward, 1998). This might also be the case in the current studies.

However, compared to the Word condition, the performances in the Tone condition varied to a great deal among subjects. Moreover, as the effect of the tone was only once significant in

Experiment A-1-0, and the subject number was quite small, it could also be an artifact. Further studies may be required to clarify this issue.

Finally, neither the high- nor the low-vocabulary 9-month-old infants displayed any reliable preference in the Word extension task. This may again suggest that the task was more difficult than the categorization task (see 5.1.3). Infants having scarce experience with language and restricted cognitive capacities did not appear to be able to succeed in this task.
In sum, studies with both 9- and 12-month-old infants demonstrated that already at the onset of language acquisition, infants with more advanced language abilities began to honor the noun-category linkage. Infants with restricted language abilities at different ages performed similarly in the categorization and word-extension tasks. They discriminated words and non-words in these tasks. However, they did not reliably honor the noun-category linkage. A bias seemed to be forming and emerging in this group of infants. Finally, infants who did not yet produce any word also did not appear to distinguish linguistic labels and non-linguistic tones in categorization and word-learning tasks. These findings supported the hypothesis that the appreciation of the noun-category linkage is more tightly related to infants' language abilities than to their age.

In both Experiment A-1-0 and A-2-0, the 9-month-old infants failed to display expected categorization but in the pilot study, the same aged infants succeeded. Why?
One possibility could be that at the beginning of language acquisition, the facilitative effect of words on categorization is only restricted to real or known words and known objects. In other words, the success in the pilot study might merely indicate the recognition of familiar word-object parings. When the objects and words are novel, the effect disappears.
A direct way to examine this possibility is to simply replace the “known” words with novel words, and keep the other parts of the pilot task unchanged. If as proposed by Waxman and colleagues (1997), infants appreciate the noun-category linkage already at the very onset of language learning, and word *per se* facilitates categorization, then a novel word should lead to the same result as in the pilot study. Consequently, Experiment A-0 was conducted.

5.5 Experiment A-0: 9-month-old infants real basic-level object categorization with pseudoword[12]

Experiment A-0 explored whether the facilitative effect of language on infant' real basic-level object categorization only restricts to real nouns or whether it holds for linguistic labels in general. The study used the same pig and rabbit categories as in the pilot study. The design and procedure was also the same. The only change was that the auditory input was replaced with German pseudowords and their matched tone sequences.

It was hypothesized that, if language *in general* facilitates object categorization already at the very beginning of word learning, then the 9-month-old infants in the pseudoword condition, but not in the Tone condition, should reveal successful categorization as they did in the pilot study.

5.5.1 Method

Participants

55 healthy 9-month-old infants (27 girls) participated in the experiment (mean age 284 days; range 249 days to 315 days). Four additional infants were excluded due to fussiness (3) or experimenter error. German was the primary language spoken at home for all but three infants. These infants were assigned to the Tone condition.

Materials

The visual stimuli were the same simple drawings of pigs and rabbits as used in the pilot study.

The auditory stimuli consisted of pseudoword phrases or tone sequences. For the “Word condition”, two German pseudoword phrases were produced by an adult female using infant-directed speech (i.e., “ein Jaloß”, which means “a Jaloß”; and “ein Frimpel”, which means “a Frimpel”). The two phrases were digitized by computer. For the “Tone condition”, two sine

[12] Some data of this experiment have been presented by: Zhang, D. & Weinert, S. (2006, September). *Language and categorization in 9-month-old infants: Innate constraint or learned word comprehension?* Paper presented at the 45th Congress of the German Psychology Society: Nuremberg, Germany.

wave tone sequences were created also by the computer, each matching to the corresponding pseudoword phrase in duration of each syllable. For the phrase “ein Jaloß”, a 400-300-500 Hz tone sequence was made. For the phrases “ein Frimpel”, a 500-300-500 Hz tone sequence was created. The phrases and the tones were matched in length and loudness and were 60dB at the position of the infant’s head.
No more change was made compared to the pilot study.
Twenty-four infants were by chance given the phrase “ein Jaloß” and its corresponding tone sequence. The remaining 31 were given the phrase “ein Frimpel” and its corresponding tone sequence. Subjects were randomly assigned to either the Word or the Tone condition.
Parents were asked to fill out I(a) and II(a) of ELFRA-1 after the experiment.

5.5.2 Results

Familiarization phase

Auditory and silent trials

As shown in Table 15, again, infants watched significantly longer during the auditory trials than during the silent trials. An analysis of variance with the difference of the average looking time between auditory and silent trials as dependent variable, with condition (i.e., Word or Tone), familiarization category (i.e., pig or rabbit), and phrase (i.e., “ein Jaloß” or “ein Frimpel”) as between-subjects factors revealed no significant effect or interaction.

Table 15
Average looking times for auditory and silent trials during familiarization in Experiment A-0.

		Looking time (s)		
		Auditory Trials	Silent Trials	$t_{(54)}$
Experiment A-0	*M*	7.33	6.67	3.34**
(n = 55)	*SD*	1.62	2.01	

** p < .005

Looking time across three blocks

An analysis of variance was conducted with average looking time of each block as dependent variable, block as within-subjects factor, and familiarization category, phrase, and condition as between-subjects factors. The main effect of block was significant, $F(2, 94) = 6.07$, $p < .003$. Tests of within-subjects contrast showed a significant linear decrement of block, $F(1, 47) = 8.88$, $p < .01$, indicating a reliable familiarization effect in both Word and Tone conditions. The average looking times were 7.65s (*SD* = 1.71), 6.92s (*SD* = 2.14), and 6.76s (*SD* = 1.97) from the first to the third blocks, respectively. No more significant effect or interaction was found.

Test Phase

An analysis of variance with novelty preference score as dependent variable, with condition, phrase, and familiarization category as between-subjects factors revealed no significant effect or interaction. The mean novelty preference score in the Tone condition was .50 (N = 27, *SD* = .09), and in the Word condition was .49 (N = 28, *SD* = .07), both not significantly different from chance level (.50). That is, no matter whether infants were familiarized with rabbits or pigs, or whether they heard the phrase “ein Jaloß” or “ein Frimpel”, no difference of looking preference was found during the test phase between Word and Tone conditions.

Additional analysis of actual looking times revealed the same data pattern. First, the overall looking time during the test phase was not significantly different between conditions. The mean overall looking time in the Tone condition was 18.96s (*SD* = 6.09) and in the Word condition 20.96s (*SD* = 5.86); $t(53) = 1.24$, $p > .22$. Specifically, in the Word condition, infants looked on average 10.40s (*SD* = 3.40) at the novel category, and 10.55s (*SD* = 3.05) at the familiar category. The difference was not significant, $t(26) = .33$, $p > .74$. In the Tone condition, infants looked on average 9.58s (*SD* = 3.61) at the novel category, and 9.38s (*SD* = 3.22) at the familiar category. The difference was also not significant, $t(27) = .29$, $p > .77$. Moreover, the looking times to the novel category were not significantly different between conditions, $t(53) = .87$, $p > .39$.. This was also the case for the looking times to the familiar category, $t(53) = 1.39$, $p > .17$.

With ELFRA-1, data was again obtained on whether the infant could produce any word. Among the 55 subjects, 15 were reported to produce at least one word (*M* = 2.3, *SD* = 1.44, ranging 1 to 7). Accordingly, these infants were labeled as high-vocabulary group and the other 40 as low-vocabulary group.

An analysis of novelty preference score as dependent variable and with condition and productive language group as between-subjects factors was run. No main effect or interaction was found. Both high and low vocabulary infants performed at chance level in both conditions.

In sum, in Experiment A-0, 9-month-old infants did not benefit from pseudowords to categorize pigs or rabbits.

5.5.3 Discussion

In Experiment A-0, pseudoword phrases instead of real nouns were used as auditory stimuli. Nine-month-old infants were given the same categorization task as in the pilot study. If language in general facilitates categorization, then the infants in Experiment A-0 should perform similarly as infants in the pilot study. However, this was not the case. The pseudowords, in contrast to the real German nouns, did not facilitate real basic-level object categorization.

During the test phase, infants in both the Word and the Tone conditions performed at chance level (.05). No novelty preference was found in either condition. In other words, infants did not appear to benefit from the pseudowords to categorize objects. As different German pseudowords led to the same result, the finding was not a random effect. This was striking since it demonstrated that when merely the real words were replaced with pseudowords, the facilitative naming effect on categorization disappeared. It shoots at the heart of the hypothesis that language *in general* facilitates object categorization.

