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Learning language from within: Children use semantic generalizations to infer word meanings

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Abstract

One reason that word learning presents a challenge for children is because pairings between word forms and meanings are arbitrary conventions that children must learn via observation – e.g., the fact that “shovel” labels shovels. The present studies explore cases in which children might bypass observational learning and spontaneously infer new word meanings: By exploiting the fact that many words are flexible and systematically encode multiple, related meanings. For example, words like *shovel* and *hammer* are nouns for instruments, and verbs for activities involving those instruments. The present studies explored whether 3- to 5-year-old children possess semantic generalizations about lexical flexibility, and can use these generalizations to infer new word meanings: Upon learning that *dax* labels an activity involving an instrument, do children spontaneously infer that *dax* can also label the instrument itself? Across four studies, we show that at least by age four, children spontaneously generalize instrument-activity flexibility to new words. Together, our findings point to a powerful way in which children may build their vocabulary, by leveraging the fact that words are linked to multiple meanings in systematic ways.

Keywords: lexical semantics; word learning; semantic development; polysemy

One reason that word learning presents a challenge for children is that the relation between a word form and its meaning is arbitrary (Saussure, 1916/2011). There is no principled reason, for example, that English speakers use the word “shovel” to label shovels, as opposed to hammers or combs: This is merely one among many conventions that children must learn, either through direct, ostensive evidence or indirectly through overhearing (Akhtar, 2005). Here, we explore whether, in some cases, children might bypass observation to *learn from within*, by spontaneously inferring new word meanings. In particular, we ask whether children can exploit lexical flexibility: The systematic use of words to encode multiple, related meanings (Barner & Bale, 2002; Copestake & Briscoe, 1995; Pustejovsky, 1995). For example, many of the same English root morphemes can be used to label instruments, as nouns, and activities involving those instruments, as verbs (e.g., *shovel*, *hammer*, *mix/mixer*, *wash/washer*; Adams, 1973; Clark & Clark, 1979; Jespersen, 1942; Marchand, 1969; see Table 1 for other examples of lexical flexibility). The present studies explore young children’s use of semantic generalizations about lexical flexibility to bypass observational learning: Upon learning one meaning of a new word via observation (e.g., that *dax* labels an activity), can children spontaneously infer another possible meaning of the word that follows a generalization (e.g., that *dax* can label the instrument itself)?

Table 1. *Patterns of Lexical Flexibility in English*

Patterns and Participating Words	Examples
Instrument for Activity (<i>shovel</i> , <i>hammer</i> , <i>mix/mixer</i> , <i>wash/washer</i> , etc.)	She has a <i>shovel</i> / She <i>shoveled</i> the snow
Agent for Activity (<i>nurse</i> , <i>boss</i> , <i>bake/baker</i> , <i>sing/singer</i> , etc.)	She is the new <i>boss</i> / She <i>bossed</i> her employees around
Substance for Transfer to Goal (<i>water</i> , <i>paint</i> , <i>salt</i> , etc.)	There <i>water</i> is warm / He <i>watered</i> the plants

Animal for Meat (<i>chicken, lamb, turkey, etc.</i>)	The <i>chicken</i> is well-fed / The <i>chicken</i> is well-salted
Object for Representational Content (<i>book, magazine, newspaper</i>)	She spilled coffee on the <i>book</i> / She thinks it is an interesting <i>book</i>
Space for Time (<i>long, on, around</i>)	The table is <i>long</i> / The movie is <i>long</i>
Body Part for Object Part (<i>leg, arm, back, etc.</i>)	He broke his <i>leg</i> / That chair has a wooden <i>leg</i>
Material for Artifact (<i>glass, tin, iron, etc.</i>)	There is broken <i>glass</i> on the floor / He drank water from the <i>glass</i>
Object for Aperture (<i>door, window, goal, etc.</i>)	They installed a new <i>door</i> / The man walked through the <i>door</i>
Place for Institution (<i>White House, Wall Street, City Hall, etc.</i>)	The <i>White House</i> has been renovated / The <i>White House</i> announced a new policy

Lexical flexibility characterizes most words of moderate to high frequency (Nerlich, Todd, Herman & Clarke, 2003), and is widespread in English (Chomsky, 2001; Copestake & Briscoe, 1995; Lakoff, 1987; Nunberg, 1979; Ostler & Atkins, 1992; Pustejovsky, 1995, 1998) and in other languages (Kamei & Wakao, 1992; Peters & Peters, 2000; Srinivasan & Rabagliati, 2015; Youn et al., 2016). Flexible uses of words can take many different forms, including metaphor (the use of a word from one semantic domain to describe another; e.g., “Christmas is *approaching*”), metonymy (using a word to label an item or something associated with that item; e.g., the *White House* made an announcement), and morphological conversion (extending a word to another grammatical category; e.g., “She *shoveled* the snow”; Table 1). Although these various kinds of flexibility can be distinguished (see, e.g., Cruse, 1986; Klepousniotou, Titone, & Romero, 2008), they are similar in that they often yield systematic patterns in which a word’s meanings are related in predictable and generalizable ways (a phenomenon known as “regular polysemy”; Apresjan, 1974; Table 1). Multiple words in English, for example, can be used to label instruments and their associated activities (e.g., *hammer, shovel*), and this pattern can be

generalized to new words (e.g., Will you *Segway* to the park? Can you *FaceTime* us once you get there?).¹

Critically, the fact that words often have multiple meanings, and that these meanings are often related in regular, predictable ways, suggests that children may not need to learn all pairings between word forms and meanings one-by-one, through observation. Instead, if children understand the semantic relations through which words can alternate between meanings, they could spontaneously infer new form-meaning pairings in many cases. Imagine, for example, a child who has not learned that rakes are called “rakes” but has observed an activity involving a rake labeled as “raking”. Rather than awaiting additional observational evidence for what rakes are called, the child could make a spontaneous inference. Guided by an understanding that words can label instruments or their associated activities, the child could infer that the rake can be labeled using the same root morpheme that describes its functional use: i.e., it could be called a “rake” (similar to cases like *hammer* and *shovel*, where the noun and verb meanings have identical word-forms), or perhaps a “raker” (similar to cases like *mix/mixer* and *chop/chopper*, where the noun forms require the additional suffix *-er*). This inference could accelerate word learning, by allowing children to anticipate many conventional form-meaning pairings that conform to the “instrument and associated activity” pattern. Inferences related to other regular patterns of lexical flexibility could have similar facilitative effects: e.g., children could anticipate

¹ Of course, there are exceptions to these regular patterns: e.g., *broom* does not label an action involving brooms. Exceptions to patterns can be thought of as “irregular” words that block a regular pattern (see e.g., Pinker, 1991, for a similar argument in the domain of morphology). Flexible patterns can be blocked by synonymy (e.g., *to broom* is blocked by *to sweep*), and by homophony (e.g., we can *summer* or *winter* in Paris, but we cannot *spring* or *fall* there because those words have other meanings; see, e.g., Barner & Bale, 2002, 2005; Clark, 1987, 1993; Clark & Clark, 1979). The presence of exceptions does not preclude the need for explaining “regular” words, or the fact that regular patterns can be generalized to new words.

that words for animals will also label their meats (e.g., *chicken*, *lamb*, *fish* etc.), that words for physical media will also label their informational content (e.g., *book*, *newspaper*, *magazine*, etc.), and so on (Table 1).^{2,3}

The present study explores whether children can infer new form-meaning pairings by exploiting lexical flexibility, and thus by learning language from within. To do so, children need to understand two properties of the language they are learning: (1) The semantic relations that license regular lexical flexibility in their language (e.g., between instruments and activities, animals and meat, etc.), and (2) The word-formation devices through which lexical flexibility is expressed in their language, i.e., the ways in which the word-form must be transformed, if at all, as it expresses different meanings (e.g., through affixation). But how might children's understanding of these two properties of language develop? It is clear that children have to learn the word-formation devices that express lexical flexibility in their language, given that these devices are differentially employed across languages. For example, in English, new word meanings are often expressed via zero-derivation – i.e., without any changes to existing word-forms – as in the case of nouns derived from verbs (three *jumps*; two *swings*, etc.) and verbs derived from nouns (*shovel* the snow; *button* the shirt, etc.). English also often makes use of suffixes to form new nouns from verbs (He used a *mixer*; She is a *teacher*, etc.). By contrast, zero-derivation is less common in Semitic languages like Hebrew. In Hebrew, noun and verb forms are often related by a common 3- or 4-consonant root, and differ with respect to the

² This account would predict that, in some cases, children will over-generalize flexible patterns, e.g., such that *broom* is used to denote sweeping and *cutter* used to denote a knife. As we review below, such overgeneralizations have been documented both in production and comprehension.

