



Productivity of Noun Slots in Verb Frames

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Abstract

Productivity is a central concept in the study of language and language acquisition. As a test case for exploring the notion of productivity, we focus on the noun slots of verb frames, such as *__want__*, *__see__*, and *__get__*. We develop a novel combination of measures designed to assess both the flexibility and creativity of use in these slots. We do so using a rigorously controlled sample of child speech and child directed speech from three English-speaking children between the ages of 2–3 years and their caregivers. We find different levels of creativity and flexibility between the adult and child samples for some measures, for some slots, and for some developmental periods. We discuss these differences in the context of verb frame semantics, conventionality versus creativity and child errors, and draw some tentative conclusions regarding developmental changes in children's early grammatical representations.

Keywords: Linguistic productivity; Child directed speech; Verb acquisition; Child language; Noun arguments; Transitive construction

1. Introduction

The expressive power of language manifests itself in many different ways, for example, in syntactic recursion (e.g., *Susan suspects that Mary thinks that...*), morphological patterns (e.g., noun + *s* → *Muggles*), and semi-formulaic lexical schemas (e.g., *the X-er the Y-er*). As a test case for exploring the notion of productivity, we focus here on the productivity of a relatively simple case: the noun slots of verb frames, such as *__want__*, *__see__*, and *__get__*. These frames are the building blocks of the transitive

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construction, which, in one form or another, is present in almost all the world's languages (Hopper & Thompson, 1980; Næss, 2007).

Productivity is a central concept in the study of language. The significance attached to productivity is partly due to the fact that, to explain the “infinite use of finite means,” in von Humboldt's phrase, has been stated as the primary goal of linguistics (Chomsky, 1980). The notion of productivity has also attracted interest from developmentalists since evidence of productivity in children—particularly overgeneralization errors of the type *he goed to the shops*—is thought to provide a window into important learning processes such as generalization and analogy. Thus, ever since the birth of modern scientific approaches to language acquisition, productivity has been of major theoretical and methodological interest (e.g., Brown's 1973, 90% provision of grammatical morphemes in obligatory contexts as a measure of acquisition, although high rates of provision of a given morpheme do not of course necessarily equate to fully productive use). We therefore apply our novel combination of productivity measures to samples of child speech (CS) and child directed speech (CDS) to draw tentative conclusions about language development.

In usage-based approaches to syntactic development, linguistic constructions build up during ontogeny in a piecemeal, concrete fashion, with fewer and weaker abstractions than are present in the adult end-state (Ibbotson, Theakston, Lieven & Tomasello, 2012). A basic prediction from this framework is that children's initial syntactic representations are based around lexical schemas. These schemas are likely to emerge where a number of different lexical items occur in a variable “slot” alongside a relatively frequent and fixed element (the frame), for example, *Where's the X?*, *I wanna X*, *More X*, *It's a X*, *I'm X-ing it*, *Put X here*, *Mommy's X-ing it*, *Let's X it*, *Throw X*, *X gone*, *I X-ed it*, *Sit on the X*, *Open X*, *X here*, *There's a X*, *X broken* (e.g., Lieven, Pine, & Baldwin, 1997). These slot and frame patterns are thought to provide initial footholds of reliability for children to bootstrap their way into more complex and abstract subject–predicate constructions by the processes of analogy, schematization, and functionally based distributed analysis (Tomasello, 2003). In contrast to more classical approaches to categorization based on perceptual similarity, the class of items which can appear in these slots is defined by their role or function in the schema—what Nelson has called slot-filler categories (Nelson, 1974, 1996; see also Mandler, 2000). Thus, the slots in a *__want__* schema could be thought of as the paradigmatic set of “things capable of wanting” and “things capable of being wanted,” respectively.

Somewhat contrary to this overall position are early abstraction accounts of acquisition. In the generative linguistics framework (e.g., Chomsky, 1975, 1981, 1995; Crain & Lillo-Martin, 1999), a basic prediction is that from the earliest observable stages children should show adult-like levels of productivity because CDS essentially provides the trigger for innate linguistic representations (e.g. Bloom, 1990; Pinker, 1984; Valian, 1986, 1991; Wexler, 1994, 1998). However, within this broad class of approaches are a number of different kinds of explanations for children's non-adult-like productions including maturation accounts (e.g., Wexler, 1998) and performance limitations on production (e.g., Bloom, 1990; Valian, 1991). Other authors also argue for early abstraction while suggesting a certain amount of conservatism on the part of the child in his or her willingness to use non-attested linguistic forms (e.g., Fisher, 2002; Naigles, 2003).

In addition to the debate on developmental process, productivity speaks to a different but related discussion on how linguistic knowledge is represented. The classic view in morphology is of an absolute distinction between those rules that are productive and those that are not (e.g., Dressler, 2003; Jackendoff, 1975). However, this view has been challenged more recently by a wide range of studies showing productivity is more of a graded phenomenon (see Hay & Baayen, 2005; for a review). There is also evidence that syntactic constructions are graded in strength depending on both the amount of input children have previously processed and the relative salience of the linguistic cues (Abbot-Smith, Lieven, & Tomasello, 2008; see also Abbot-Smith & Tomasello, 2006). Overall, the evidence—both from developmental and adult psycholinguistic data—provides some support for theories that posit distributed, overlapping, and graded representations.¹ The current study is relevant to this debate as it investigates whether productivity is best characterized as a continuum of flexibility and creativity or whether there is some threshold at which a child's use can be considered productive.

All of this raises an obvious question: What do we mean by productivity? There is more at stake here than an arcane debate about definitions. Opposing theoretical approaches have used the idea of productivity to make strong claims about how children learn language—on this basis characterizing the early language learner as either an “avid grammatical generaliser” (e.g., Naigles, Hoff, & Vear, 2009) or a “conservative learner” (e.g., Tomasello, 2003). This point has been debated at length for a number of different semantic, pragmatic, and syntactic phenomena (for a long and in-depth debate about the determiner category, see Pine, Freudenthal, Krajewski, & Gobet, 2013; Pine & Martindale, 1996; Pine & Lieven, 1997; Valian, 1986; Valian, Solt, & Stewart, 2009). The practical question that emerges out of these debates is how best to measure productivity.