As the words in Experiment A-0 were selected from a list of German pseudowords for language studies, the prosodic features of the words were not strange to the infants. Thus, the difference between the real words and the pseudowords was forthright: the former might have been heard and associated with the corresponding objects by the infants, the latter was completely new. Therefore, Experiment A-0 and the pilot study together seemed to indicate that at the onset of language comprehension, only known words help infants to access familiar categories. The findings in the pilot study, accordingly, might be merely the recognition of familiar word - object parings.

In Balaban and Waxman’s study (1997), they also used content-filtered words as auditory stimuli. The content-filtered words (or low-path-filtered words) were created by filtering out the high frequencies (i.e., higher than 650Hz) from naturally pronounced words. They sounded like being produced by someone in a thick container. Adults hearing the words could tell that words were being spoken but had difficulties to discern their meanings (Balaban & Waxman, 1997). That is, the words sounded like speech, but were blurred. Balaban and Waxman used these filtered words as auditory stimuli and obtained the similar effects as the original real words. They then concluded that word per se facilitate categorization.

However, the content-filtered words still remained the key prosodic cues as the real words. Except the high pitch, the intonation, the stress and the rhythm of the words were intact. It was possible that at this young age, the 9-month-old infants accepted the low-path-filtered words as the original real words based on their key prosodic cues (Mehler et al., 1988). Alternatively, even the filtered words were not immediately perceived as the real words, as infants hearing the filtered-words and seeing the "appropriate" pictures simultaneously, the paring between the original word and the picture might be primed and a familiar word-object match could be recognized. Thus, content filtered words are not typical for "word *per se*". Instead, novel words or pseudowords would be more appropriate. Unfortunately, with pseudowords, Experiment A-0 failed to demonstrate the expected word effect on categorization.

While recognition of familiar word-object parings may account for infants' success in the pilot study, a so called "mutual exclusivity" bias might explain their failure in Experiment A-0. It has been proposed that at the early stage of language acquisition, young children tend to accept just one name for a given object, especially with the basic-level objects. They are reluctant to learn a second label for an object for which they already have a name (Au & Glusman, 1990; Clark, 1991; Ishida et al., 2003; Liittschwager & Markman, 1994; Markman, Wasow, & Hansen, 2003; Merriman & Stevenson, 1997). Accordingly, if infants knew the labels for pigs and rabbits, the presence of the pseudoword could have confused them and be responsible for their failure in the task.

In comparison, 9-month-old infants are less likely to have a name for a global-level category, as infants' early nouns are primarily basic-level words (Bates et al., 1988; Bates et al., 1994; Fenson et al., 1994; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Infants would also not have a name for an artificial category. If infants did honor a noun-category linkage, they should demonstrate it in tasks involving these categories. Failures in these tasks can not be attributed to the mutual exclusivity bias, but indicate that infants do not yet appreciate the linkage between nouns and categories.

Present studies consistently suggested that at the very onset of language acquisition, infants do not reliably honor the noun-category linkage.

In Experiment A-0, both high- and low-vocabulary infants performed at chance level. Did they both treat the pseudowords and the non-word tones equivalently? Not necessarily. Examining the three categorization tasks with the 9-month-old infants together, another explanation may be conceivable.

In the pilot study, both the words and categories might be familiar to the infants. A facilitative word effect was demonstrated[13] (i.e., significant novelty preference). In Experiment A-0, the categories might be familiar but the linguistic labels were new. No significant word effect was found in either language group (i.e., no preference). In Experiment A-1-0 and A-2-0, the categories were new, or the categorical commonalities were obscure, and the words were also new. A “debilitative” word effect appeared in the high-vocabulary infants (i.e., significant familiarity preference), but no effect appeared in the low-vocabulary group. These results together appeared to indicate that the high-vocabulary group infants might indeed discriminate words from non-linguistic tones in all cases. Whether infants display a novelty preference, a familiarity preference, or an in-between behavior seems to be a function of the task complexity and infants’ language ability (Figure 12). Such an interaction between task difficulty and language ability fits well into the hypothesized schema that the noun-category linkage is immature and emerging in the infants, and the emergence is strongly correlated with infants’ language development status.

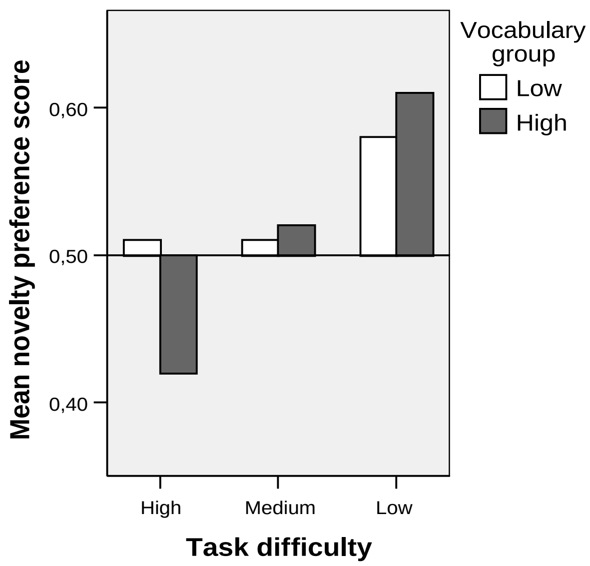

Figure 12. A simulated novelty preference pattern as a function of language ability and task difficulty in categorization tasks based on data obtained from 9-month-old infants in Experiment A and the pilot study.

[13] Unfortunately, in the pilot study no language assessment has been conducted. It was not known whether the high- or low-vocabulary infants performed equally on the real word - real object category task.

At the beginning, infants may first learn to match known words to familiar categories. Both high- and low-vocabulary infants may succeed in tasks in which recognition of familiar word-category parings was required.

However, infants already diversify at this initial stage. Those with more advanced language abilities start to differentiate the function of words and non-words. They are on their way of acquiring the linkage between words and categories. When they are encountered with a complicated categorization task, in which novel words and novel categories, or categories with heterogeneous perceptual features are presented, the presence of novel words leads infants to show a familiarity preference. The low-vocabulary infants, as a comparison, do not seem to treat the words and non-words differently in such tasks.

When infants are confronted with an intermediate task, in which familiar categories with homogeneous perceptual features are presented, but accompanied with a novel word, an intermediate response may appear. In such tasks, although infants' performances do not appear to be different between language groups, the similar behavior may be caused by dissimilar mechanisms. For the high-vocabulary infants, this may imply a transitional juncture between familiarity and novelty preference. For the low-vocabulary infants, this may suggest either a transitional response or, more likely, a non-differentiation of words and non-words.

However, as no significant preference was found in Experiment A-0, such interpretation is only an assumption - an assumption encompasses infants' behavior across interrelated tasks with different levels of complexity. According to this assumption, infants already diverge at this early stage of language learning. Those with a little more advanced vocabulary start first to notify the inherent distinction between words and non-words. The linguistic cues have a special influence on their attention in categorization-relevant contexts. As infants' language and concept learning proceeds, a noun-category bias may emerge. Infants will gradually acquire the natural link between nouns and object categories, which will reversely helps them to learn new words and new categories.

5.6 Summary

Experiment A systematically investigated the emergence of the noun-object category linkage with 9- and 12-month-old infants (Table 16). It demonstrated that by the time infants produce their first words, they begin to benefit from the linkage to learn *novel* words and form *novel* categories. However, the ability is still developing and fragile.

First, it could be overridden by infants' natural preference. Second, when encountering perceptually more heterogeneous categories, only the language more advanced 12-month-old infants were found to honor the linkage but the language less advanced same aged or younger peers did not. Third, the 9-month-old infants only succeeded in the real word - real object categorization task but failed in the same task if only the real words were replaced with pseudowords. Finally, although the 9-month-old infants as a whole failed in categorization tasks including novel words or novel objects, the high-vocabulary infants still performed distinctively from the low-vocabulary peers.

These findings together implied that at the very onset of language learning, infants do not have a reliable expectation linking nouns and object categories. Rather, the noun-category linkage is gradually forming and developing. Each step of progress is associated with infants' language development.

Table 16

Overview of results in the Word condition in Pilot study and Experiment A (*n.p.*: no preference).

		Real basic-level object category		Artificial object category		Real Global-level object category	
Perceptual feature	Visual stimuli	homogenous familiar		homogenous novel		heterogeneous	
	Auditory stimuli	familiar	novel	novel		novel	
Language ability		low and high		low	high	low	high
Categorization task	9-month-old	novelty preference	*n.p.*	*n.p.*	familiarity preference	*n.p.*	familiarity preference
	12-month-old	-	-	novelty preference	novelty preference	familiarity preference	novelty preference
Word-extension task	9-month-old	-	-	*n.p.*	*n.p.*	*n.p.*	*n.p.*
	12-month-old	-	-	familiarity preference tendency	familiarity preference tendency	*n.p.*	familiarity preference tendency

6. Experiment B[14]

As planned in Chapter 3, in parallel to Experiment A, Experiment B was conducted with 15- and 18-month-old infants with a modified match-to-sample task presented with preferential looking paradigm.