³ Some flexible words (referred to as “irregular polysemy”; Apresjan, 1974) do not appear to participate in predictable, generalizable patterns. For example, the word *arms* can label a body part or weapons, and *board* can label a physical object or administrative organization. Insofar as these words do not appear to fall into larger patterns, children would not be able to use semantic generalizations to acquire them.

vowels that populate the root. For example, the verb *grow* in Hebrew, *gadal*, can be nominalized as *gdila* (Berman, 1999; Ravid & Avidor, 1998).

The above discussion suggests that children have to learn which word-formation options are available and productive to express lexical flexibility in their language. But how does children's understanding of the *semantic relations* that license lexical flexibility develop, e.g., their understanding that the same root can be used to denote an instrument and its associated activity? One possibility is that, just as word-formation devices vary from language to language, the semantic relations that license lexical flexibility also differ, and thus need to be learned by children. If true, this would constitute a substantial learning challenge for children, since there is in principle an unbounded number of possible semantic relations between word meanings, most of which will not provide a basis for lexical flexibility in a particular language. For example, although English permits many animal words to label their derived meat (*chicken*, *lamb*) and fur (*mink*, *chinchilla*), it does not permit these words to label other animal products (e.g., eggs, milk, etc.) or other items associated with animals (e.g., barn, hay, etc.). In face of such limits, and in absence of prior constraints on their hypotheses, learners might require a great deal of exposure to flexible words in the input to learn which semantic relations license flexibility in their language, and might thus only gradually construct semantic generalizations about flexibility.

The account described above – in which children have to learn which semantic relations license lexical flexibility in their language from the linguistic input – would predict that semantic generalizations regarding flexibility should be gradually abstracted from concrete exemplars. A related account of how children form linguistic generalizations can be found in usage-based theories of how children learn abstract syntax-semantics mappings: By these theories, children initially learn regularities about individual items (e.g., that the agent and patient roles of *kick* are

linked to grammatical subject and object positions, respectively) and only later generalize these observations to similar items (e.g., that the agents and patients of *all transitive verbs* are linked to subjects and objects; see, e.g., Lieven & Behrens, 2003; Tomasello, 2000, 2003). Applying a usage-based account to the case of lexical flexibility, we might expect that children would (1) Initially treat the different meanings of flexible words like *shovel* as unrelated homophones (see Conwell & Morgan, 2012), (2) Later form “islands of flexibility” that relate the meanings of individual words together (e.g., allowing *shovel* and *hammer* to each alternate between their specific noun and verb meanings), and (3) Gradually form higher-order semantic generalizations by comparing many similar islands (e.g., such that any word can label an instrument as a noun or its associated activity as a verb; see Figure 1). Further, children’s progression through these stages should be linked to their exposure to attested flexible words in the input.

Figure 1. A usage-based approach to how children might construct a semantic generalization about instrument-activity flexibility.

Critically, if the usage-based account is right, and children only construct semantic generalizations about flexibility after learning many flexible words item-by-item, such generalizations may play only a limited role in facilitating children’s acquisition of form-

meaning pairings that follow these generalizations, since children will have already learned many attested flexible words via observation prior to forming generalizations. Further, if the process of abstracting semantic generalizations from concrete exemplars requires an ability to reflect on word uses and to construct explicit analogies about usage (e.g., because *shovel* and *hammer* label a tool and its activity, so can *google*; see e.g., Fodor & Lepore, 1998; Murphy, 2007; Panagiotidis, 2005), children may have difficulty constructing generalizations altogether, given their relatively fragile capacity for meta-linguistic reflection and analogical reasoning (Bialystok, 1986; Gentner, 1988; Gombert, 1992; Rattermann & Gentner, 1998).

An alternative possibility, however, is that children do not have to learn which semantic relations license lexical flexibility, *per se*. Instead, children may expect words to alternate along specific semantic relations from early in acquisition, due to innate, generative properties of word meaning. For example, inspired by Aristotle's theory of knowledge and causal explanation, Pustejovsky (1995) – following an earlier analysis by Moravcsik (1975) – argued that individual word meanings are structured on the basis of four distinct generative components, or *qualia*, which specify an object's form, its material composition, its function, and its origin. These *qualia* structures are argued to be innate, abstract frameworks that constrain not only how we speak about the world, but also how we form concepts and acquire knowledge (for discussion, see Moravcsik, 1975, 1981, 1990; Prasada, 2000). Most relevant to the present study, Pustejovsky has argued that *qualia* structures give rise to systematic lexical flexibility, and explain why words alternate along specific semantic relations, e.g., such that words can label instruments and functional uses of those instruments. Critically, this account predicts that children should not need to observe how flexible words are used in the input to understand the semantic relations that license flexibility. Instead, once children have learned the meaning of a new word – e.g., and

filled information into its qualia structure – they should spontaneously anticipate the different flexible uses of that word, facilitating their acquisition of additional conventional form-meaning pairings.

In sum, the two accounts reviewed above make different predictions about how easily children should develop semantic generalizations about lexical flexibility, and consequently, how great of a role such generalizations should play in lexical development. If the usage-based account is correct, children may only gradually construct generalizations regarding flexibility from the input, and such generalizations may not play a role in early word learning. By contrast, if the generative account is correct, semantic generalizations regarding flexibility should be present throughout development: Even young children may use them to bypass observational learning and infer new form-meaning pairings. The present studies explore these predictions by testing whether young children use a semantic generalization about instrument-artifact flexibility to infer new word meanings.

To our knowledge, although previous studies suggest that young children are capable of using words in innovative ways, they have not asked whether children might use semantic generalizations regarding flexibility to infer new form-meaning mappings. For example, a number of studies suggest that by as early as 2 years of age, children coin new word meanings in their spontaneous speech. Interestingly, some of these innovations appear to extend the patterns exemplified by words like *shovel*, *baker*, and other words with noun and verb forms: e.g., “You’re *gunning* him” (Kuczaj, 1978), “Don’t *broom* my mess,” “It’s *trucking*” (Clark, 1982; see also Bowerman, 1983; Smith, 1933). Children also produce innovations in studies designed to elicit novel uses of words from children: e.g., “I’ve got a picture here of someone who burns things...Someone who burns things is a _____” (Clark & Hecht, 1982; see also Berman, 1999;

Clark & Berman, 1984).

However, although such lexical creativity provides evidence of children's understanding of the word-formation devices that express lexical flexibility in their language, it does not show that children understand the semantic relations that license flexibility. In particular, although children's innovations may provide evidence that they expect words to be used flexibly in specific ways – e.g., for the same root morphemes to label instruments and their associated activities – it is also possible that these innovations only reveal children's ability to stretch their vocabulary to fill communicative gaps (Clark, 1978, 1982). Thus, a child may use *broom* to label sweeping not because they think it is an appropriate label for the activity, but only because it is the closest, most relevant word they can access to convey their intended meaning. Consistent with this, previous work suggests that overextension of a word in production – e.g., calling a horse a “dog” – is not necessarily diagnostic of a child's representation of that word's meaning, as such overextensions do not always occur in comprehension (see Naigles & Gelman, 1995).