Some authors have thought about productivity as being roughly equivalent to flexibility, that is, the type frequency of a particular slot (e.g., Bybee, 1985, 2001; Naigles et al., 2009; also known as “realised productivity” Bauer, 2001, p. 49 Corbin, 1987). The idea is that the productivity of a particular slot is determined by its flexibility, with slots showing greater flexibility in use also being more readily available for generalization to novel items (e.g., the English regular past tense marker “ed”). Some researchers additionally view flexibility as having a kind of threshold property, such that when a slot reaches a certain level of flexibility, it is said to become productive, for example, *I want it, I want some, I want cake* → *I want X*. For example, using flexibility as a proxy for productivity, Naigles et al. (2009) carried out a diary study of eight children's first 10 uses of 34 target verbs, starting from their first verb productions at between 16 and 20 months. The data were examined to determine the pragmatic, semantic, and grammatical flexibility of children's first verb uses. Of relevance to the current discussion, Naigles et al. assumed that the production of three to five verbs in a given frame (e.g., transitive, intransitive) could be used as a measure of “the productivity of children's syntactic frames” (p. 49). Furthermore, they report that “Lexical (subject) flexibility was the norm” (p. 54) with children using around one-third of their verbs with more than one lexically expressed subject type and almost half of their verbs with more than one lexically expressed object type. Again,

the implication is that variation in use, here of subject and object items with individual verbs, equates to productivity. Note, however, that the authors did not include any analysis of the input. Whether one takes their data as evidence that the child is productive only begs the question: productive compared to what? One cannot make claims about whether the child is an “avid generaliser” or “conservative learner” without looking at the language children hear, a point the authors readily acknowledge (2009, p. 6):

because we do not have access to all the verbs [sic] uses the children have experienced, we will be unable to specify the extent to which their demonstrated extendability goes beyond the input given.

However, going beyond simple imitation of the input is what many would consider an important part of what it means to be productive with language. This is precisely why novel verbs which children have never been exposed to outside of the laboratory are a mainstay of language acquisition experiments and why errors such as “*She giggled me,*” unattested in adult speech, are of such interest in naturalistic data (Bowerman, 1982).

A few recent studies have begun to apply new and rigorous methodological techniques to assess the productivity or flexibility of child speech in relation to adult speech with respect to morphology (Aguado-Orea, 2004; Krajewski, Lieven & Theakston, 2012) and the determiner category (Pine et al., 2013). In the current paper, we implement a range of measures of productivity, adopting similarly controlled procedures, to assess the extent to which children go beyond what they have heard, and how this changes over two developmental periods.

In adult speech, the issue of “creative productivity” raises something of a conundrum. One wants to measure the productivity of the number of established forms that conform to a pattern. However, being creatively productive involves the ability to create new forms for the individual and the language community. So if a form is new, that is, not already created in the language, it cannot be counted (because it does not exist yet). Baayen and Lieber (1991) developed a way to assess the number of *potential* forms of a productive morphological pattern based on the type/token ratio and size of the corpus. We use a similar approach here in the sense that the verb types are controlled for between CS and CDS and we count, for a given corpus size, how many tokens that verb frame licenses. We sidestep some of the issues specific to measuring productivity in adult speech (the extent to which adults introduce novel forms, for example) by treating CDS as the baseline against which CS productivity is judged. For the child to be “creatively productive” in this sense is to use a word in a particular slot that is not evidenced in his or her CDS sample; sometimes this is because it is an unconventional or ungrammatical use, as in *me do it* and sometimes not. In the latter case, it means we simply cannot find evidence that that particular combination was in our CDS sample. This is not to say that the child has never heard this example in CDS—we are of course just dealing with samples—but it does give us a way to quantify the creativity of particular uses relative to those items that are evidenced in the CDS.

First, we compare measures of *flexibility* in CS at two developmental time points with the *flexibility* observed in the matched sample of CDS, both in absolute and relative terms. Absolute flexibility simply means we compare the average type frequency of noun slots in verb frames between CDS and the CS. Relative frequency measures whether the type frequency (flexibility) of noun slots tied to a particular verb frame in CDS is predictive of the same noun slots in the CS. We do this on a sample of CS and CDS speech that has been rigorously controlled for vocabulary, sample size, and semantic verb type (explained in greater depth in Methods). Note that these analyses already go beyond (to our knowledge) existing analyses of CDS–CS productivity with regard to verb frames. However, the limitation of this approach is soon evident. It is not sensitive to the relationship between the actual lexical items (the nouns in the verb frames) used in CDS and in the child's speech. Second, we therefore use two more measures to assess *creativity*. One measure looks at the degree of overlap in the lexical items used with specific verbs between a child and their input. The second measure looks at how verb specific a particular noun use is. Overall, the four measures of flexibility and creativity give us a more methodologically rigorous way to test the theoretically important question of whether early on the child shows adult-like productivity (at least with respect to noun use in verb frames), and how this changes over development. It is important to note that while we focus on the productivity of noun slots in verb frames, the measures we develop here have wider implications for how we think about productivity in general. Thus, we have two main aims: (a) to explore the notion of productivity with a novel combination of four different measures, and (b) using a methodologically rigorously controlled sample of CS and CDS, to draw tentative conclusions regarding developmental changes in early productivity in language development.

2. Method

2.1. The corpus

We present naturalistic child speech data from three monolingual English-speaking children and their associated child directed speech. Fraser's, Thomas's, and Eleanor's data are taken from the Max Planck Dense Database (Lieven, Salomo, & Tomasello, 2009). At the beginning of recording Fraser and Eleanor were 2;0 and at the end of recording they were 3;1. From 2;0 to 2;1, they were recorded for 10 separate hourly sessions per week, from 2;2 to 2;11 for 10 h per month and from 3;0 to 3;1 there were 10 hourly sessions per week. Thomas's data are also taken from the period from 2;0 to 3;2. During this period, Thomas was recorded for 5 separate hours every week. The time period (2;0–3;2) corresponds with a period when children are typically constructing their first multiword utterances. The children were recorded in their homes during typical daily activities such as play, mealtimes, and so on as determined by the caregivers. A researcher was present during some recordings. The data were transcribed in CHAT format (MacWhinney, 2000), and the *mor* and *post* programs were used to assign grammatical labels to words in utterances.