In Experiment B, infants were confronted with different global-level object categories. As would be predicted by the taxonomic constraint assumption, infants were expected to extend different novel words categorically.

It was hypothesized that:

a. By the time infants rapidly acquiring novel words, they honor the taxonomic constraint and can extend novel words categorically in top-down word learning tasks.
b. The performance is more closely related to infants' language abilities than to their age.

6.1 Method

<u>Participants</u>

Seventeen (9 girls) healthy 15-month-old (mean age 15 months and 14 days; *SD* = 12.68) and 37 (19 girls) 18-month-old (mean age 18 months and 29 days; SD = 21.05) infants participated in the experiment. One additional 15-month-old infant was excluded as she did not come for the second visit (see <u>Design and procedure</u>). Six additional 18-month-old infants were excluded due to fussiness (2), absence for the second visit (3), or experimenter error (1). German was the only language spoken at home for all infants.

<u>Materials</u>

The visual stimuli were 10 true-color picture-triads of different objects (see Table 17 for a complete list of triads and Figure 13. for an illustration of a triad). Each triad was composed of a target picture (e.g., an apple), a picture of a different object from the same global-level category (e.g., a strawberry) and a picture of a thematically related object (e.g., a tree). All

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[14] Some data of this experiment have been presented by: Weinert, S. & Zhang, D. (2007, March). *Early lexical development and the emergence of the taxonomic bias in 15- and 18-month-old German infants*. Poster presented at the biennial meeting of the Society for Research in Child Development: Boston, MA, USA.

the objects were about 25cm in height and were presented against a pleasant light-colored background.

Table 17

Object-triads presented in Experiment B.

	Target picture	Taxonomic match	Thematic match
1	pot	pan	oven
2	sheep	horse	meadow
3	dress	shorts	coat hanger
4	tractor	truck	highway
5	bed	table	baby
6	apple	strawberry	tree
7	bee	beetle	flower
8	carrot	tomato	hare
9	T-shirt	cap	washing machine
10	cake	pretzel	bread knife

Table 18

Pseudowords and their matched tones presented in Experiment B.

Pseudoword phrase	Frequency of each syllable of the matched tone sequence (Hz)	Duration of each syllable for both the pseudoword phrase and the matched tone sequence (ms)
eine Brame	300-400-500	322-275-351
ein Dobus	300-300-300	432-332-461
ein Zawo	500-300-500	332-492-424
eine Ihle	300-500-400	381-301-260
ein Maling	400-400-500	310-350-345

The auditory stimuli consisted of pseudoword-phrases or matched tone sequences. For the “Word condition”, five German pseudoword-noun-phrases were produced by an adult female using infant-directed speech (see Table 18 for a complete list of pseudoword-phrases). The noun phrases were digitized by a computer. For the “Tone condition”, 5 sine wave tone sequences were created also by the computer, each matching to the corresponding noun

phrase in duration of each syllable (see Table 18 for the components of frequency for each matched tone sequence). The words and the tones were matched in loudness and were 60dB at the position of the infant's head.
Stimuli were also presented with PowerPoint.

Design and procedure

Each infant was tested with a Tone and a Word condition on two separate visits, with a one-week interval in between. Half of the infants were presented with the Tone condition first and the other half the Word condition first. Infants viewed five of the ten picture-triads in one condition and the remaining triads in the other condition. The selection of triads and their presenting order were rotated across subjects. Picture-triads were presented equally often in both conditions. Audio stimuli were presented in a fixed order as shown in Table 18 in the appropriate condition.
At the onset of the experiment, an animated penguin appeared on the central monitor against a blue background, accompanied with a pleasant bell ring for 3s to attract infant's attention. This was immediately followed by the first picture-triad.
Each picture-triad was presented in a familiarization and a test phase. During the familiarization phase, the target picture was shown on the central monitor three times, each for 7 seconds, with 1 second interval between trials. This was immediately followed by two test trials, on which the taxonomic match and the thematic match of the target picture were presented one on the left and one on the right monitor simultaneously. The left-right position of the taxonomic match on the first test trial was randomized and was then reversed on the second test trial. The first test trial was presented for 8 seconds and was immediately followed by the second trial for 7 seconds (see Figure 13 for an illustration). The interval between two picture-triads was 2 seconds.

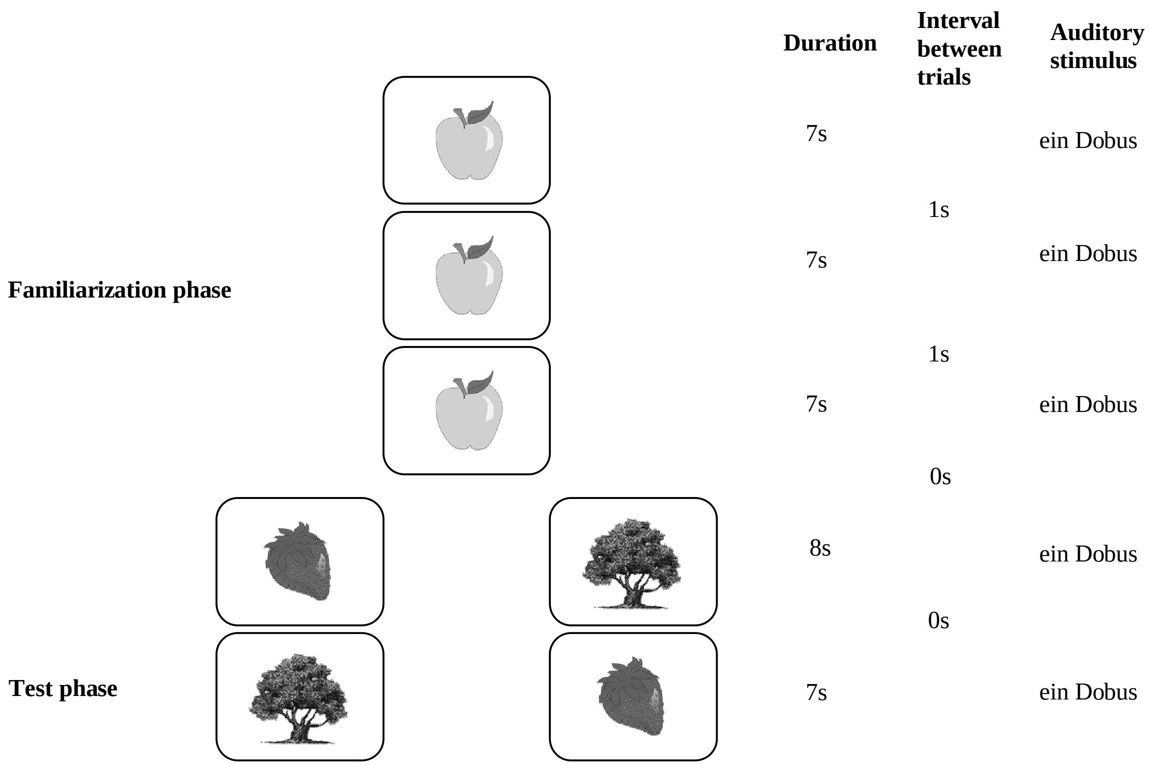

Figure 13. Example of the presentation of one picture-triad in the Word condition in Experiment B.

In the Word condition, each picture-triad was accompanied with one of the five pseudoword phrases. The same phrase was presented once on each familiarization and test trial. In the Tone condition, triads were presented with the corresponding sine wave tone sequences. The onset of the phrase or the tone sequence was synchronized with the onset of the picture. In the Tone condition, the auditory stimulus was replaced with the corresponding tone-sequence shown in Table 18.

During the experiment, infants sat on their parent’s lap 1.20m away from the central monitor. Parents were asked to look only at their child but not to the monitors and not to draw the infant’s attention in any way.

An experimenter stayed in a room next to the observation room during the whole experiment. After starting the PowerPoint presentation, she controlled the camera to track and record the eye movement of the infant for later coding.

At the end of the first visit, parents were given the language checklist ELFRA-1 and asked to fill it out and bring it back on their second visit.

6.2 Results

Familiarization phase

First, it was examined whether infants systematically reduced their looking time from the first to the third trial during the familiarization phase. An analysis of variance was run, with looking time as dependent variable, with trial order (1st to 3rd) and condition (Word or Tone) as within-subjects factor, and with age group as between-subjects factor.

Table 19
Experiment B average looking times (*SD*) averaged across five picture triads on each familiarization trial.