Researchers have also explored children's understanding of lexical flexibility using comprehension methods (e.g., Berman, 1999; Bushnell & Maratsos, 1984; Lippeveld & Oshima-Takane, 2015). For example, in one study (Lippeveld & Oshima-Takane, 2015), 2.5- and 3-year-olds first learned that a novel noun *vop* labeled a kind of novel object and observed that it could open bottles. Later, when children were asked to interpret a new verb formed from the noun – e.g., to “Find the one that *vops*” – the 3-year-olds looked longer at a video that depicted a novel object opening bottles than at one that depicted an object performing a different function, suggesting that they preferred to interpret a verb formed from an instrument noun as labeling a functional use of that instrument. But critically, these results, and those of other related studies (Berman, 1999; Bushnell & Maratsos, 1984; Lippeveld & Oshima-Takane, 2015), do not show

that children spontaneously expect a word to have multiple meanings, e.g., such that a word that labels an instrument will also label its functional use. Instead, children may only form new word meanings in these studies because they are given direct evidence for their existence: A request to “find the one that *vops*” presupposes that *vop* has an additional verbal meaning.⁴ Thus, these findings are neutral with respect to whether children use semantic generalizations to spontaneously infer new word meanings, or whether they instead require observational evidence to form those meanings (i.e., hearing “find the one that *vops*”).

The Present Studies

In contrast to previous work, the present studies explore whether preschoolers can use semantic generalizations regarding flexibility to bypass observational learning and anticipate new word meanings, in absence of any communicative pressure to extend a word to a new meaning, or evidence that a new form-meaning pairing is possible. To test this, we used a mutual exclusivity task (Diesendruck & Markson, 2001; Markman & Wachtel, 1988; Merriman, Bowman, & MacWhinney, 1989; Mervis & Bertrand, 1994), but used this classic method in a novel way, to probe whether children spontaneously infer untrained meanings.

In our experiments, children watched a video in which a novel verb – e.g., *dax* – labeled an event in which an agent used an instrument to act upon a patient. Then, children were presented with two pictures, one that depicted an instrument of the same basic-level kind, and the other that depicted a patient of the same basic-level kind. They were then asked to choose the referent of a second novel word, this time a novel noun – e.g., “Show me the *kiv*!” Although *kiv* could in principle label either object, we reasoned that if children spontaneously expect the root

⁴ Further, children could have succeeded even without forming a verb from a noun. When children were taught what a *vop* was, they could have initially linked *vop* not just to the object but also to the bottle-opening event that it participated in. This would allow them to look longer at that event at test, due to the phonological overlap between *vop* and *vops*.

morpheme *dax* to label not only the trained action but also the instrument that enabled it (e.g., such that the instrument could be a *dax* or *daxer*), then it should block the use of *kiv* to label the instrument, via mutual exclusivity. Thus, children should expect *kiv* to label the patient.

Critically, this paradigm is sensitive to children's spontaneous inferences about word meaning:

Children are not placed under communicative pressure to extend the first novel word, nor do they receive observational evidence that this word can be used with a new meaning.

Using this method, in Experiment 1 we began by teaching 4- and 5-year-old children new labels for familiar activities, like shoveling, as verbs, and asked whether they would expect these labels to also refer to their associated instruments, as nouns – e.g., shovels. For this first experiment, it was important that the labels and meanings were known to children. This allowed us to test whether, for cases that exemplify the instrument-activity pattern, like the word *shovel*, 4- and 5-year-olds treat its noun and verb meanings as unrelated homophones (e.g., like the baseball and animal uses of *bat*), or instead link these meanings together, either using “islands of flexibility”, or perhaps through a higher-order semantic generalization about this pattern of flexibility (i.e., that words can label instruments or their associated activities; Figure 1).

In Experiment 2, we tested whether 4- and 5-year-olds have abstract, higher-order semantic generalizations by using entirely novel word meanings. In this experiment, children were taught labels for novel activities that were performed by novel instruments, and were then given mutual exclusivity tests as in Experiment 1. Thus, we explored whether children use a semantic generalization about instrument-activity flexibility to spontaneously infer that a new root morpheme that labels an activity involving an instrument can also label the instrument itself. Experiment 3 then followed up on the results of Experiment 2, to verify that children's responses were not driven solely by non-linguistic properties of the videos they observed.

Finally, Experiment 4 further explored how generalizations about instrument-activity flexibility might develop, and whether the development of such generalizations depends on children's prior exposure to attested flexible words, as suggested by the usage-based account. Adapting the method of Experiment 2, we probed whether 3-, 4-, and 5-year-olds spontaneously infer new meanings of novel words, and whether children's inferences are linked to their knowledge of attested flexible words with noun and verb meanings.

Experiment 1

Experiment 1 explored whether 4- and 5-year-olds have lexical structures that allow familiar flexible words like *shovel* to label instruments and their associated activities. We first taught children that a novel verb from "muppet language" labeled an activity involving a familiar instrument – e.g., that *buck* labeled shoveling. We then asked whether children would spontaneously expect the word to be used flexibly, and label the instrument (i.e., the shovel), with *buck* used as a noun. Previous studies using this same method have shown that when children learn that a novel "muppet" word labels the referent of one English homophone (e.g., that *dax* labels a baseball bat), they do not expect the novel word to also label the referent of the other homophone (e.g., an animal bat; Srinivasan & Snedeker, 2014), though they do expect novel words to alternate between the related meanings of polysemous words like *book* (e.g., *heavy book* vs. *interesting book*) or *chicken* (e.g., *thirsty chicken* vs. *tasty chicken*). Thus, we reasoned that if children treat familiar noun and verb meanings as unrelated homophones they should not expect a novel label for a familiar verb meaning (e.g., *buck* to label shoveling) to also label the corresponding noun meaning (e.g., *buck* to label a shovel). In contrast, if 4- and 5-year-olds have a semantic generalization allowing words to label instruments and their associated activities – or have constructed islands of flexibility that allow familiar flexible words to shift

between their different meanings (see Figure 1) – they may infer that a novel label for the familiar verb meaning will also label the corresponding noun meaning, thus blocking a second novel word from labeling it via mutual exclusivity (e.g., blocking *gork* from labeling a shovel).

Method

Participants. The participants were 20 monolingual, native English-speaking children (7 girls) between the ages of 4;1 and 5;11 (mean age = 4;11). Four additional children participated but were excluded due to failing the warm-up control trials that gauged their understanding of the task ($n = 1$), or because they didn't want to continue ($n = 3$). In this experiment and the other experiments reported here, all children were either tested in a university lab setting or recruited from daycares in the surrounding areas. All children received a token gift for participating.

Materials and Procedure. Each child participated in a pretest before proceeding to the mutual exclusivity task.

Pretest. Children only received a particular critical item in the mutual exclusivity task if they could correctly use the English noun and verb uses related to that particular item (e.g., use *shovel* as both a noun and verb). Children were tested on the noun and verb forms of *comb*, *shovel*, *tape*, *bicycle*, *button*, *brush*, *hammer*, and *lock*. We probed knowledge of the critical nouns by asking children to name pictures of the relevant instruments. We then tested children on the verbs, by showing them pictures of people using the instruments (e.g., a woman hammering a nail) and asking them to describe what they were doing. If children did not immediately name these actions, we prompted them – e.g., for the hammering item: “What is she doing to the nail?” Responses were only coded as correct if they included the target verb: e.g., “*shoveling* the snow” was accepted, but “picking up the snow with the shovel” was not.

Mutual Exclusivity Task. The mutual exclusivity task tested whether children spontaneously extend novel labels between the different meanings of words like *shovel*. We familiarized children to the task by introducing them to a character named Monkey and telling them that they would learn some words from Monkey, who spoke a special muppet language.