2.2. Extraction procedure

The spontaneous (pro)noun-verb-(pro)noun utterances (hereafter NVN utterances) for the children were automatically extracted from the corpus using custom-written computerized routines operating over the *mor* tier. Typical sentences were *I want it*, *You get teddy*, *She wants cake*. This amounted to 1,321 utterances for Fraser (2;0.1–3;1.11), 2,819 for Thomas (2;0.12–3;2.12), and 2,217 for Eleanor (2;0.2–3;1.17). The identical extraction procedure was applied to their respective CDS corpora, and the corresponding figures were 1,536 NVN utterances for Fraser's CDS, 7,511 for Thomas's CDS, and 2,085 for Eleanor's CDS. After all the controls were applied, this sample was reduced to 108 NVN utterances for Fraser, 136 for Thomas, and 157 for Eleanor. For the purposes of this study, we were not concerned with the distribution or content of other lexical material such as auxiliaries, negation, or adjectives in the NVN frame, so as far as the slot-filler identity is concerned, a sentence such as *Becky really wants a big cake* is treated as *Becky wants cake*. Also, different forms of the same verb were analyzed separately; for example, the noun collocation statistics were calculated for *get*, *got*, and *getting*. Collapsing across lexemes of the same verb would have (i) obscured any potential differences in the way particular forms collocate with nouns, either in the flexible or creative sense, and (ii) made the assumption that a 2-year-old had made the conceptual link between these different verb forms.

2.3. Preparing the corpus for analysis

The productivity of a slot is influenced by the opportunities one has to use that slot (for our purposes, the frequency of the verb frames in the corpus); the resources one has available to fill that slot with different lexical items (vocabulary); and the collocations that the semantics of the particular slot will allow (semantic valency). Thus, we can identify three factors that could affect the productivity of a slot relevant to the current study (a) sample size: a speaker cannot show more flexibility than there are opportunities to be flexible, (b) vocabulary: a speaker cannot show more flexibility than he or she has words to be flexible with, and (c) semantic valency: a speaker cannot conventionally show more variability than the semantics of the slot will allow. The procedure below explains how we controlled for these elements and prepared the corpus for analysis.

First, we defined two developmental windows in the child's corpus so that we could compare productivity at one time point to another (and also compare both of these time points to the CDS sample). We selected these developmental windows so that they were as far apart in time as the corpus would allow in order that we maximized our chance of finding a developmental difference (if there is one). Time 1 (T1) was defined as the child's first 300 NVN constructions of the corpus for Eleanor and Fraser and 500 NVN constructions for Thomas. We aimed to match the number of NVNs across children but the strict verb-match and vocabulary controls meant that Thomas had too few verbs that met these criteria with a cutoff of 300 NVNs, so we relaxed this to 500 NVNs to capture more variation. The important point is regardless of the differences between children, the

number of utterances is matched for each CS–CDS pair. The number of constructions we take as T1 is a somewhat arbitrary cutoff point; however, taking the first N utterances to some extent controls for rate of development in different children (although not, of course, if some children are more talkative or sampled more densely than others, and it is also likely that the children were at slightly different stages of development at the start of the recordings) as slow children will reach the first N at a later time than others. To create a dataset for Time 2 (T2), we split the remaining NVN utterances for each child in half and used those from the latter half of the data to ensure that there was a developmental gap between the two datasets.

Secondly, in order to control for the noun and verb vocabulary occurring in each sample, the vocabulary was then determined by creating lists of all the words that occurred in the T1 sample, in the T2 sample, and in the CDS sample for each dyad regardless of whether they appeared in NVN utterances or not, and then creating a master vocabulary list of words that occurred in all three samples for each dyad.

To compare the child's language at T1 and T2, and against the input (CDS), we then created a list of verbs occurring in NVN utterances, with their associated subjects and objects, including only those utterances where both the subject and object were in the master vocabulary list. For every analysis, only verbs used four or more times in NVN at T1, at T2, and in CDS were included. Where the number of utterances with a given verb was larger in one sample than in another, the larger sample was randomly reduced down to the lower number. Thus, the actual number of utterances analyzed for any given verb equates to the smaller of the number of occurrences in the samples (i.e., if the child produces fewer tokens of a specific verb in T2, this is the number analyzed, if in T1 then vice versa; similarly if the child at either time point produces fewer tokens of a specific verb than are found in their CDS, the CDS sample was randomly reduced to the lower number, or vice versa). This random reduction was repeated 10 times to control for the possibility that any particular random sample may be unrepresentative. For example, a single sample could contain utterances that are very close developmentally to the utterances from the other time period, and we could fail to find a difference between T1 and T2 even if one exists over a longer developmental period. We took averages across these 10 samples in our counts of subject, object, and verb type frequencies; hence, we sometimes have decimal values for mean subjects/objects/verbs randomly sampled.

Finally, as outlined above, each comparison between T1, T2, and CDS is restricted to the same set of verbs (those occurring four or more times at T1, T2, and in the input). We do this because the semantics of the verb will contribute to the combinatorial possibilities of the items it can appear with. For example, one could imagine a situation where the object slot in the NVN frame *__want__* is relatively more open than *__break__*; that is, the set of “wantable” things is larger than the set of “breakable things.” Whether this is true or not for these verbs is irrelevant—the point is that each verb to some extent defines the scope of the items it is free to combine with. Because of the various controls we have in place, this means that the set of verbs we use for the analyses is not exactly the same for all children (although there is often overlap). To do so would have imposed criteria so strict that the number of NVN frames available for study would have been too

small. Within each dyad, the verb types are kept constant across all four analyses. Table 1 shows the verbs analyzed for each child, along with the number of verb tokens analyzed following application of the various controls, and the overall number of verb NVN tokens for each verb in CS and CDS. For Eleanor and her CDS, these were as follows: *have*, *doing*, *need*, *get*, *want*, *love*, *do*, *got*, *find*, *see*, *getting*, and *like* ($\underline{M}$ tokens per verb = 13.1, range 4–42). For Fraser and his CDS, these were as follows: *got*, *did*, *get*, *love*, *found*, *like*, *see*, *want*, *getting*, *do*, *need*, and *hurt* ($\underline{M}$ tokens per verb = 9, range 4–21). For Thomas and his CDS, these were *get*, *open*, *got*, *eat*, *hold*, *like*, *see*, *go*, *find*, and *do* ($\underline{M}$ tokens per verb = 13.6, range 4–55). The differences in the identity of the verbs analyzed between children mean that a degree of caution is needed when making claims about between-child differences, particularly with respect to absolute levels of flexibility or creativity. We, therefore, mostly concentrate on making comparisons between developmental time points for the same child and comparisons between a particular child and his or her CDS where the verbs are always matched.