		Familiarization Trial		
	Condition	1	2	3
15-mon-old	Tone	6.19	5.62	5.43
		(0.68)	*(0.93)*	*(0.81)*
	Word	6.00	5.71	4.98
		(1.10)	*(1.26)*	*(1.16)*
	Total	**6.10**	**5.67**	**5.21**
		(0.79)	*(0.81)*	*(0.71)*
18-mon-old	Tone	6.44	5.50	5.17
		(0.83)	*(1.12)*	*(1.32)*
	Word	6.62	5.68	5.26
		(0.89)	*(1.06)*	*(1.36)*
	Total	**6.53**	**5.59**	**5.21**
		(0.72)	*(0.95)*	*(1.18)*

The main effect of trial order was significant ($F(2, 104) = 68.44$, $p < .0001$), showing that infants significantly reduced their looking time from the first to the third familiarization trial. The interaction between trial order and age group was significant, $F(2, 104) = 4.07$, $p < .02$, which turned out to be caused by the longer looking time on the first familiarization trial by the 18-month-olds than the 15-month-olds, $t(54) = 1.98$, $p < .06$ (Table 19). No more significant effect or interaction was found. In other words, infants in both age groups were familiarized to the same extent in both conditions.

Test Phase

A taxonomic preference score in each condition was calculated for each infant: the total looking time at the taxonomic matches by an infant over the five picture-triads was divided by her total looking time during the test phases.
An analysis of variance with taxonomic preference score as dependent variable, with condition (Word or Tone) as within-subjects factor, and with age group as between-subjects factor revealed no significant main effect. However, the interaction between condition and age group approached significance, $F(1,52) = 2.08$, $p < .08$, one-tailed.
Subsequent analysis revealed that infants at 15 months of age did not demonstrate reliable taxonomic preference in any condition. The mean taxonomic preference score was .50 (*SD* = .05) in the Tone condition, and .51 (*SD* = .06) in the Word condition. Neither was significantly different from chance level.
The 18-month-old infants displayed a different data pattern. Paired-Samples *t*-test revealed a higher taxonomic preference score in the Word than in the Tone condition, $t(36) = 1.82$, $p < .04$, one-tailed. In the Word condition, the mean taxonomic preference score was .52 (*SD* = .07), which was significantly higher than chance level (.50), $t(36) = 1,99$, $p < .054$, indicating a taxonomic preference. In the Tone condition, the score was .49 (*SD* = .07), which was not significantly different from chance level, $t(36) = .45$, $p > .65$. Among 37 infants, 24 (64.9%) displayed a taxonomic preference score greater than .50 in the Word condition. In the Tone condition, only 13 infants had a taxonomic preference score higher than .50. The difference was significant, $\chi^2(1, N= 37) = 4.39$, $p < .05$.

Table 20
Overall looking times during the test phases for both age groups in the Tone and the Word condition in Experiment B.

		Condition		
		Tone	Word	
15-month-olds	*M*	12.76	12.56	$t_{(16)} = .56$, $p > .58$
	SD	1.18	1.99	
18-month-olds	*M*	12.95	12.86	$t_{(36)} = .31$, $p > .76$
	SD	1.40	1.46	

A separate analysis transposed the data set of the 18-month-olds. The ten picture-triads were accordingly taken as cases, with scores averaged across the subjects as variables. It revealed the similar result. Paired-samples t-test showed that across picture-triads, the taxonomic preference score was significantly higher in the Word than in the Tone condition, $t(9) = 2.76$, $p < .03$. The mean taxonomic preference score in the Tone condition for the ten picture-triads was .50 (*SD* = .14) and in the Word condition was .53 (*SD* = .12). For 8 of the ten picture-triads, the taxonomic preference score was higher in the Word than in the Tone condition.

Additional analysis of actual looking times during the test phases revealed a compatible data pattern. The overall looking time during the test phase was first examined. For both age groups, this was not significantly different between conditions (Table 20).

In more details, in the Word condition, 18-month-old infants looked on average 6.73s (*SD* = 1.24) at the taxonomic exemplars, and 6.13s (*SD* = .95) at the thematic exemplars. The difference was significant, $t(36) = 2.17$, $p < .04$. In the Tone condition, they looked about equally long at the taxonomic (*M* = 6.43, *SD* = 1.28) and the thematic exemplars (*M* = 6.52, *SD* = 1.01), $t(36) = .29$, $p > .78$. Also, the looking time at the thematic exemplars was longer in the Tone than in the Word condition, $t(36) = 1.71$, $p < .05$, one-tailed, indicating that infants tended to reduce their attention to the thematic matches in the Word condition.

Infants at 15 months of age, again, did not show any looking preference in either condition. In the Tone condition, their looking time at the taxonomic exemplars was 6.45s (*SD* = .87), and was 6.31s (*SD* = 1.24) at the thematic exemplars; and in the Word condition, they were 6.24s (*SD* = 1.16) and 6.32s (*SD* = 1.13) respectively.

It seemed that only the 18-month-old but not the 15-month-old infants appreciated the taxonomic constraint. However, this was far from the whole story.

Infants' receptive and productive language data measured by ELFRA-1 are shown in Table 21.

Table 21

Infants' productive and receptive language measured by ELFRA-1 in Experiment B.

	15-mon-olds n = 17		18-mon-olds n = 37	
	Reception	Production	Reception	Production
M	81.24	22.47	132.62	62.70
SD	*35.27*	*18.51*	*26.65*	*48.84*
Min.	7	2	63	14
Max.	132	61	180	180
50 Percentile	*86*	*15*	*134*	*37*

The correlation between the receptive language size and the increment of the taxonomic preference from the Tone to the Word condition was calculated. Person correlation $r_{(n = 54)}$ = .24, p < .08, indicating the taxonomic bias was influenced by infants' receptive language size. In order to examine whether infants with the similar language abilities also performed similarly in the match-to-sample task, infants of different ages but with similar language abilities were compared. Twelve 15-month-olds and sixteen 18-month-olds were matched on their language abilities (Table 22). Neither the receptive nor the productive language size was significantly different between age groups.

An analysis of variance with the taxonomic preference score as dependent variable, with condition as within-subjects factor, and with age group as between-subjects factor revealed no significant effect or interaction. In other words, when infants with matched language abilities were compared, the difference between age groups disappeared. Both groups performed similarly on the match-to-sample task (Table 22). No group has displayed a reliable taxonomic preference in either condition.

Table 22

Taxonomic preference scores from language ability matched infants at different ages in Experiment B.

		15-month-olds n = 12		18-month-olds n = 16	
		Receptive language	Productive language	Receptive language	Productive language
	M	**99.67**	**24.42**	**107.81**	**32.19**
	SD	19.86	18.90	15.14	15.19
	Min.	60.00	6.00	63.00	14.00
	Max.	132.00	61.00	130.00	62.00
Percentile	25	86.00	8.00	100.75	20.00
	50	**103.00**	**16.50**	**111.50**	**29.00**
	75	113.25	43.00	115.75	44.50
	Condition				
Taxonomic preference score (*SD*)	Tone	.51 (*.05*)		.48 (*.07*)	
	Word	.49 (*.04*)		.50 (*.07*)	

For the 18-month-old infants, an analysis of variance with the taxonomic preference score as dependant variable, with condition as within-subjects factor, and with receptive language group (high-low groups was divided by the 50th percentile) as between-subjects factor was run. It revealed a significant effect of condition, F (1, 35) = 5.00, $p < .04$. The interaction between condition and receptive language group approached significance, F (1, 35) = 3.89, $p < .06$.

Paired samples t-test showed that for the high receptive language ability group, the difference of the taxonomic preference score between conditions was significant, $t(14) = 2.91$, $p < .01$. For the lower receptive language ability group, this was not significant, $t(21) = .20$, $p > .84$ (Table 23).

Table 23

The taxonomic preference scores compared between high- and low-language ability groups in different conditions in 18-month-old infants in Experiment B. Scores significantly different from chance level (.50) are flagged.

Condition	Receptive language Group	*M*	*SD*	n
Tone	Low	0.50	0.08	22
	High	0.49	0.07	15
	Total	0.49	0.07	37
Word	Low	0.50	0.06	22
	High	**0.55***	0.06	15
	Total	**0.52^{+}**	0.07	37

* $p < .05$, $^{+}p < .06$

In addition, infants with the highest and lowest receptive language sizes were compared (Table 24). Each group contains 12 subjects. The same data pattern was revealed. The high-language ability infants demonstrate significant taxonomic preference in the Word but not in the Tone condition. The difference between conditions was significant, $t(11) = 2.53$, $p < .03$. The lower receptive language ability group showed no reliable preference in either condition.

Taken together, only the high receptive language ability infants displayed the assumed taxonomic constraint. They showed a clear taxonomic preference in the Word but not in the

Tone condition. Infants with the same age but lower language abilities did not display the bias, nor did the younger infants with the similar language abilities.