Warm-up Phase. Before receiving any critical items, the children received four warm-up items, which included three *same-kind* warm-up items and one *different-kind* warm-up item. As described below, *same-kind* and *different-kind* items also appeared after the warm-up phase, in the test phase. The *same-kind* items measured children's ability to make basic mutual exclusivity judgments that only require shifting a noun between two exemplars from the same basic-level kind. For example, in one trial, children were taught that *blicket* labeled a book, and then had to judge whether *tima* labeled another book (same-kind match) or a CD (different-kind foil). We expected that children would choose the different-kind foils on these trials if they could make basic mutual exclusivity judgments, which was a pre-requisite for interpreting their performance on the critical test trials. Children that did not choose the different-kind foil on the first same-kind warm-up item were given feedback, but children that could not get two out of three of these items correct without feedback were excluded ($n = 1$).

For the *different-kind* items, children had to choose between two items that were from different basic-level kinds than the trained meaning. For example, in one item, children were taught that *spado* labeled a knife and then had to decide whether *parma* labeled a table or chair. These items were included to prevent children from expecting that the first novel word could always be extended to one of the two choice items that were presented.

Test Phase. After the warm-up items, the children moved onto the test phase, where they were tested on their understanding of the relation between the noun and verb meanings of

familiar words. Children were tested with between one and four critical items; this depended on how many noun-verb pairs they had produced in the pre-test, since children only received items that tested noun-verb pairs they had produced earlier. On average, children received 3.8 critical items, and these items were administered in a fixed order (e.g., the *biking* item was always presented before the *hammering* item, which was always presented before the *shoveling* item, and so on; see Table 2). For each critical item children received, they were also tested on an additional same-kind and different-kind control item (described before). Because children did not receive feedback on these same-kind control items, they provide a ceiling measure of children's ability to make basic mutual exclusivity judgments, which we report below.

Each critical trial included a *training phase* and a *judgment phase*. We initiated the training phase by asking the children if they knew the meaning of a muppet verb – e.g., “Sometimes, Monkey likes to *buck* stuff from one place to another. Do you know what *bucking* is?” We then showed children a video in which the novel verb was used to refer to a familiar action. For example, in one trial, children were shown a video in which Monkey shoveled sand from a plate into a bowl, and heard the verb *buck* used to describe the action in a number of ways. Children heard the verb used in the infinitive to refer to what Monkey was going to do (“He’s going to use it to *buck* something into the bowl”), in the progressive to refer to the action as it was ongoing (“Wow, Monkey’s *bucking* it into the bowl”), and in the past tense to label the completed action (“Monkey *bucked* some stuff into the bowl”). The video also described how the affordances of the instrument facilitate the action (“What Monkey has is pretty long and it can carry the stuff well”). Critically, however, children did not receive any evidence that the novel word could refer to the instrument itself (e.g., that *buck* could label the shovel).

Immediately after the video ended, the experimenter initiated the judgment phase by

asking the child to indicate the referent of a second novel word: e.g., “So that’s what *bucking* is. Now we know what *bucking* is. But now, I want the *gork*. Show me the *gork*!” The child was then presented with a slide containing two pictures. The pictures depicted (1) an instance of the kind of instrument used in the video (“the instrument”; e.g., a shovel of a different color), and (2) an instance of the kind of object or substance that had been acted upon (“the patient”; e.g., sand).⁵ The child’s choice – which they typically indicated by pointing – was then recorded. We reasoned that if children expect a word for an activity involving an instrument (e.g., shoveling) to also label the kind of instrument that carries out that action (e.g., shovels), they should exclude the instrument as the referent of the second novel word and instead choose the patient (the sand). Critically, the instruments and patients were not labeled in the training videos – e.g., we referred to the shovel as a “thing” or “what Monkey has,” and referred to the sand as “stuff” or “something” – such that they could each serve as candidate referents of the second novel label.

Finally, we constructed two versions of the task that varied with respect to whether the pictures in the judgment phases of trials were presented to the left or right of the child. All of the second novel words that were used in the judgment phases also avoided overlap in phonological onset with the English names of the presented pictures.

Table 2. *Critical Items of Experiment 1*

Training Phase Event	Judgment Phase
<i>Moop</i> (bike) to school building	<i>Tima</i> = bike or school
<i>Dax</i> (hammer) nail into wood	<i>Kiv</i> = hammer or nail
<i>Buck</i> (shovel) sand into bowl	<i>Gork</i> = shovel or sand
<i>Tig</i> (brush) hair on head	<i>Lum</i> = brush or hair
<i>Wug</i> (tape) picture to box	<i>Koon</i> = tape or picture

⁵ For one of the critical items – the *biking* item – the “patient” match actually depicted the goal of the event. In the training phase, children saw an event in which Monkey biked to a school building, and then chose whether a bicycle (the instrument match) or a school building (the “patient” match) was the referent of the second novel word.

<i>Kraz</i> (lock) box	<i>Bip</i> = lock or box
<i>Lorp</i> (button) sweater	<i>Zot</i> = button or sweater
<i>Jop</i> (comb) hair on head	<i>Raj</i> = comb or hair

Results and Discussion

For the same-kind control items, when children were asked to choose the referents of the second novel words, they chose the different-category foils on 80% of trials ($SE = 8\%$), which was reliably more often than chance (50%), Wilcoxon signed-rank $W = 69.5$, $p < .005$ (see Figure 2). This indicates that children were readily able to make basic mutual exclusivity judgments, which required shifting a noun between two exemplars from the same kind (e.g., between two books).

Figure 2. Results from Experiments 1 through 3. The proportion of trials in which children chose the patient matches on critical trials and the different-kind foils on control trials is plotted (ME = mutual exclusivity; WE = word extension; error bars indicate ± 1 standard error).

For critical trials, which required generalizing a verb form to an untrained noun form, our dependent measure – in this experiment, and the other experiments reported in this paper – was the percentage of trials in which children selected the patient as the referent of the second novel word, rather than the instrument.⁶ Children chose the patient on 73% of the trials ($SE = 7\%$), which was reliably more often than chance, $W = 75, p < .005$ (see Figure 2).⁷ These results suggest that children typically expected the first novel word – which had labeled an activity involving an instrument (e.g., shoveling) – to also label the instrument itself (e.g., the shovel), in absence of any observational evidence that it could.

Children's spontaneous extension is unlikely to have been caused by phonological overlap between the familiar noun and verb forms – e.g., the fact that *shovel* has the same phonological form when used as a noun or verb. As noted before, previous evidence using the same task indicates that children do not extend novel labels between unrelated homophones like *bat*, which also overlap phonologically (Srinivasan & Snedeker, 2011, 2014). Further, children's extension could not have been driven by linking the first novel word to the entire training event

⁶ Because children were given a two-alternative forced choice between the patient and the instrument, nearly all children in our studies selected the instrument when they did not select the patient. However, one child in Experiment 3 refused to provide a response on two critical trials (2.38% of all critical trials in the study), and one child in Experiment 4 did not respond on one critical trial (0.30% of all critical trials).

⁷ Six of 6 children chose the patient match in the *biking* item, 14 of 19 in the *hammering* item, 4 of 9 in the *shoveling* item, 10 of 14 in the *brushing* item, 10 of 12 in the *taping* item, 1 of 2 in the *locking* item, 7 of 10 in the *buttoning* item, and 4 of 4 in the *combing* item. For this and the subsequent three experiments, no significant differences in performance by item were found. In each case, a logit model fit to the object selection (instrument or patient) for the critical trials with item as a predictor revealed no effect of item (all p 's > 0.05).

and any of its participants (e.g., linking *buck* to the shoveling event). Although this mapping would allow the first novel word to apply to the instrument (the shovel), it would also allow it to apply to the patient (the sand), since both were participants in the event.

Instead, the results of Experiment 1 suggest that 4- and 5-year-olds do not treat the noun and verb meanings of familiar words like *shovel* as unrelated homophones, but instead relate these meanings, either using islands of flexibility, or as part of a higher-order semantic generalization that the same root morphemes can label instruments and their associated activities (see Figure 1). To explore whether children of the same age have an abstract, higher-order generalization about this pattern of flexibility, Experiment 2 tested their interpretation of entirely novel words, with novel meanings.