These controls are important. Any change in flexibility, creativity, or productivity between T1 and T2 cannot be attributed to the fact that there were more sentences at T2 than T1 (sample size control), nor can it be that the child knows more words at T2 than at T1 (vocabulary control), nor can it be that the set of verbs in either the child or CDS samples combine more flexibly with nouns (semantic valency control).

3. Results

3.1. Analysis 1: Absolute flexibility

Table 2 shows an example of what we mean by absolute flexibility. This measure is simply the number of types in a particular slot for a particular verb, here the object slot for the verb *want*. Higher type frequencies could be taken to indicate greater absolute flexibility of a particular slot.

3.1.1. Procedure

From the matched verb samples (taken from the pool of utterances that has already been controlled for sample size, vocabulary, and verb identity), for each verb we simply counted the number of different types of items that appeared in the subject and object slot in the NVN frame for the children at T1 and T2 and for their CDS. Fig. 1 shows the mean subject and object types combined with individual verbs for each of the children and their caregivers.

3.1.2. Results and discussion

Mixed effects models were fitted to the data with random effects of Dyad (Eleanor, Fraser, Thomas) and Verb (to account for random variation caused by the inclusion of three different children and their caregivers, and a different set of verbs for each dyad) and the fixed effect of Time (T1, T2, CDS) to determine whether there were differences

Table 1
Number of NVN verb tokens available for analysis for each verb

	Tokens After Controls Applied	Total NVN in CS at T1	Total NVN in CS at T2	Total NVN in CDS
Eleanor				
Like	21	21	41	51
Getting	12	12	24	41
See	9	9	10	26
Find	5	5	7	26
Got	8	8	10	18
Do	42	42	72	184
Love	7	7	10	57
Want	26	26	109	45
Get	8	22	8	26
Need	8	8	20	10
Doing	4	4	6	9
Have	7	7	23	32
Total	157	171	340	525
Fraser				
Hurt	7	9	7	16
Need	4	4	7	11
Do	21	27	21	106
Getting	11	11	15	33
Want	9	9	51	34
See	13	13	33	73
Like	5	5	51	29
Found	9	9	10	19
Love	4	4	11	11
Get	14	16	14	19
Did	7	8	7	32
Got	4	24	4	16
Total	108	139	231	399
Thomas				
Do	55	209	55	186
See	18	18	31	224
Eat	21	22	21	67
Find	4	4	4	17
Open	4	4	4	27
Like	7	7	30	188
Go	4	4	5	15
Hold	14	29	14	50
Get	4	4	42	35
Got	5	5	8	29
Total	136	306	214	838

in the type frequency of the subjects and objects combined with individual verbs in the child and caregiver samples. For subjects, there were significantly fewer types in the children's data at both T1 and T2 ($\underline{M}$ T1 = 2.88, T2 $\underline{M}$ = 2.87) than in their CDS ($\underline{M}$ = 3.72,

Table 2
Example of absolute flexibility in the object slot for *want*

		Object Type Frequency
Child T1	<i>I want it, I want it, I want cake</i>	2
Child T2	<i>I want it, I want cake, I want drink</i>	3
CDS	<i>I want it, I want her, I want cake</i>	3

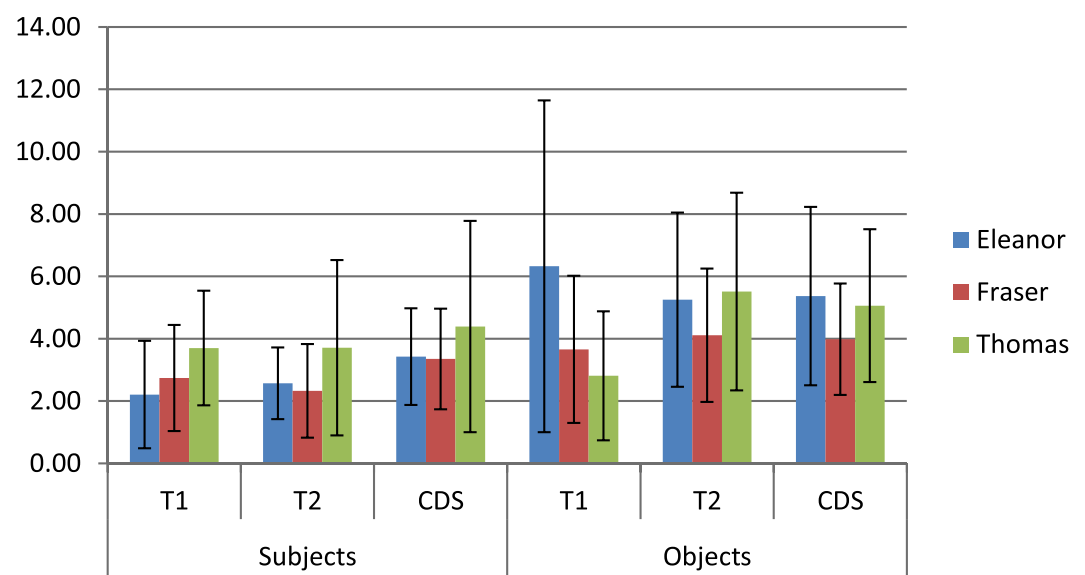


Fig. 1. Mean type frequency of subjects and objects (& SD) combined with individual verbs in the children's and their caregivers' speech (CDS).