Table 24

The taxonomic preference scores compared between the highest and the lowest language ability groups in different conditions with 18-month-old infants in Experiment B. Scores significantly different from chance level (.50) are flagged.

Condition	Receptive language Group	*M*	*SD*	n
Tone	Lowest	0.49	0.07	12
	Highest	0.49	0.08	12
	Total	0.49	0.07	24
Word	Lowest	0.51	0.08	12
	Highest	**0.56***	0.04	12
	Total	**0.53***	0.07	24

* $p < .05$

6.3 Discussion

Experiment B gave a modified top-down match-to-sample task to infants between 15 and 18 months of age. It suggested that the ability to take advantage of the taxonomic constraint to learn novel words and then to extend them categorically may emerge during this period. The study augmented knowledge on the taxonomic constraint with infants younger than 2 years of age. Importantly, it revealed that the emergence of the constraint was closely related to infants' language development. Infants with more advanced language ability succeeded in the match-to-sample task in Experiment B, whereas those at the same age with lower language ability did not. The latter group performed just similarly as their younger peers with comparable language abilities did. It was evident that whether infants appreciate the taxonomic constraint was not determined by their age, but more strongly associated with their language learning progressions.

In Experiment B, most 15-month-old infants had only limited productive language. Only one infant was reported to produce more than 50 words. The skewness value of the distribution was 1.12, indicating a strong positive skew. The receptive language had a broader and more normal distribution among these infants. It had also a greater overlap with the receptive language of the 18-month-old group. Therefore, the analysis has taken the receptive language score as criterion when comparing infants' language ability.

The experiment chose the global-level object categories as stimuli with the following consideration. First, it has been reported that naming effect on categorization is especially salient with global-level categories (Fulkerson & Haaf, 2003; Waxman & Markow, 1995). It was also found that infants with high or low vocabulary sizes performed differently on categorization tasks when presented with the global-level object categories (Waxman & Markow, 1995). As the different language ability effects on the emergence of the taxonomic constraint was of interest in the current research, to select global-level categories appear to be promising. Second, a pilot study conducted by the author with both basic- and global-level categories seemed to indicate a "mutual-exclusivity effect" with the basic-level categories. In this pilot test, infants at different ages were sampled. During the familiarization phases, upon hearing the pseudowords, several infants explicitly shook their heads or repeatedly said "nein" (means "no") to the basic-level categories. During the test phases, infants did not display any significant preference with the basic-level object categories. The new names for known objects seemed to have distressed the infants (see also 5.5.3). For these reasons, Experiment B only selected the global-level categories. However, it is certainly not excluded that the taxonomic constraint may also facilitate infants to learn novel basic-level nouns (Golinkoff et al., 1995; Markman & Hutchinson, 1984; Shuff-Bailey, 1996)

Experiment B did not intend to find a causal relationship between word learning and the appreciation of the taxonomic constraint. Rather, it provided evidence that both are undergoing developing changes. They interact intimately with each other. As infants building their lexicon, they might gradually gain the insight that nouns name objects of the same kind. Reversely, the insight may facilitate novel word learning forcefully. A word learning constraint may itself be learned through the word learning process.

To sum up, just as hypothesized, Experiment B provided evidence that by 18 months of age, infants began to honor the taxonomic constraint. The emergence of the constraint was more closely related to infants' language abilities than to their age.

7. Summary of experiments

The current research was the first attempt to systematically investigate the emergence and development of an assumed word learning constraint - the taxonomic constraint.

The constraint has been proposed to account for young children's rapid noun learning starting around 18 months of age. It has been well demonstrated in children at 2 years of age or older. Only few studies have been conducted with younger infants. From infants starting to comprehend words to 2 years of age, substantial developmental changes take place in language learning and other areas. Does a constraint supposed to facilitate word learning emerge during this period? Does it interact with infants' language development?

Two lines of experiments were conducted to explore these questions.

In the first line of experiments, infants at 9 and 12 months of age were sampled. A series of bottom-up categorization tasks and word-extension tasks were conducted. It was explored whether a precursor of the taxonomic constraint might already be evident at the onset of language acquisition.

It was found that towards the end of the first year of life, the language more advanced infants began to honor the linkage between nouns and object categories. They were able to rapidly learn a novel name for a novel category or for a global-level category. They could also take advantage of the novel linguistic label to form a novel category or to access global-level categories. A prelude of the taxonomic constraint - the noun-category bias - became evident. However, the bias was vulnerable and subjected to infants' natural preference.

Between 9 and 12 months of age, infants start to produce their very first words. These infants were not found to reliably honor the noun-category linkage. Although they were already biased to discriminate words and non-words, whether they could take advantage of the noun-category linkage to learn novel words or to form categories was highly contingent. Sometimes they even appeared to be hindered than supported by linguistic cues in the categorization and word-extension tasks.

By 9 months of age, most infants do not produce any word. These preverbal infants seemed to first learn to match some known words to some known categories. They did not yet discriminate novel words and non-word tones in the categorization and words-extension tasks.

Importantly, the emergence of the noun-category linkage turned out to be more closely related to infants' language development status than to their age. At 12 months of age, when perceptual features of the object categories were heterogeneous, only infants with higher language abilities honored the noun-category linkage. Those with restricted language abilities did not. When perceptual features of the object categories were more homogeneous, both language groups succeeded, yet the expected interaction between task and condition was only significant in infants with higher language abilities. At 9 months of age, infants with higher vocabulary sizes performed similarly as the low-language ability 12-month-old infants. Yet they appeared to be even more restricted by their general processing capacities on the tasks. The low-vocabulary 9-month-old infants demonstrated no sign of honoring the noun-category linkage.

In the second line of experiments, infants at 15 and 18 months of age were sampled. It was investigated whether the taxonomic constraint, manifesting in a top-down manner, emerges during this period. The assumed constraint was first found in the 18-month-old group but not in the 15-month-group. However, closer examination revealed that the constraint was more associated with infants' language abilities than with their age. First, the task performance was significantly correlated with infants' receptive vocabulary. Second, when the language abilities were matched, infants from different age groups performed as the same. Third, within the same 18-month-old group, only the high-language ability infants demonstrated the constraint while the lower group did not.

The two lines of experiments have converged to suggest that the assumed taxonomic constraint emerges gradually as young infants acquire language. Shortly after word production begins, a precursor of the constraint is evident. By the time infants begin to more efficiently expand their productive language, they benefit from the taxonomic constraint to learn novel words. The emergence and the development of the constraint seem to be closely related to the status of infants' language development.

8. General discussion

8.1 Advantages and restrictions of methods and measurements

The current research applied consistent methods to systematically investigate the taxonomic constraint. The preferential looking paradigm has been used for all the experiments. In Experiment A, a bottom-up procedure was used. With the same tasks, infants at different ages and with disparate language abilities were compared. Moreover, with the same task structure, a range of stimuli were compared (i.e., real words, pseudowords, or non-word tones; global- or basic- level, or artificial categories). In Experiment B, a top-down procedure was adapted. It was proved to be sensitive to discover targeted behavior within and across different age and language groups.

Some aspects of the methods have been proved to be contributive to the current research.

First, in both Experiment A and B, only minimal auditory stimuli were presented. Infants heard just a word phrase or its matched tones for each task or sub-tasks. No more redundant cues (i.e., social, functional, etc.) were provided. In so doing, infants' performances in different conditions (Tone or Word) were directly attributable to the presence or absence of the linguistic label. This has certain advantages than previous studies using more complicated auditory instructions. For example, in previous studies with similar tasks, infants in the Word or Label condition were often prompted by sentences like "Look, this is a *X*. Do you see the *X*? Where is the *X*? Can you find the *X*?" (*X* is a novel word), and so on. In the No-label condition, infants often heard "Look. Look at this (one). Do you see this (one)? Where is it? Can you find it/another one?" or alike. Sometimes the pronouns were replaced with a non-linguistic sound or mouth-noise (e.g., Fulkerson & Haaf, 2003; Woodward & Hoyne, 1999). This kind of instructions may attract some infants' attention but may also raise the issues such as the Word and Tone conditions are prone to be incomparable (Mareschal & Quinn, 2001), or the No-label condition could still remind the infants of typical naming routines (Waxman & Lidz, 2006). Both, if true, would be detrimental to the experiment. In the current research, such confusions can be excluded. The concise auditory stimuli turn out to function well in the experiments. The short auditory stimuli are especially recommendable to studies in which excessive instruction may induce unwanted task complexity (e.g., when children have limited or impaired language or cognitive abilities).