Experiment 2

Experiment 1 indicates that 4- and 5-year-olds expect familiar words for activities to also label the instruments that carry out those activities. Although this finding indicates that children of this age have captured the flexibility of familiar words like *hammer* and *shovel*, it leaves open whether they have a higher-order semantic generalization that allows the same root morphemes to label instruments and their associated activities. For example, according to a usage-based approach, 4- and 5-year-olds may not have had sufficient exposure to flexible words in the input (e.g., to *hammer*, *shovel*, *mix/mixer*, *chop/chopper*, etc.) to have yet constructed a generalization about those words, and may have instead only constructed “islands of flexibility” that encode relations between familiar meanings (see Figure 1; Lieven & Behrens, 2003; Tomasello, 2000, 2003). By contrast, according to an account in which lexical flexibility emerges from innate, generative properties of word meaning (e.g., Pustejovsky, 1995), children should have abstract,

higher-order semantic generalizations throughout development: i.e., once children learn a new word's meaning, they should anticipate its different flexible uses.

Experiment 2 tested this question by exploring whether children expect a label for a novel activity to also label a novel instrument used to carry out that activity. We explored this in two ways. First, one group of children completed a mutual exclusivity task, as in Experiment 1. For each critical item, children were taught that a novel word (e.g., *daxing*) labeled an activity in which a novel instrument was used to act upon a novel patient. They were then asked to indicate the referent of a second novel word (e.g., "Show me the *kiv*"), and could choose between an instance of the instrument and patient. We expected that children would exclude the instrument and choose the patient if they expect the same root morphemes to label instruments and their associated activities (in this example, children might think the instrument should be called a "*dax*" or a "*daxer*"). Second, to test the assumption that children's choices of the patients in the mutual exclusivity task reveal that they spontaneously extend labels for activities to instruments, we gave another group of children a word extension task. On each critical trial, children learned a novel verb just as before (e.g., *daxing*) but were then asked to indicate the referent of this same word when it was re-used as a noun via zero-derivation (e.g., "Show me the *dax*"). We reasoned that if children expect the instrument to be labeled by the same word as the activity, then they should extend the word for the activity to label the instrument in the word extension task.

Method

Participants. The participants were 40 monolingual, native English-speaking children between the ages of 4;0 and 5;10 ($M = 4;10$). A total of 20 children (8 girls) between the ages of 4;1 and 5;10 ($M = 5;1$) participated in the mutual exclusivity task, and 20 children (9 girls) between the ages of 4;0 and 5;5 ($M = 4;7$) participated in the word extension task. An additional

5 children participated but were excluded for failing the warm-up trials that gauged their understanding of the task.

Materials and Procedure. Children either participated in the mutual exclusivity task or in the word extension task.

Figure 3. Critical Items of Experiment 2 (The pictures shown were displayed during the judgment phases of the trials)

Event	Instrument Match	Patient Match
<i>Dax</i> = Instrument flattens out patient
<i>Moop</i> = Instrument stirs patient
<i>Tig</i> = Instrument picks up patient
<i>Wug</i> = Instrument cuts patient into shape

Mutual Exclusivity Task. As in Experiment 1, children first received same-kind and different-kind trials in the warm-up phase, and also received these trials in the test phase. However, the critical trials differed from those in Experiment 1: Instead of depicting events involving familiar instruments (e.g., a shovel) acting upon familiar objects and substances (e.g., sand), the videos depicted novel instruments that acted upon novel objects and substances.

All children received the same four critical trials (see Figure 3). Each of the critical instruments was unique in shape and color, and was used with a novel activity. For example, for the activity that we called *wugging*, we created the novel instrument that enabled the activity by

taking a cookie cutter and attaching blocks of different colors to it. The patients of these activities were also unique. For example, for the activity that we referred to as *daxing*, the instrument acted upon a clay-like substance that had some loose-leaf tea embedded within it (see Figure 3). In the video that was shown to children in the training phase of each trial, the novel verb was modeled to children as they observed the novel activity involving the novel instrument. As in Experiment 1, children heard the novel verb used in the infinitive to refer to what Monkey was going to do (“to *wug*”), in the progressive to refer to the activity as it was ongoing (“*wugging*”), and in the past tense to refer to the completed activity (“*wugged*”). The videos also described the functional affordances of the instruments (e.g., “What Monkey has is sharp on the bottom”).

Immediately after the training phase, we initiated the judgment phrase just as before – e.g., “So that’s what *wugging* is. Now we know what *wugging* is. But *now* I want the *lum*. Show me the *lum*!” The two pictures – an instance of the novel instrument and novel patient – were then presented and the child’s choice was recorded. These pictures depicted different tokens of novel instruments and patients from the same “categories” as those used in the videos. For example, the instrument choice in the *wugging* item had different-colored blocks attached to it, and the patient choice in the *daxing* item was composed of a different-colored clay.

Word Extension Task. The materials and procedure were the same as in the mutual exclusivity task described above, except that the experimenter initiated the judgment phase of each trial by asking the child to make their choice by re-using the first novel word as a noun (i.e., as the parent noun of the verb): e.g., “So that’s what *wugging* is. Now we know what *wugging* is. And now it’s your turn! Show me the *wug*!” The two pictures – which were the same as those used in the mutual exclusivity task – were then presented, and the child’s choice was recorded.

This word extension method was used not just in the critical trials, but also for the same-kind and different-kind trials, which were presented both during the warm-up and test phases. For example, for one same-kind trial, children were taught that *blicket* labeled a book, and then had to extend *blicket* either to another book – the same-kind match – or to a CD – the different-kind foil. These trials provided a measure of children’s ability to perform basic word extensions among exemplars of the same kind.

Results and Discussion

As in Experiment 1, children were readily able to make mutual exclusivity judgments on the same-kind control trials, which required shifting a noun between exemplars from the same category (e.g., between two books). On these trials, children in the mutual exclusivity condition chose the different-category foils on 95% of trials ($SE = 3\%$), which was significantly more often than chance, $W = 104.5$, $n = 19$, $p < .0001$ (see Figure 2).

Our dependent measure on the critical trials of the mutual exclusivity task was the percentage of trials in which children excluded the instrument and chose the patient as the referent of the second novel word. Children chose the patients on 76% of trials, which was reliably more often than chance ($SE = 6\%$), $W = 86$, $p < .001$ (see Figure 2).⁸ This suggests that children avoided mapping the second novel word to the instrument because they spontaneously expected the novel verb for the activity to be re-used as a noun to label the instrument. Consistent with this, when children were presented with a re-use of the first novel word as a noun in the word extension task, they strongly preferred to interpret it as labeling the instrument

⁸ Sixteen of 20 children in the mutual exclusivity condition chose the patient match in the *wugging* item, 14 of 20 in the *daxing* item, 16 of 20 in the *mooping* item, and 13 of 20 in the *tigging* item.

of the event (rather than its patient), and did so on 75% of trials ($SE = 7\%$), which was reliably more often than chance, $W = 75.5$, $p < .005$ (Figure 2).^{9,10}

Together, these findings suggest that 4- and 5-year-olds have an abstract semantic generalization about the flexibility of words like *shovel* and *hammer*, which leads them to infer that a newly learned word that labels an activity, as a verb, will also label the instrument that carries out that activity, as a noun. The fact that this inference occurs spontaneously, in absence of observational evidence that the word for the activity can also label its instrument (or can even be used as a noun), suggests that 4- and 5-year-olds are not limited to “islands” that encode the flexibility of known, familiar words. Instead, children of this age appear to have a higher-order semantic generalization that they can use to infer new form-meaning pairings (Figure 1).