T1 $\beta = -0.85$, $t = -2.73$, $p < .01$; T2 $\beta = -0.86$, $t = -2.78$, $p < .01$). There was no difference in the type frequency of subjects in the children's data between T1 and T2 ($\beta = -0.02$, $t = -0.06$, $p = .95$). For objects, there was no difference between the children's object use at T1 ($M = 4.27$), at T2 ($M = 4.96$) and in the CDS ($M = 4.80$) (T1 vs. CDS $\beta = -0.44$, $t = -0.81$, $p = .42$; T2 vs. CDS $\beta = 0.14$, $t = 0.25$, $p = .80$; T1 vs. T2 $\beta = 0.57$, $t = 1.06$, $p = .29$). However, it is clear from Fig. 1 that there is considerable variation, both between speakers and between verbs in the variability of items appearing in the subject and object slots.

Our first analysis of productivity is similar to the Naigles et al. (2009) approach in that we counted the items that appear in a particular grammatical context (NVN). However, it differs in that we make an explicit comparison to the input and we control for vocabulary and sample size. Overall, we find that the children show lower productivity with their subject slot than is seen in CDS, but their flexibility with objects is similar to that seen in CDS even at T1.

In this first analysis, the identity of the verb was treated as a random variable, thus essentially glossing over the identity and therefore the semantic nature of what items actually appear in the slots and how they were distributed. In the next analysis, we examine the flexibility of slots on a verb-by-verb basis to determine whether relative differences in slot flexibility with individual verbs in CDS can also be observed in CS.

3.2. Analysis 2: Relative flexibility

Slot frequency is counted in exactly the same way as the previous analysis for the same verbs; the difference is that we analyze the data on an individual verb basis, with type frequency of a particular slot for a particular verb in CDS matched to that same information for that same verb in CS. In the example in Table 3, we show a hypothetical example of the patterning for two verbs. In this example, we can see that the absolute level of flexibility of the child is always below that of the input. That still leaves open the question as to whether there is a relationship between the relative levels of flexibility for individual verbs. In this example, it appears as if there is (although there are only two verbs to keep things simple). So, even though absolute levels are always lower in the child, both child and caregiver combine nouns in the object position more flexibly with *see* than they do with *want*. Of course, it could have been the other way round, such that the caregiver shows greater flexibility with *want* than with *see*—the mean type frequency of the object slot across verbs would remain the same, but the extent to which CS and CDS are related would differ. The following analysis determines whether these kinds of relationships hold for the actual data.

3.2.1. Procedure

Again, analysis is restricted to those verbs that are shared with CS and CDS at T1 and T2 and taken from the pool of utterances that has been controlled for vocabulary and sample size. This time, analysis was conducted on matched pairs (e.g., for a particular child, the CS subject slot for *want* was paired with the CDS subject slot for *want*). Fig. 2 shows the type frequency of subjects and objects with individual verbs in CDS and CS at T1 for illustrative purposes.

Table 3
Example of relative flexibility of the object slot according to verb

		Object Type Frequency	
		<i>Want</i>	<i>See</i>
Child	<i>I want some, I see her</i>	1	2
	<i>I want some, I see her</i>		
	<i>I want some, I see him</i>		
CDS	<i>I want some, I see her</i>	2	3
	<i>I want her, I see some</i>		
	<i>I want her, I see cake</i>		

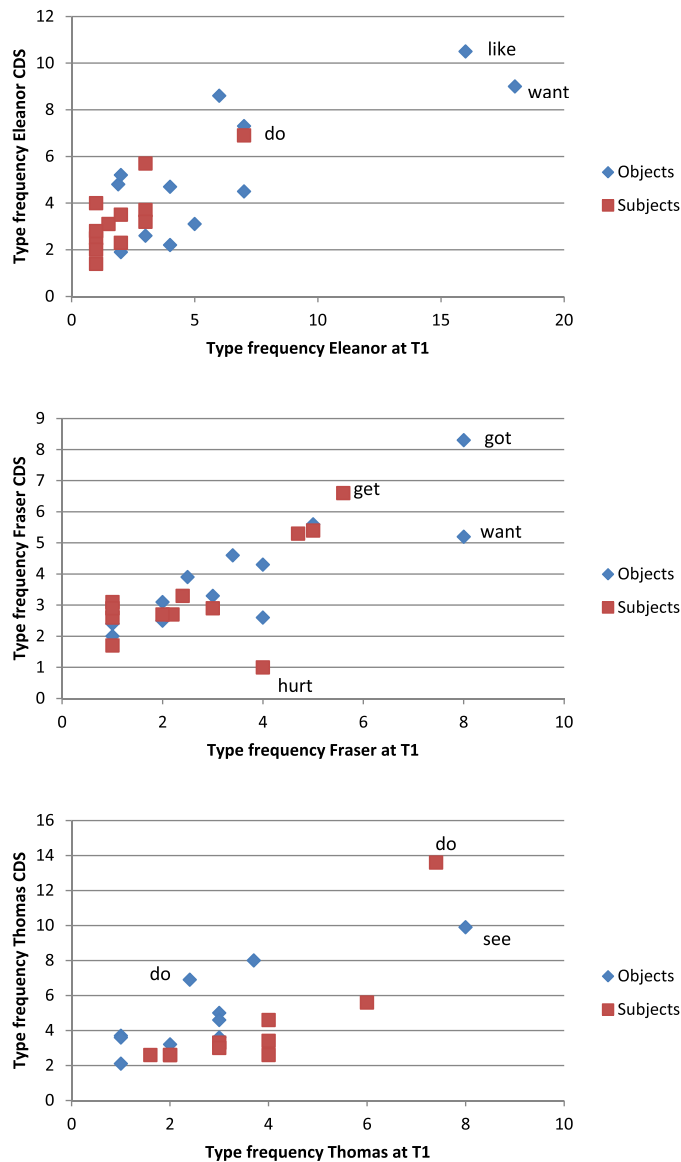


Fig. 2. Mean type frequency of subjects and objects with individual verbs in children's speech at T1 and in CDS.