Second, in Experiment A, novel object categories and novel words were used as stimuli. Previous studies in young infants have mostly used real common objects as stimuli in categorization tasks (but see Fulkerson & Haaf, 2006). This restricts the generalizability of their findings. With novel artificial categories and pseudowords, the recognition effect can be ruled out. Novel object categorization and novel word-learning have been evaluated. Further studies with artificial materials representing different levels of concepts are desirable in exploring infants' language and concept acquisition.

Third, a new word-extension task has been introduced in the current research. It was the first attempt to investigate whether very young infants could learn a novel label for an object category, in contrast to just a single object, and then extend the label categorically. It provided a comparable task to the categorization task. Some expected differences in performances have been revealed in the two different tasks in the current research. However, as the word-extension task might require more complicated cognitive processes (see discussion in 5.1.3), the hypothesized familiarity preference in the Word condition was not always apparent. It was sometimes not clear-cut whether a no-preference result indicated a word effect (in a sense of inhibiting a novelty-preference) or simply no effect. Although a no-preference might indicate a transitional period between the familiarity and the novelty preferences, it can not be taken as a given. Comparisons between categorization and word-extension tasks and between Word and Tone conditions are meaningful but not sufficient in all cases. For example, with the high-vocabulary 9-month-old infants, when they displayed a significant familiarity preference in the Word condition in the categorization task (e.g., Experiment A-2-0), and there was no difference between conditions in the word-extension task, it was difficult to provide a clear explanation. Did infants simply treat the tone and the word in the word-extension task as the same, or they treated them differently but just could not succeed in the extension task yet? Current studies could not yet answer these questions.

Some limits related to the research paradigm and methods also appeared as the experiments proceeded.

First, the fixed-trial familiarization procedure does not take account of individual differences in processing capacity and pace. Infants were not habituated to the same criterion with this procedure. When infants displayed unexpected no-preference or familiarity preference, the fixed-trial familiarization procedure could not clearly conclude whether the performance was caused by the absence or immaturity of the word learning bias or simply caused by under-familiarization. Such ambiguity might be better clarified with an infant-adapted habituation procedure.

Second, with the preferential looking paradigm, there is always an issue whether the stimuli during the test phase are comparable. When only a limited number of subjects are available, as was the case in the region of Bamberg, a priority test of stimuli is a luxury. If the researcher uses strictly only the pre-selected equally attractive stimuli in preference tasks, he will have to spend many subjects before he can find suitable and enough experiment stimuli. On the other hand, if the researcher accepts unequal test stimuli, the risk would be that the priority effect might interact with other experimental factors. For instance, in Experiment A-1, although there was a priority effect (i.e., infants preferred animals to fruits), it did not interacted with other experimental variables. However, in Experiment A-2, the priority effect significantly interacted with other experimental factors. This had certainly affected the results. With the rectilinear category, no reliable effect was observed. It was rather unclear, whether the strong priority effect has covered the naming effect, or the linguistic label had no influence with this object category. At this time, unfortunately, the question has to be left open.

Third, as discussed before, the author was aware that the bottom-up and the top-down procedures were not equal. Yet, an expected data pattern revealed by the bottom-up procedure indicated at least a precursor of the taxonomic bias. It is questionable whether very young infants, with their very limited knowledge of objects, can also be tested with the same top-down task as the one used with the older infants. If one is interested in the continuous developmental changes, more ingenious tasks that can be conducted across a wide range of age groups are still needed. Alternatively, longitudinal studies may serve as compensation. It could be a correlation between the early performance on the bottom-up tasks and the later performance on the top-down tasks. This can be followed up along with infants' language and cognitive developments.

Fourth, no appropriate language development assessment was available for the 9-month-old infants. A simple criterion of language development status was taken in the current research, i.e., whether the infant produce any word at all. This partition has led to interesting results but has also generated strongly unbalanced sizes of contrasting groups. The findings from analyses with small and unbalanced cell sizes may be subject to artificial effects. Interpretation of such findings has to take caution. Replication of the studies with expanded sample sizes may serve as compensation.

Finally, the preferential looking model relies heavily on infants' processing of perceptual information. Yet as the current research did not aim at pitting against infants' perceptual and conceptual knowledge in the categorization and the word-learning tasks, the preferential looking paradigm was appropriate for the presented research goals. Actually, successful performance on the tasks was inseparable to either body of knowledge. The input of the tasks were perceptual-dependent. Infants had to be able to detect, discriminate, and associate the visual and auditory information. At the same time, the processing of perceptual information may activate infants' conceptual knowledge to link linguistic cues with categorical commonalities of objects.

8.2 Implication for theoretical debates

8.2.1 A developmental view on the development of the taxonomic constraint

In a recent chapter of the *Handbook of Child Psychology* written by Cohen and Cashon (2006), the authors advocated stronger efforts of investigating continuous developmental changes and the underlying mechanisms of infant cognition. They wrote:

> When examining developmental changes in most cognitive abilities more closely, one often finds that (a) developmental change occurs gradually over time; (b) change is often situation or task specific; (c) change does not always produce improvement – in some cases infants' development may, at least superficially, appear to regress to a simpler way of processing; and (d) change may appear stagelike but the underlying process may be gradual and continuous. A reemphasis on developmental change and progressions can lead to valuable information regarding issues such as the viability of innate modules or core abilities. …
>
> Once the importance of developmental change is acknowledged, the most critical question becomes the mechanisms of change. (p. 217)

The findings in the current research turned out to accord with Cohen and Cashon's view of development. The taxonomic constraint seems to emerge gradually as infants acquiring language. During this time, infants' performance was task contingent. The presence of linguistic labels did not always promote infants' categorization and infants did not reliably take advantage of constraint to learn novel words. In some intermediate periods, linguistic cues even seemed to "hinder" infants' performance. Infants made achievements in taking advantage of the taxonomic bias at different ages but this continuously tied to their word learning progressions. Whether infants demonstrated the taxonomic bias (or its precursor) was not determined by their age, but more closely related to their language abilities. The results suggested that the word-learning constraint may be acquired through and interact with language learning process.

8.2.1.1 Nouns and categories: An innate general linkage?

It has long been a debate whether a word-learning constraint is inherent and already functional at the very onset of language acquisition or whether it may be acquired.

Waxman and her colleagues argued for the former assumption. On many occasions, Waxman has suggested that infants are endowed with some expectations between words and concepts (Waxman & Lidz, 2006; Waxman, 2003; 2004). For example:

> We have proposed that infants embark on the task of word learning not as tabulae rasae, but equipped with a broad, universally shared expectation that links words to commonalities among objects. This initial expectation, which guides lexical acquisition from the start, provides infants with a means to establish a stable rudimentary lexicon.
> (Waxman, 2004; p. 324)

After reviewing other researchers' proposals on core knowledge and innate modules, Waxman summarized:

> …they [these proposals] share a commitment to understanding the rapid acquisition of complex systems, and to embracing the contributions of expectations or constraints inherent in the learner … (Waxman, 2004; p. 296)

To support the claim that the noun-category linkage is functional from the very beginning, Waxman and colleagues have conducted several experiments with young infants (Balaban & Waxman, 1997; Fulkerson et al., 2006; Waxman & Markow, 1995). In a recent study, they reported that even 6-month-old infants appreciated the noun-category linkage (Fulkerson et al., 2006; Fulkerson & Waxman, in press). They argued that as the 6-month-old infants had little experience with language and concepts, the linkage could not be learned through associative learning mechanism.

In this study, infants were familiarized with 8 exemplars of an object category (e.g., dinosaur), each for 20 seconds. Accompanied with each trial, infants heard either "Oh look, it's a toma. Do you see the toma?" (the Word condition) or two sequences of pure tones (400 and 800Hz). During the single 10s test trial, infants saw a new in-category exemplar and an out-of-category exemplar (e.g., a fish) in silence. It was reported that infants in the Word condition displayed a significant novelty preference at test, thus honor the noun-category linkage, whereas those in the Tone condition did not.

This finding was impressive. Although the task seems to be simple, it tapped on sophisticated linguistic and cognitive abilities. The infants had to at least detect the linguistic label, to process divergent visual images and extract the commonalities of them (according to Waxman, this was facilitated by the to-be-detected linguistic label), and to associate the auditory information (the label) with the visual information (the commonalities of the objects).

At 6 months of age, infants just start to segment words from fluent speech (Saffran et al., 2001; Saffran et al., 1996). They have difficulties to integrate relational information even after 7 months of age (Cohen & Cashon, 2001; Madole, 1996; Madole & Cohen, 1995; Madole & Oakes, 1999; Madole, Oakes, & Cohen, 1993; Younger, 1992). The ability to process relational stimuli relies on the activities of hippocampus and surrounding cortex, which become mature in the second half of the first year of life (Nelson et al., 2006). Considering young infants' restricted general processing capacity, the finding from Waxman and colleagues was remarkable.