Before exploring further how this semantic generalization might arise in development, we first sought to rule out an alternative explanation for our findings. In particular, our reading of the results of Experiments 1 and 2 is that children interpreted the novel words in the training videos as verbs (e.g., interpreting the use of *wug* in “Monkey is *wugging* the stuff” as a verb), and spontaneously extended them to label the instruments, as nouns. An alternative possibility, however, is that children did not specifically learn the first novel words as verbs that label activities, but instead ignored the syntax in which these words were presented, and directly associated them with the instruments. For example, children may have associated the novel words with the instruments because they were more salient than other aspects of the events – e.g., than the agents, patients, or activities themselves. Critically, if this alternative is correct, the findings of Experiments 1 and 2 may not stem from syntactically-mediated inferences about

⁹ Thirteen of 20 children in the word extension condition chose the instrument match in the *wugging* item, 14 of 20 in the *daxing* item, 15 of 20 in the *mooping* item, and 18 of 20 in the *tigging* item.

¹⁰ Children in the word extension task also chose the same-category matches on 100% of the same-kind control trials.

meaning – i.e., in which children expect words to shift between specific verb and noun meanings – but instead solely from the relative salience of the instruments in the initial events. To rule out this possibility, we conducted an additional study to verify that children do indeed attend to syntax in our paradigm and do not respond purely on the basis of the relative salience of event participants (if in fact, the instruments in the videos were more salient than the patients).

Experiment 3

In Experiment 3, we used the same videos as in Experiment 2 but made one critical change: Instead of using the first novel word as a verb, to label the activity, we used it as a noun, to label the patient of the event – e.g., “Monkey made a shape in the *wug*” rather than “Monkey *wugged* the stuff.” If children in our previous studies ignored the syntax used in the training videos, and mapped the first novel word to the instrument due to its relative salience, they should continue to respond as before. That is, they should assume that the first novel word labels the instrument, and at test expect that a second novel word cannot label the instrument, and must instead label the patient. If, in contrast, children attend to the syntax in which the first novel word is used, they should be more likely to think it labels the patient, and thus be more likely to select the instrument as the meaning of the second novel word than they did in the mutual exclusivity condition of Experiment 2.

Method

Participants. The participants were 21 monolingual English-speaking children (6 girls) between the ages of 4;0 and 5;11 ($M = 4;8$). One child who completed two of the four possible critical trials was included in our analyses. An additional three children participated but were excluded due to failing the warm-up control trials that gauged their understanding of the task.

Materials and Procedure. The materials and procedure were similar to that of the mutual exclusivity condition of Experiment 2, except that in the critical trials, the first novel word was not introduced as a verb, to label the activity, but instead as a noun, to label the patient. Accordingly, we initiated the training phrase of each critical trial by asking children if they knew the meaning of a novel noun – e.g., “Sometimes, Monkey likes to press shapes into this stuff called *wug*. Do you know what *wug* is?” Having established that the novel noun was an unfamiliar word, we showed children a video in which it was used to refer to the patient of a novel action (e.g., “Monkey’s going to use it to press it into the *wug*”; “Wow, Monkey’s making shapes in the *wug*”, etc.). By using the same videos as in Experiment 2 and simply recording different voice-overs, we kept all non-linguistic aspects of the videos – and thus, the relative salience of the instruments vs. patients – the same. After presenting each video, we initiated the test phase of the trial – e.g., “So that’s what *wug* is. Now we know what *wug* is. But *now* I want the *lum*. Show me the *lum*!” The two pictures, which were the same pictures used in Experiment 2, were then presented and the child’s choice was recorded.

Results and Discussion

As in our previous experiments, on the same-kind control trials, children were readily able to make mutual exclusivity judgments, choosing the different-category foils on 84% of trials ($SE = 4\%$), which was significantly more often than chance, $W = 115.5$, $p < .0001$ (Figure 2).

Our dependent measure on the critical trials was the same as in the mutual exclusivity conditions of Experiments 1 and 2: The percentage of trials in which children excluded the instrument and chose the patient as the referent of the second novel word. In contrast to in Experiment 2, where children chose the patient match on 76% of trials ($SE = 6\%$), children in Experiment 3 chose the patient match significantly less often, on only 38% of trials ($SE = 8\%$),

Wilcoxon Rank Sums $z = 3.32, p < .001$ (see Figure 2).¹¹ Children also chose the patient match significantly less often than in Experiment 1 ($z = 3.0, p < .005$). Instead of choosing the patient match, children's choices in Experiment 3 did not significantly differ from chance, $W = 41, p = .14$.

These findings suggest that children in Experiments 1 and 2 did not simply ignore the syntax in which the first novel words were embedded, and directly link them to the instruments due to their relative salience. If the salience of the instruments had alone driven children's previous responses, the results from Experiment 3 should have been broadly similar. Instead, the contrasting results of Experiment 3 suggest that children are sensitive to the structure in which the first novel word is embedded – e.g., whether it is used as a noun to label the patient of an activity (e.g., “Monkey made a shape in the *wug*”), or a verb to label the activity (e.g., “Monkey *wugged* the stuff”). This indicates that children's responses in Experiments 1 and 2 were likely driven by a semantic generalization that leads them to infer that a verb for an activity can also label the instrument that carries out that activity, as a noun.

Experiment 4

Experiments 1 through 3 suggest that 4- and 5-year-olds spontaneously expect new words to label instruments and their associated activities, which could allow them to bypass observational learning to infer new form-meaning pairings. Left open by these findings, however, is how semantic generalizations arise in development, and in particular whether they are implicitly learned from experience or instead emerge from innate, generative properties of lexical semantic structure.

As discussed in the Introduction, one central difference between the usage-based and

¹¹ 8 of 21 children in Experiment 4 chose the patient match in the *wugging* item, 10 of 21 in the *daxing* item, 7 of 20 in the *mooping* item, and 7 of 20 in the *tigging* item.

generative accounts is whether exposure to flexible words in the input is required for children to acquire semantic generalizations about lexical flexibility: Whereas such experience is required on the item-based account, it is not needed on the nativist, generative account. Thus, the item-based account predicts that children's ability to spontaneously infer flexible uses of a novel word may be linked to their knowledge of attested flexible words. To explore this idea, we tested 3-, 4- and 5-year-olds (using an adapted version of the mutual exclusivity task of Experiment 2), and probed whether children's inferences were related to their knowledge of words like *shovel* and *hammer*, as measured by caregiver report.

A second goal of Experiment 4 was to test whether children's ability to generalize instrument-artifact flexibility to new words might be limited by task demands, or by cognitive or motivational differences among children. To test this, we used children's performance on same-kind control trials – which probe children's ability to make basic mutual exclusivity judgments – as a predictor of their performance on critical trials, which rely on an ability to make mutual exclusivity judgments.

Method

Participants. The participants were 84 monolingual, native English-speaking children (42 girls) between the ages of 3;0 and 5;11 ($M = 4;5$), including 29 3-year-olds ($M = 3;6$), 29 4-year-olds ($M = 4;5$), and 26 5-year-olds ($M = 5;6$). Twelve other participants were tested but excluded due to experimenter or technical error (8), interference resulting from a distracting testing environment (3), or because they had witnessed another child participate previously (1).

Materials and Procedure. The procedure for this experiment was the same as Experiment 2, with two exceptions. First, rather than using the first three same-kind warm-up trials as a means for screening children who could not make basic mutual exclusivity judgments,

we added a fourth same-kind trial, and used children's performance on these four trials as a measure of their understanding of the task. Consequently, unlike in Experiments 1 and 2, children did not receive feedback on any of their choices in these trials.

Second, we also asked the caregivers of our participants to fill out a vocabulary survey, to assess children's knowledge of attested noun-verb pairs. The survey probed 33 attested noun/verb pairs (see Appendix A), and asked caregivers to report children's production and comprehension of each word form separately (e.g., for the noun/verb pair *bike*, caregivers were asked to report whether their child understood the noun form *bike*, the verb form *to bike*, and whether they produced each of these forms). We received complete responses from caregivers for 70 of the 84 participants. To create a metric to represent children's knowledge of noun and verb pairs, we averaged together the number of noun and verb pairs children were reported to comprehend (e.g., a child was credited with comprehension of *shovel* if their caregiver reported that they could comprehend both its noun and verb forms) with the number of pairs they were reported to produce.

Figure 4. Results from Experiment 4, plotting the proportion of trials in which children chose the patient matches on critical trials and the different-kind foils on control trials (error bars indicate +/- 1 standard error).