3.2.2. Results and discussion

Mixed effects models were fitted to the data to determine the relationship between CDS and CS in subject and object flexibility for individual verbs. Random factors of Verb and Dyad (as in Analysis 1), and fixed effects of Time (T1 vs. T2) and type frequency in CDS and their interaction were entered into the model as predictors of type

frequency of subjects and objects in CS with individual verbs. For subjects, maternal type frequency predicted child type frequency ($\beta = 0.56$, $t = 6.35$, $p < .001$), but there was no interaction between maternal type frequency and Time ($\beta = 0.13$, $t = 1.20$, $p = .23$) and, as in Analysis 1, no effect of Time ($\beta = -0.49$, $t = -1.07$, $p = .29$). For objects, maternal type frequency predicted child type frequency ($\beta = 1.20$, $t = 7.89$, $p < .001$), but there was no interaction between maternal type frequency and Time ($\beta = -0.20$, $t = -1.03$, $p = .31$) and no effect of Time ($\beta = 1.54$, $t = 1.46$, $p = .15$).²

These results show that there was a strong relationship between the relative flexibility of both the subject and object slots with individual verbs in CDS and CS, and that this held at both time points.

We reiterate that the results did not have to be this way—there are clearly many ways to achieve the overall means in terms of subject and object type frequency (flexibility) seen in Analysis 1 (see Fig. 1), only one of which is for the correlations to line up as they do on a verb-by-verb frame basis. Thus, the children are not using a given verb slot in an arbitrary way relative to the CDS they hear; rather, they seem to be paying close attention to the statistics of the combinatorial possibilities on a verb-by-verb frame basis, presumably based on the semantics of the verb and the pragmatic demands of the discourse context. Flexibility is not simply a consequence of token frequency. To illustrate, consider the following examples. First, the verb *do* has the highest sample frequency for all three children. However, although it also shows the highest subject slot flexibility at T1 for two of the children (third for Fraser), it is ranked third, sixth, and eighth in terms of its object type frequency in the children's speech. Second, Eleanor's most productive object slot at T1 is *want*, produced with 18 different items (*it, that, mama, one, video, breakfast, weewee, bottle, hat...*), yet it is also one of her verbs with the least productive subject slot, appearing with only one item, predictably *I* (this is Fraser's second most productive object slot appearing with eight objects and three different subjects, but note that Thomas's sample does not contain the verb *want* at all, demonstrating some of the between-child differences observed). Some of Eleanor's other verbs such as *have* show greater flexibility in the subject slot, appearing with three different items in CS at T1, despite occurring approximately one quarter as often as the verb *want*. Thus, the variance in CS–CDS verb slot use seems best explained as an interaction between the conventional semantic affordances of the verbs (there is presumably some agreement between speakers of a language) and the individual way in which the parents and, in turn, their children choose to talk about the world based on their particular experience.

Given the substantial body of evidence showing close links between the way adults use particular words, morphemes, and phrases in CDS and the way children learn them (e.g., Cameron-Faulkner, Lieven, & Theakston, 2007; Clark, 2004; Freudenthal, Pine, Aguado-Orea, & Gobet, 2007; Kirjavainen, Theakston, & Lieven, 2009; Naigles & Hoff-Ginsberg, 1998; Pine, Rowland, Lieven, & Theakston, 2005; Rowland & Pine, 2000; Rowland, Pine, Lieven, & Theakston, 2003; Theakston, Lieven, Pine, & Rowland, 2001, 2002), it is perhaps not surprising that the flexibility of use of items in the input should have a close relationship with the way in which children use these items. What

we underline here is the importance of looking at productivity on multiple levels and from different perspectives.

Gaining flexibility, defined as learning a number of different items in a particular slot, is obviously an important part of the learning process; both in terms of having some critical mass of exemplars over which analogies can form and in terms of the shape of the type/token distribution (Casenhiser & Goldberg, 2005; Krajewski, Siebenborn & Lieven, 2011). However, these measures do not take into account the identity of the items that appear in the slot. Therefore, the next two measures examine the creative part of what it means to be productive where we look at the identity (not just the type frequency) of actual items used in the slots.

3.3. Analysis 3: Creativity (overlap)

The measure of creativity we consider here is what we call overlap, reflecting shared lexical subject, and object items used with particular verbs in the CDS and CS samples. In the example in Table 4, we compare two situations with respect to items found in CDS. Notice that in both situations the type frequency of the object slot (flexibility) is *identical* yet the degree of creativity (overlap) varies. In the first instance, it is easy to see how the child could be just repeating particular collocations attested in the input, which gives the illusion of productivity by being flexible. In the second instance, there is the same level of flexibility, but there is a reduced level of overlap between the items used in CDS and CS and an increase in “unique items”—that is, items that are found uniquely in either CS or CDS that indicate relative creativity. We clearly need a way of distinguishing between these two scenarios that are intuitively different in terms of productivity.

We, therefore, measure overlap in two ways, as illustrated in Table 5. To begin with, we identify items that are shared between CS and CDS in a particular slot with a particular verb. For our first measure, we calculate the proportion of all items used in that particular slot with that verb in CDS that also appear with that verb in that same slot in CS. There are (at least) three possible scenarios. If the children start out with the same creativity with respect to a given slot as their caregivers, we should see no developmental change in this measure. On the other hand, if children start out with more limited creativity, by sticking more closely to a limited number of lexical items in a given slot (Example A), then over the course of development one of (at least) two things could occur. The children could become more flexible, but in a way that mirrors use in their input; thus,

Table 4
Example of creativity (overlap) in two CS–CDS scenarios

		Object Type Frequency	Shared Forms
Child	<i>I want it, I want her, I want cake</i>	3	3
CDS	<i>I want it, I want her, I want cake</i>	3	
Child	<i>I want it, I want more, I want cake</i>	3	1
CDS	<i>I want him, I want more, I want dogs</i>	3	

Table 5

Creativity (overlap) as a function of subject and object forms in CS and CDS

Measure 1—% CDS Forms in CS			Object Type Frequency	Shared Forms	Proportion Forms in CDS Found in CS	
E.g., A	Child	<i>I want it, I want it, I want cake</i>	2	2	2/3 = 66.7%	
	CDS	<i>I want it, I want her, I want cake</i>	3			
E.g., B	Child	<i>I want it, I want her, I want cake</i>	3	3	3/3 = 100%	
	CDS	<i>I want it, I want her, I want cake</i>	3			
E.g., C	Child	<i>I want it, I want more, I want cake</i>	3	2	2/3 = 66.7%	
	CDS	<i>I want it, I want her, I want cake</i>	3			