Inconsistent with their study, the current research demonstrated that at 9-months of age, infants failed to benefit from novel words to access or form object categories. The discrepancy might be caused by the task differences. In their 2006 study, each familiarization trial lasted 20 seconds, during which the naming sentences involving the novel label appeared twice. On all the 8 trials, the same sentences were repeated. The infants had 160 seconds to examine the objects and heard the novel label 16 times. In the current study, the familiarization trial lasted 10 seconds each. Only a noun phrase (not a sentence) was presented once on each auditory trial (not on silent familiarization trials). Infants had altogether 90 seconds to watch the objects and heard the novel label 6 times. Infants in the current study had less time to learn the novel label and the category. It is possible that with extended familiarization or full habituation, the 9-month-old infants would also succeed in novel word - object categorization tasks.

It has also to be pointed out that in their 2006 study, the instruction in their Word condition did not only include rich linguistic cues, but also redundant social-pragmatic cues. In the Tone condition, infants only heard two pure tones. This could have made the two conditions incomparable. The authors did not report in detail whether the looking times between conditions were comparable during the familiarization phase.

Due to the inconsistency between their 2006 and the current studies, replications of Waxman and colleagues' finding would be meaningful to clarify whether the very young infants do honor the linkage between novel nouns and categories.

8.2.1.2 Taxonomic constraint: A learned word-learning bias?

Against Waxman's view of inherent universal bias, Smith and colleagues have provided evidence to demonstrate that a word-learning bias is acquired through general attentional learning. The emergence and change of a bias is dependent on individual's language learning experience (see 2.4).

Smith's theory finds support in brain-inspired connectionist models. The explicit computational models are based primarily on associative learning mechanisms. In the recent years, a range of different models have simulated the acquisition of early cognitive abilities, including object unity (Mareschal & Johnson, 2002), object permanence (Munakata, McClelland, Johnson, & Siegler, 1997), perception of causal relations (Cohen et al., 2002), rule learning (Shultz & Bale, 2001), and categorization (Mareschal, French, & Quinn, 2000; Quinn & Johnson, 2000). Many of these early cognitive abilities have been regarded as innate “core knowledge” by some researchers (e.g., Spelke, 1998). The computer simulations demonstrate at least that even these possibly innate abilities do can be learned through experiences, with the simple but powerful associative learning mechanism. Rapid acquisition of a complex system does not necessarily depend on innate concepts.

8.2.1.3 Taxonomic bias: An emerging and developing constraint

Is the taxonomic bias an innate or a learned constraint? The overall findings in the current research seem to favor a learning account. First, infants have not been found to reliably honor the noun-category linkage at the onset of language learning. Instead, they seem to form the word learning constraint step by step while accumulating new words. Second, the experiments have converged to show that whether infants display a word learning bias ties closely to their language development and has little to do with their age.

However, the current research applied the fixed-trial familiarization procedure. It can not be ruled out that with lengthened learning phase even infants who can not yet produce any word would also show a word learning bias. Moreover, even the emergence of the taxonomic constraint is tightly related to infants’ language progressions, it is still possible that the experience of language acquisition is a trigger and activator of an innate bias. An assumption that infants may start with an inherent expectation between language and concepts is still plausible.

Waxman and colleagues have not explained the origin of the assumed general expectation between language and concepts. After all, if the ability is regarded as innate, little is left for discussion about its origin. However, this also closes the door to discover other possible mechanisms underlying the formation of early abilities.

Although different theorists do not agree with each other on the origin of the word-learning constraint, no one denies that the constraint can change and it is influenced by particular language learning experiences. In this case, the critical question becomes how the constraint changes as infants learning language.

The current research has focused on the developmental changes of the taxonomic constraint. The results suggested that a word learning constraint may be acquired through word learning process itself. Infants may first learn to tease apart words and non-word sounds. At the same time, they gradually discover the natural links between nouns and categories. During this course, immature bias may also be influential, interacting with infants' ongoing word and concepts learning. As experiences with language and concepts accumulating dynamically, the emerging bias will be continuously refined and a mature rule-like constraint may gradually come out, which will then significantly facilitate infants' language and concept learning.

8.2.2 Linguistic labels: hindrance or promotion?

Recently, some researchers proposed another view on the role of language on categorization in infancy (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004; Robinson & Sloutsky, in press). They believed that early in development, auditory information (both linguistic and non-linguistic) dominates visual information processing. The presence of auditory stimuli competes for infants' limited processing resources, hence gets in the way of perceptual categorization rather than facilitates it. Unfamiliar sounds often have greater overshadowing effects than words. As words (especially real words) have prosodic features that are more familiar to infants, they compete less for the processing capacity than other sounds. Therefore, sometimes infants perform better in the Word than in the Tone condition in categorization tasks. It is not that the words facilitate categorization. Rather, words impede the perceptual categorization not as much as the tones.

In supporting their view, these researchers showed that 8- and 12-month-old infants both performed much better in a categorization task in the silent condition than in the auditory conditions (real words, pseudowords, and tones) (Robinson & Sloutsky, in press). In the silent condition, infants at both ages demonstrated significant greater novelty preference than the baseline preference. The 12-month-olds also displayed a higher novelty preference in the Real-word than in the Tone condition. The novelty preference in the real-word condition approached significance. The 8-month-olds did not show significant preference in the auditory conditions. The authors suggested that the real words were more familiar than the strange tones for the older children. Although the words obstructed their categorization, they did so to a less extent than tones.

This competition assumption is plausible. It is true that early in development, infants have limited cognitive capacity. The ability of processing and integrating complex information from different modals is developing. The phenomenon that auditory processing dominates visual processing in early infancy has also been reported by other researchers (Lewkowicz, 1988a; Lewkowicz, 1988b).

Some findings from the current studies seemed also to favor the overshadowing assumption. Especially with language less advanced infants, words appear to have "hindered" their categorization. Yet inconsistent with their prediction that non-linguistic tones should be even more intrusive than linguistic labels, current studies show that the tones have in general no effect or even a positive effect on categorization (only on one occasion, see Experiment A-1-0). According to their attention competition interpretation, the pseudowords in the current studies would have been perceived by the infants as even “stranger” and more intrusive than the pure tones.

However, in both Experiment A-1-0 and A-2-0, language less advanced 9-month-old infants did not perform differently in the Tone and the Word condition, yet their language more advanced peers did. For the low-vocabulary infants, the auditory stimuli (both the tone sequence and the noun phrase) neither facilitated nor hindered their categorization. They performed just at baseline level in both conditions. The auditory stimuli seemed to have simply no effect on their responses. For the high-vocabulary group, on the contrary, the difference between the Tone and the Word condition was evident. The noun phrase seemed to “hinder” infants’ categorization while the tone sequence did not. Was the noun phrase more complex and hence more impeding than the tone sequence for the infants? Why then, did both the noun phrase and the tone sequence have no influence on low-vocabulary infants? The competition assumption can not answer this question.

Alternatively, the high-vocabulary infants were not hindered by the linguistic label in the categorization task. Rather, the word is special and alerting rather than disturbing for them. Unlike the low-vocabulary peers, they tried to process the co-occurrence of the word and the group of objects, which was a demanding task as the infants did not have a mature bias linking nouns and categories. In this case, the auditory word did not simply compete for processing resources with visual processing. Instead, it might have prompted infants to redistribute their processing resources. In different tasks, the linguistic label presented in the familiarization phase caused the high-vocabulary infants to focus more on the in-category members during the test phase.

While pointing out the possible hindering effects of auditory input on categorization, Robinson and colleagues (in press) also demonstrated that if the auditory stimuli were first made more familiar to the infants, they would then facilitate categorization. This explained how language can transit from a competition role to a facilitative role in early categorization. Namely, when infants are more acquainted with the linguistic systems they are learning, and have more chances to associate language with objects, the transition will occur. The researchers concluded that “infants do not initially assume that labels refer to categories; rather, this knowledge is acquired after infants have established a corpus of knowledge about words, objects, and the categories they denote” (p. 25).

8.2.3 Language on cognition: not merely reflection

An important finding in the current research was that even the youngest group (i.e., the high-vocabulary 9-month-old infants) discriminated the words and non-word sounds, and the words held consequences for their object categorization. Although for the high-vocabulary 9-month-old infants, the presence of novel words did not lead to an expected facilitative effect on categorization, the words reliably altered infants' direction of attention in categorization contexts. The effect of words was distinctive to that of the non-linguistic tones in the same tasks. At this very early stage of development, words were treated differently than non-linguistic tones. The results suggested that language had a special effect on infants' categorization by the time infants uttering their very first words. Shortly after, when infants were able to speak a few more words, the presence of a novel word began to help them to form a novel category.