Results and Discussion

Children of all ages were reliably above chance at choosing the different-kind foils on the same-kind control trials: 3-year-olds chose the different-category foils on 62% of trials ($SE = 4\%$; $W = 108$, $p < .05$), 4-year-olds on 70% of trials ($SE = 6\%$; $W = 139.5$, $p < .005$), and 5-year-olds on 91% of trials ($SE = 3\%$; $W = 175$, $p < .0001$; Figure 4). We also observed age-related changes in performance on these trials, suggesting a developing ability to perform basic mutual exclusivity judgments: 5-year-olds chose the different-category foils reliably more often than 4-

year-olds ($z = 3.13, p < .005$), and 3-year-olds ($z = 4.86, p < .0001$), although the performance of 4-year-olds and 3-year-olds did not differ.

As before, our dependent measure on the critical trials was the percentage of trials in which children excluded the instrument and chose the patient. While 4- and 5-year-olds reliably chose the patient of the verb more often than chance (4-year-olds: $M = 60\%$ ($SE = 5\%$), $W = 87$, $p < .05$; 5-year-olds: $M = 65\%$ ($SE = 5\%$), $W = 98$, $p < .01$), 3-year-olds did not ($M = 52\%$ ($SE = 6\%$), $p = .79$; Figure 4). As can be seen, 4- and 5-year-olds performed worse on critical trials than similarly-aged children in Experiment 2, who chose the patient on 76% of trials. This was likely because, in Experiment 4, we did not include warm-up same-kind trials to familiarize children with the task (in which children were provided feedback), nor did we exclude children from our analyses who failed a majority of the same-kind trials (and thus who likely did not understand the task).¹²

To understand the observed developmental change in performance on critical trials we conducted an analysis on the subset of children for whom we had vocabulary data ($n = 71$). Specifically, we fit a logit model to children's responses on critical trials with item, age, vocabulary, and each child's mean same-kind control trial performance as predictors. The model did not detect differences in performance based on individual item (for each level of the item factor, $p > 0.30$). Further, vocabulary was not a significant predictor of children's responses ($\beta = 0.00$, $SE = 0.00$, $z = 0.21$, $p = 0.83$), despite the fact that children's knowledge of attested noun-verb pairs increased significantly with age, $F(1, 69) = 9.77$, $p < 0.005$ (see Figure 5). However,

¹² Indeed, 4- and 5-year-olds who accurately responded to all four of the same-kind control trials ($n = 28$) performed comparably on the critical trials to children from Experiment 2, and chose the patient on 71% of trials ($SE = 5\%$).

performance on the same-kind trials was a reliable predictor ($\beta = 0.97$, $SE = 0.49$, $z = 1.96$, $p < 0.05$), over and above age ($\beta = 0.21$, $SE = 0.17$, $z = 1.24$, $p = 0.22$).¹³

Figure 5. The number of flexible words with noun and verb meanings that children were reported to produce and comprehend.

Together, these findings suggest that exposure to attested flexible words like *hammer* and *shovel* is not a critical determining factor in whether 3- to 5-year-olds generalize the instrument-activity pattern to novel words. Instead, children who failed to generalize may have been limited by difficulty understanding the task – as indexed by performance on same-kind control trials – which could also in turn stem from more general cognitive or motivational differences among

¹³ The model did not detect differences in performance based on individual item (for each level of the item factor, $p > 0.30$).

children. This raises the possibility that even 3-year-olds – who failed to show evidence of generalization as a group – may nevertheless have a semantic generalization about instrument-activity flexibility, but that our task was not sufficiently sensitive to detect this.

General Discussion

The current studies explored whether young children can use semantic generalizations about flexible words like *shovel* and *hammer* to bypass observational learning and infer new word meanings. To test this, we taught children novel words for activities in which an instrument was used to act upon a patient. We then presented children with pictures of the instruments and patients, and asked them to indicate the referents of additional novel words. Across our studies, 4- and 5-year-olds – but not 3-year-olds (Experiment 4) – systematically chose the patient, suggesting that they spontaneously expected that the same root morpheme that had initially labeled an activity would also label the instrument that carried out that activity, thus blocking a second word from labeling the instrument. They displayed this tendency both when the first novel word had a familiar meaning (Experiment 1), and when it had an entirely novel meaning (Experiments 2 and 4). Further, children attended to how novel words were used syntactically, and did not base their judgments purely on the relative salience of the instruments in the training videos alone (Experiment 3). These findings are important because they provide plausibility to a powerful mechanism through which children might build their vocabularies. Given that lexical flexibility is widespread across languages and often falls into regular, predictable patterns (Table 1), children may not need to learn all pairings between word forms and meanings one-by-one, through observation. Instead, via semantic generalizations about lexical flexibility – and an understanding of the word-formation devices through which lexical flexibility is expressed – children could anticipate many conventional form-meaning pairings. Of course, future studies

will be needed to determine whether semantic generalizations about lexical flexibility actually facilitate lexical development in practice.

To our knowledge, our studies are the first to show that children expect new words to be used flexibly. Although previous studies have shown that children are capable of producing and comprehending extensions of words to new meanings (Berman, 1999; Bushnell & Maratsos, 1984; Clark & Berman, 1984; Clark & Hecht, 1982; Lippeveld & Oshima-Takane, 2015), these studies have tested children in situations where they were under communicative pressure to extend words to new meanings (which could be rooted in pragmatics, rather than semantics), or by teaching new words and asking children to interpret them (thus giving them evidence of the new word meanings). By contrast, we taught children a first novel word to label an activity, and probed whether this word was assumed to also name an instrument by asking how children interpreted a second novel word.

The idea that young children expect new words to have multiple, related meanings – and that this expectation could facilitate word learning – departs from classic and contemporary theories of word learning (e.g., Bloom, 2002; Markman, 1990, 1991; Xu & Tenenbaum, 2007; Yu & Smith, 2007). For example, according to Markman (1990, 1991), children make several assumptions about word meaning that help get word learning off the ground, including the *taxonomic assumption* (Markman & Hutchinson, 1984), by which children expect a new word to label items of the same kind (e.g., such that *chicken* is extended from one chicken animal to other chickens, as opposed to thematically-related items like eggs). Critically, a strong version of this constraint might lead children astray when learning flexible words, which have multiple meanings and thus often label items of different kinds (e.g., *chicken* can label not just animals but also their derived meats; Srinivasan & Snedeker, 2014). In particular, to preserve a

taxonomic constraint, children might mistakenly assume that the different meanings of flexible words correspond to distinct words (e.g., such that *chicken*[animal] and *chicken*[meat] are homophones), or that the items labeled by flexible words are of the same taxonomic kind (e.g., such that chicken animals and meat are conflated as exemplars of a common, broad category). Similarly, models of cross-situational word learning have argued that children use statistical evidence to focus in on the single, most likely referent of a new word (Smith & Yu, 2008; Yu & Smith, 2007). However, this strategy could impede children's ability to learn flexible words that label multiple kinds of referents (e.g., statistical evidence for one possible mapping could interfere with evidence for others). While these previous accounts are not necessarily incompatible with the idea that children expect words to have multiple different meanings they have not directly explored this possibility, and thus are not currently formulated to explain flexible semantic generalizations.

Our studies also provide insight into how semantic generalizations about lexical flexibility might develop. The fact that 4- and 5-year-olds generalize flexibility to new words (Experiments 2 and 4) strongly militates against the idea that generalizations about flexibility are constructed via meta-linguistic and analogical reasoning, given that these abilities are known to be relatively weak in children of this age (Bialystok, 1986; Gentner, 1988; Gombert, 1992; Piaget, 1929; Rattermann & Gentner, 1998). What is less clear, however, is whether these generalizations are constructed through implicit learning mechanisms (usage-based account), or if they do not need to be learned because they emerge from innate, generative properties of word meaning (generative account). On the one hand, the fact that 3-year-olds failed to show evidence of generalization in Experiment 4 poses problems for the generative account, which predicts that children should anticipate flexible uses of new words throughout acquisition. On the other hand,

the fact that exposure to attested flexible words was not a predictor of 3- to 5-year-olds' spontaneous inferences in Experiment 4 poses problems for the usage-based account, which holds that generalizations about flexibility are gradually constructed via exposure to flexible words in the input.