Measure and CS	2—% Total Forms	Shared Between CDS	Object Type Frequency	Shared Forms	Total Forms	% Shared
E.g., A	Child	<i>I want it, I want it, I want cake</i>	2	2	3	2/3 = 66.7%
	CDS	<i>I want it, I want her, I want cake</i>	3			
E.g., B	Child	<i>I want it, I want her, I want cake</i>	3	3	3	3/3 = 100%
	CDS	<i>I want it, I want her, I want cake</i>	3			
E.g., C	Child	<i>I want it, I want more, I want cake</i>	3	2	4	2/4 = 50%
	CDS	<i>I want it, I want her, I want cake</i>	3			

we would expect to see a greater proportion of items used in CDS also occurring in CS in that same slot with that same verb (Example B). On the other hand, children could become more flexible by producing a range of lexical items not attested in that slot in their input, demonstrating creativity. In this case, the proportion of items found in CDS that also occur in CS would remain constant (as in the case of no developmental change, Example C), but the number of items unique to CS would increase. Our second measure was designed to capture this possibility. In the second measure, we calculate the proportion of all items used in this slot with this verb in either CS or CDS that are used by both speakers. On this measure, examples A & B give the same results as previously because the items used (productivity) in the child's speech corresponds to the items produced by the caregiver. But by looking at the total variation, rather than just that seen in the caregiver's speech, we are able to capture the possibility that an increase in flexibility might result from the child's increased use of items not attested in the input (Example C). In this scenario, we would expect the proportion of the total pool of items used in a particular slot with a particular verb by both speakers (CS & CDS) to reduce over development, reflecting increasing creativity in child use. The following analysis applies these measures to the actual nouns used in the verb frames.

It should be said at this point that the sample of CDS and child speech we are working with here is, of course, only a sample and we reiterate a point from the introduction. For the child to be "creatively productive" in the way that we are interested in here is to use a word in a particular slot that is not evidenced in his or her CDS sample. This could be because it is an unconventional use, as in *me do it*, but will also reflect correct combinations that have just not occurred in our matched CDS sample. Of course, we are not claiming that the child has never heard this example in CDS—we are dealing with sam-

ples—but it does give us a way to quantify the creativity of particular uses relative to those items that are evidenced in the CDS. All things being equal, we are most likely to sample subject and object forms that are used with particular verbs frequently, and these are therefore also more likely to appear in both CS and CDS samples. Conversely, lower frequency forms are less likely to be sampled at all, and less likely to show overlap between CS and CDS. But children will also have less evidence that these forms can be used with particular verbs in their input, and thus their use in children's speech is more likely to represent creativity than rote-learned collocations. The absolute levels of overlap are only a guide therefore, and more generally, raw scores of overlap are in themselves not very interesting theoretically—members of the same speech community by definition share knowledge about their language including vocabulary. What are important are any changes in the overlap between developmental periods (T1 and T2) as this is indicative of a shift in the children's usage patterns.

3.3.1. Procedure

Again analysis was carried out on the same pool of NVN frames controlled for vocabulary, sample size, and semantic valency. For each child and caregiver, we determined which nouns they used with individual verbs in their respective NVN frames in the T1, T2, and CDS samples. We then identified which of these nouns for each verb were found in the same position (subject or object) in both CS and CDS, and which nouns for that verb in that slot belonged uniquely to CS or CDS usage. Fig. 3 shows the proportion of items in (a) CDS, and (b) the combined sample of CS and CDS that were shared between speakers with the same verb and in the same slot for T1 and T2.

3.3.2. Results and discussion

To determine whether the percentage of subject and object items in the children's speech that were shared with forms found in their input changed over development, mixed effects models were fitted to the data. Random effects of Verb and Dyad were entered into the models (as in Analyses 1 & 2) along with the predictor variable of Time (T1, T2). For Measure 1, for both subjects and objects, there was an increase in the proportion of items used in CDS that were also produced by the children with the same verb between T1 and T2 (subjects T1 = 36%, T2 = 48%, $\beta = 0.10$, $t = 2.76$, $p < .001$; objects T1 = 32%, T2 = 41%, $\beta = 0.09$, $t = 3.54$, $p < .001$). For Measure 2, there was an increase in the proportion of the total pool of subject forms in CDS and CS that were produced by both the mothers and children with the same verbs between T1 and T2 (T1 = 28%, T2 = 37%, $\beta = 0.08$, $t = 2.82$, $p < .01$), but there was only a marginally significant change in the proportion of the total pool of objects that was produced by both the mothers and children with the same verbs (T1 = 22%, T2 = 26%, $\beta = 0.03$, $t = 1.90$, $p = .06$).

These results suggest that over the course of development, the children were beginning to use more of the same subjects and objects as were found in their caregivers' speech. For subjects, this reflects the gradual shift toward adult-like levels of flexibility observed in Analysis 1, but here we are able to see that the increase in flexibility is related to the particular forms used in CDS. In fact, overlapping subjects are overwhelmingly a small