This finding was in line with the perspective that language has formative influence on human's cognition already early in life. In the last decades, a wide range of evidence has been provided that language does not merely reflect thoughts but can also transform thinking from early on. Some researchers have argued that language is responsible for some quantum changes in young children's cognitive development areas such as categorization, means-ends skills and object-permanence (Gopnik, 2001). Some have provided evidence that children learning different languages have distinct understanding about objects and space (Behrens, 2001; Bowerman & Choi, 2001; Brooks, Braine, Jia, & Da Graca Dias, 2001; Clark, 2001; Gentner & Boroditsky, 2001; Gentner & Namy, 2000; Gumperz & Levinson, 1996; Imai & Gentner, 1997; Levinson, 2001; Lucy & Gaskins, 2001; Majid, Bowerman, Kita, Haun, & Levinson, 2004). Still others demonstrated that preverbal infants take advantage of linguistic inputs but not non-linguistic sounds to differentiate individual objects or access familiar object categories (Balaban & Waxman, 1997; Waxman & Markow, 1995; Xu, 1998; Xu, 1999). Consistent with these studies, the current research provided further evidence that even before infants can produce many words, language plays a distinguishable role in the context of object categorization. This role is evolving and getting more significant with development.

8.3 Implication for empirical research and suggestion for further study

Current research has left open questions for further investigation.

First, all the tasks involving word learning have not tested infants' retention after a period of delay. Genuine word learning requires the learner to be able to remember the newly-learned words and extend them later in different situations (Fernald, Swingley, & Pinto, 1998; Markson & Bloom, 1997; Waxman, Philippe, & Branning, 1999; Woodward, Markman, & Fitzsimmons, 1994). Was the successful word-extension demonstrated by the infants only a temporary learning, or does the learning have a long-term effect? Is the ability of retaining newly-learned words also related to infants' language abilities? Future study shall explore these issues.

Second, as discussed before, the reasons for young infants' failure in the categorization and word-extension tasks was not thoroughly investigated. Since fixed-trial familiarization procedure has been applied in the current studies, it was sometimes ambiguous whether the failure was caused by under-familiarization or by the absence or immatureness of a word-learning bias. As some researchers have found that infants as young as 6 months displayed the noun-category bias (Fulkerson et al., 2006), it is meaningful to carry out further studies with different paradigms and methods in order to clarify the ambiguities.

Third, as the preferential looking paradigm examines infants' categorization based primarily on perceptual similarities, it does not answer the question whether early categorization is more perceptual-dependent or rather conceptual-driven, which is an intense debate area (Booth et al., 2005; Cohen, 2003; Eimas, 1994; Freeman & Sera, 1996; Gershkoff-Stowe & Rakison, 2005; Gureckis & Love, 2004; Landau, Smith, & Jones, 1998; Madole & Oakes, 1999; Mandler, 1999; Mandler, 2004; Mandler & McDonough, 1993; McDonough, 2002; Pruden, Hirsh-Pasek, & Parish, 2006; Quinn & Eimas, 1997; Rakison, 2005; Shutts & Spelke, 2004; Welder & Graham, 2001). Some researchers believe that other paradigms such as object manipulation or delayed imitation may be more appropriate to reveal conceptual knowledge based categorization (Mandler, 2003; Mandler & McDonough, 1996; Mandler & McDonough, 2000). Further research may apply different paradigms to explore such issues.

Fourth, current studies have created artificial categories. This turned out to be a suitable strategy to investigate genuine novel word learning and novel object categorization. Future investigation may try to use different kinds of artificial objects. In particular, it would be meaningful to create objects at different conceptual levels (i.e., basic or global). This may be especially preferable for research in older infants who already have a basic repertoire of words and concepts. Artificial categories and words will circumvent possible problems with the mutual exclusivity bias. In addition, it is also important to explore whether the top-down model can also be applied to very young infants with different kinds of artificial objects.

Fifth, current studies indicated that in typical developing infants, the emergence and development of the taxonomic constraint is related to infants' language development progressions. This raised a question whether the finding is generalizable to language development deviant children. Some recent studies reported that language impaired young children do not have the same word-learning biases as typical developing children (Jones, 2003; Jones & Smith, 2005; Stevens & Karmiloff-Smith, 1997; Weinert, 2004). It is an interesting question whether the absence of the biases can be detected in the very early period of development. Such investigations may provide insights on early diagnose and intervention. In the current studies, even as young as 9 months of age, infants with different achievements in language development displayed distinguishable performances. How do these earliest differences change with development? Do these initial individual differences hold consequences for later language development? Longitudinal studies shall be conducted to examine these significant issues.

Finally, a recent trend in infant research has been to investigate actual mechanisms of developmental changes (Bowerman & Levinson, 2001; Cohen & Cashon, 2006). The current research is only an attempt to explore how a possible word-learning bias emerges and evolves and what mechanisms may be underlying the progress. Many related issues still remain ambiguous or open. With support of modern technology, researchers are able to study developments with ingenious methods. With support of neural and computer science, researchers have the possibility to explore the same issue and embrace evidence from different perspectives. The development of a word-learning strategy is only a small topic in the research area of language and conceptual development. However, just as with other research topics, to study the nature and mechanism of development, investigation will benefit from an open and developmental view that allows growing understanding of developmental changes. It is important to encompass relevant and available data from different sources, without focusing only on a small subset of evidence but ignore others especially contrary ones. For this reason, the current research is far from completion. Many open questions, some opposite theories and contrary empirical evidence provided by other researchers necessitate and motivate continuous research.

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Curriculum Vitae

Zhang Dajie

Ausbildung

1992 –1996 Peking Normal University, China

Studium der Psychologie (B.S.; Bachelor of Science)

1996 –1999 Peking Normal University, China

Kognitive Psychologie (M.S.; Master of Science)

1999 –2000 Arizona State University, USA

Postgraduate Ausbildung in Counseling Psychology

2005 – Otto-Friedrich-Universität Bamberg, Deutschland

Doktoratsstudium in Psychologie

Berufserfahrung

1994 –1999 Peking Normal University, Institute of Cognitive Science and Psychological Assessment, China

Wissenschaftliche Assistentin

1999 –2000 Arizona State University, College of Counselling and Education, USA

Wissenschaftliche Assistentin

2000 –2001 Crossair, Basel, Schweiz

Assessment und Training

für Piloten im Bereich ‘Crew Resource Management’

2002 – Otto-Friedrich-Universität Bamberg, Lehrstuhl Psychologie I, Deutschland

Wissenschaftliche Angestellte

Wissenschaftliche Präsentationen

Miller, K. F., Zhang, D., & Zhang, H. (1999, April). *How phonological awareness changes as children learn alphabetic scripts: A longitudinal study in China and the United States*. Paper presented at the biennial meeting of the Society for Research in Child Development, Albuquerque, NM, USA.

Weinert, S. & Zhang, D. (2005, July). *Word-category linkage in 12-month-old infants*. Paper presented at the X International Congress for the Study of Child Language: Berlin, Germany.

Weinert, S. & Zhang, D. (2007, March). *Early lexical development and the emergence of the taxonomic bias in 15- and 18-month-old German infants*. Poster presented at the biennial meeting of the Society for Research in Child Development: Boston, MA, USA.

Zhang, D. & Weinert, S. (2006, September). *Language and categorization in 9-month-old infants: Innate constraint or learned word comprehension*? Paper presented at the 45th Congress of the German Psychology Society: Nuernberg, Germany.

Zhang, D. & Weinert, S. (2007, March). *The noun-category linkage and its relationship with early lexical development in 12-month-old German infants*. Poster presented at the biennial meeting of the Society for Research in Child Development: Boston, MA, USA.

Statutory Declaration

Dajie Zhang
Lehrstuhl Psychologie I
Otto-Friedrich-Universität Bamberg
Markusplatz 3
96047 Bamberg

- Ich erkläre, dass ich die vorgelegte Dissertation selbständig angefertigt, dabei keine anderen Hilfsmittel als die im Quellen- und Literaturverzeichnis genannten benutzt, alle aus Quellen und Literatur, einschließlich des Internets, wörtlich oder sinngemäß entnommenen Stellen als solche kenntlich gemacht und auch die Fundstellen einzeln nachgewiesen habe. Von Programmen der elektronischen Datenverarbeitung wurde *SPSS* zur Niederschrift eingesetzt.
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- Betreuer der Dissertation ist Universitätsprofessorin Dr. Sabine Weinert
- Promotionsfach ist Psychologie
- Gewünschte Prüfer:
  - Als Erstgutachter der Dissertation: Prof. Dr. Sabine Weinert
  - Als Zweitgutachter der Dissertation: Prof. Dr. Thomas Lachmann

  Als weitere/r Prüfer/-in: Prof. Dr. Ute Schmid

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