The findings from Experiment 4 suggest a solution to this impasse. In particular, 3-year-olds may have failed to show evidence of generalization is because they may not have understood our task well; These children performed relatively poorly even on same-kind control trials, and performance on these trials was a reliable predictor of performance on critical trials. This opens the possibility that even 3-year-olds may have some understanding of instrument-activity flexibility, but our task may not have been sensitive enough to detect this. By using a more sensitive dependent measure, like preferential looking, future studies could explore the relation between younger children's understanding of lexical flexibility and their exposure to flexible words in the input. If the usage-based approach is correct, children's relative exposure to flexibility should predict whether they have 1) formed higher-order generalizations about flexibility, 2) capture the flexibility of familiar words with lexical islands, or 3) treat them as homophones (see Figure 1). By contrast, if the generative approach is correct, children should show evidence of generalization from the onset of acquisition, regardless of their relative exposure to flexibility in the input.

At stake in the question of whether generalizations about flexibility are formed bottom-up from the input or instead emerge from innate, generative properties of lexical semantic structure, is the degree to which such generalizations might facilitate lexical development. If generalizations about flexibility are constructed only gradually, after learning many flexible words, they will by definition not play a role in the acquisition of those flexible words. Prior to

forming generalizations, children would have to acquire each meaning of those flexible words independently, with separate observational evidence for each meaning (Barner & Bale, 2002). If, on the other hand, semantic generalizations about flexibility emerge from innate, generative properties of word meaning, they would allow children to supplement observational learning from the onset of acquisition, and anticipate many of the conventional form-meaning pairings they need to acquire. The latter view would suggest that lexical flexibility can be thought of as a “design feature” that makes the lexicon optimally learnable (Srinivasan, 2016; Srinivasan & Rabagliati, 2015).

One piece of evidence that differentiates the generative and usage-based accounts is the degree to which lexical flexibility varies across languages. If the generative account is correct, children should find it easier to learn flexible uses of words that follow some semantic relations compared to others; This would predict that similar patterns of flexibility should evolve across different languages (though the specific word-formation devices used to express flexible patterns might differ). By contrast, according to the usage-based account, there should not be strong constraints on which kinds of lexical flexibility children can learn, allowing different patterns to develop in different languages. Consistent with the generative account, Srinivasan and Rabagliati (2015) found that nearly all of 26 different patterns of lexical flexibility attested in English were present in 13 other languages (see also Youn et al., 2016). Further, the one pattern that was least attested across languages – the English use of words to label substances and their transfer away from source locations (e.g., *weed* the garden) – is also difficult for English-learning children to acquire (Srinivasan & Barner, 2013), lending preliminary support to the idea that learnability pressures have shaped cross-linguistic variation in lexical flexibility.

Before closing, we should note that the study of the development of lexical flexibility is

compelling not solely because of its implications for word learning, but also because it provides insight into children's conceptual development. Children's understanding of instrument-activity flexibility, for example, suggests that they may conceptualize artifacts in terms of their functions, given that knowledge about the functions of *hammers* and *shovels* constrains what these words typically mean when they are used as nouns and verbs (Clark & Clark, 1979): When used as nouns, these words typically label objects that share a common function, and when used as verbs, they label activities involving those objects that respect their functions. Of course, other interpretations of these words can be computed, through pragmatic reasoning (Clark & Clark, 1979; Falkum, 2010; Papafragou, 1996; Wilson, 2003). For example, in conversation, hardware store employees might use *shoveling* to label the placement of shovels on display racks within the store. However, in absence of a context and common ground among interlocutors that supports an alternative interpretation, default interpretations of words like *hammer* and *shovel* invoke functional information.

Consistent with the idea that an early understanding of instrument-activity flexibility may reveal an ability to conceptualize artifacts in terms of their functions, a large body of work suggests that young children adopt a "design stance" toward objects, and seek to understand (Callanan & Oakes, 1992; Chouinard, 2007; Greif, Nelson, Keil & Gutierrez, 2006; Kemler Nelson, Chan & Holt, 2004) and explain artifacts in terms of their intended functions, as opposed to their physical properties alone (Casler et al., 2009; Dennett, 1989; German & Johnson, 2002; Kelemen & Carey, 2007; Kelemen, 1999; Kemler Nelson et al., 2004). For example, even two-year-olds expect artifacts to be used for a single, specific purpose. After being introduced to a new artifact and learning its function, two-year-olds avoid using the artifact for other purposes (Casler & Kelemen, 2005) and spontaneously protest when others use the artifact in these ways

(Casler et al., 2009). Further, children prefer to extend a new word for an artifact on the basis of shared function – even when pitted against shape – when that artifact has affordances that suggest a specific designed function (Kemler Nelson et al., 2000; Kemler Nelson, 1995). Given these findings, an interesting direction for future research will be to explore how the ability to adopt the design stance relates to children’s understanding of flexible words like *hammer* and *shovel* (see, e.g., Kemler Nelson, Herron, & Holt, 2003).

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Appendix A. Survey of Children's Knowledge of Flexible Noun-Verb Pairs

This questionnaire asks you about whether your child understands and says different words. We are interested in your child's current use of language.

Does your child **understand** and/or **say** the following words, as nouns (as in "She picked up the _____")? Please place a check in the appropriate box (Yes/No/Not Sure).

WORD	Understands this?			Says this?		
	Yes	No	Not Sure	Yes	No	Not Sure
1. Bicycle						
2. Brush						
3. Buckle						
4. Button						
5. Canoe						
6. Chain						
7. Comb						
8. Floss						
9. Glue						
10. Hammer						
11. Iron (clothing)						
12. Lock						
13. Microwave						
14. Mop						
15. Nail (tool)						
16. Paddle						
17. Parachute						
18. Pedal						
19. Pin						
20. Raft						
21. Rake						
22. Saw						
23. Screw						
24. Shampoo						
25. Shovel						
26. Skate						
27. Ski						
28. Spear						
29. Staple						
30. Tape						
31. Telephone						

32. Towel						
33. Whip						

Does your child **understand** and/or **say** the following words, when they are used as verbs?

Below we provide an example of each verb. Please place a check in the appropriate box (Yes/No/Not Sure).

WORD	Example	Understands?			Says?		
		Yes	No	Not Sure	Yes	No	Not sure
1. Bicycle	She bicycled (biked) to work						
2. Brush	She brushed her hair						
3. Buckle	She buckled her belt						
4. Button	She buttoned her shirt						
5. Canoe	She canoed on the river						
6. Chain	She chained the door shut						
7. Comb	She combed her hair						
8. Floss	She flossed her teeth						
9. Glue	She glued the poster to the wall						
10. Hammer	She hammered the nail						
11. Iron (clothing)	She ironed her clothes						
12. Lock	She locked the door						
13. Microwave	She microwaved her food						
14. Mop	She mopped the floor						
15. Nail (tool)	She nailed it to the wall						
16. Paddle	She paddled the boat forward						
17. Parachute	She parachuted out of the plane						
18. Pedal	She pedaled home						
19. Pin	She pinned the paper to the board						
20. Raft	She rafted down the river						
21. Rake	She raked the leaves						
22. Saw	She sawed the wood in half						
23. Screw	She screwed the pieces together						
24. Shampoo	She shampooed her hair						
25. Shovel	She shoveled the snow						
26. Skate	She skated to the park						
27. Ski	She skied down the mountain						
28. Spear	She speared a fish						
29. Staple	She stapled the papers together						

30. Tape	She taped the poster to the wall						
31. Telephone	She telephoned (phoned) her friend						
32. Towel	She toweled herself dry						
33. Whip	She whipped the horse						