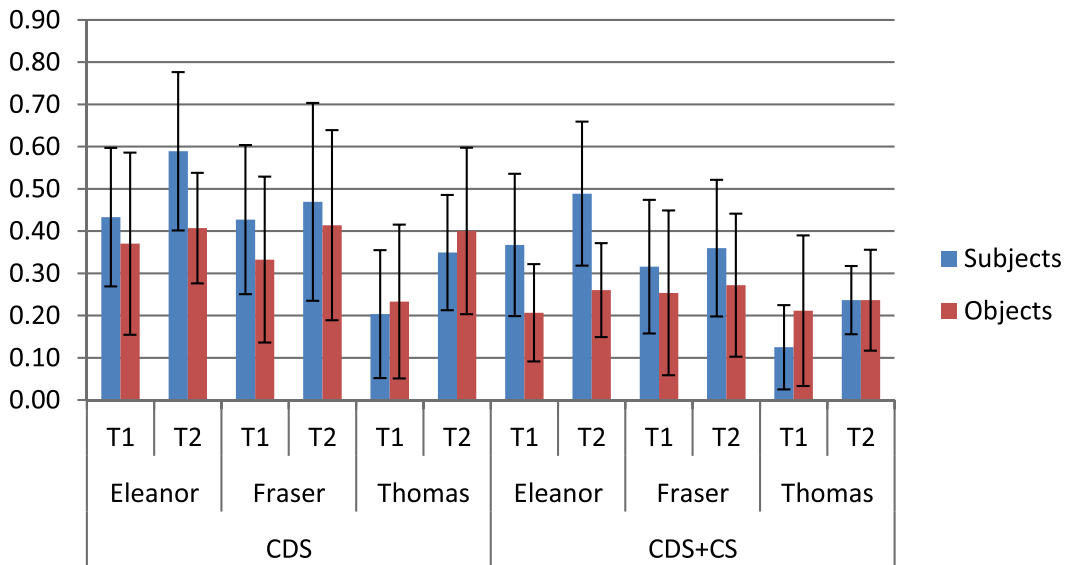


Fig. 3. Mean proportion (& SD) of subject and object forms in CDS, and subject and object forms in CDS and CS combined, that are produced by both mother and child.

number of pronominal forms for Eleanor and Fraser, and proper names for Thomas at T1, and the increase in overlap at T2 reflects the children's growing command of a range of different pronoun forms that were, nevertheless, present in their speech at T1 (e.g., see Theakston, Maslen, Lieven, and Tomasello [2012] for more detailed analysis of Thomas's early transitive utterances). Thus, an increase in flexibility for subjects largely indicates an increase in the use of forms also used by the caregivers, and not an increase in the use of unique forms that would be expected to reduce rather than increase the overall overlap (Measure 2). This is perhaps not surprising—the subjects of transitive sentences are typically realized pronominally, and thus the range of available forms is relatively limited (Du Bois, 1987).

For objects, an increase in the proportion of items in CDS that are also produced by the children is not accompanied, to the same extent, by a general increase in the proportion of the total object items produced that are shared. This indicates that as well as increasing their use of items produced by their caregivers, the children are also increasing their use of unique object forms, that is, forms that are not attested in that slot with that same verb in their input. Many of these are idiosyncratic to the particular semantics of the verbs concerned, for example, Fraser's use of the forms *pasta*, *spaghetti*, and *Postman-Pat* with the verb *like*, indicating a more flexible but semantically governed creativity. Where changes in the children's subject use seemed to reflect the more general preference for highly frequent pronominal forms as the subject of transitive utterances, their choice of object forms also seems to reflect the more general patterning of the language. The children use lexical nouns in the object slot of their transitive sentences and these are more varied and often less frequent than their pronominal counterparts.

Developmentally, one can think about these results in (at least) two ways. One might have expected the proportion of shared items to be higher at T1 as children conservatively “stay close” to usage patterns in CDS and only gradually expand their repertoire to include novel forms. Alternatively one could characterize development as learning to become more conventional, in which case the identity of CS items should begin to look more like CDS as time progresses. In fact, both processes seem to be at work, but there is an added dimension to consider, namely the particular features of the slot under consideration. Children seemingly move closer to CDS in their subject use, but in addition to this, they also show increased creativity in their object use, reflecting the distribution of items in these slots in their input, which, in turn, reflects the properties of preferred argument structure—that subjects typically represent given information and are realized pronominally, whereas objects represent new information and are realized as lexical noun phrases (Du Bois, 1987). One source of the increase in conventionality, particularly in subject use, might be early CS errors. That is, if children are producing ungrammatical uses at T1 that are not found in CDS (e.g., Eleanor’s *all doing* __, Fraser’s *me get* __, and Thomas’s *me hold* __), and are supplanted by correct uses at T2, then they are more likely to increase their proportion of shared items with CDS. However, it is important to recall that only items present in the vocabulary at both T1 and T2 were included in these analyses, so these results do not simply reflect the acquisition of new lexical forms. Note also that the purely quantitative approach to measuring flexibility in terms of type frequency adopted in Analyses 1 and 2 fails here and we need to look at the identity of items to uncover evidence of development.

The measure we have used here of “shared items” in the subject and object slots is as shared for CDS as it is for CS, by definition. In the next and final analysis, we explore the nature of these shared items further and ask whether there are ways we can distinguish more or less productive use of these items in CS and CDS.

3.4. Analysis 4: Creativity (specificity)

What we mean by specificity is the degree to which a noun is tied to a particular verb frame or whether it is “promiscuous” and appears with lots of other verbs. In the example in Table 6, CS use of the pronoun *some* is restricted to the object slot of *want*. In the CDS sample, *some* appears with *want*, but it also appears with *see* and *get*. Note how the previous flexibility measures (Analyses 1 & 2) are insensitive to this difference because in this example the type frequency count for objects with the verb *want* in both CS and CDS is identical (3). The previous analysis of overlap creativity is also insensitive to the specificity difference because it measured only whether for a particular slot, the same noun occurred for both input and child, and not the extent to which a noun was used across different verbs. In this specificity analysis, each noun occurring in a subject or object slot is given a specificity score, according to how many different verbs (from the matched set of NVN frames) that noun combines with in that same slot. In the example in Table 6, there are three verbs in the sample (*want*, *see*, *get*). The child’s object slot for

Table 6

Example of the specificity measure for the object *some*

		Specificity—No. of Verbs Item Used with (shown for <i>some</i>)
Child	<i>I want some, I see her, I get cake</i>	1
	<i>I want it, I see her, I get cake</i>	
	<i>I want more, I see him, I get cake</i>	
CDS	<i>I want some, I see her, I get cake</i>	3
	<i>I want cake, I see some, I get her</i>	
	<i>I want her, I see cake, I get some</i>	

the form *some* scores 1 because there are two other verbs *some* could have appeared with but did not. In comparison, CDS scores 3 as *some* appears with *want*, *see*, and *get*.

3.4.1. Procedure

As with previous analyses, this analysis was restricted to the set of verbs that appeared at least four times at T1, T2, and in the CDS for each child, to the vocabulary items that appeared in all samples, and to matched sample sizes for individual verbs. We first identified for these verbs the group of nouns that appeared for the child in a particular slot with any of these verbs that *also* appeared in the same slot in their CDS with any of these verbs (i.e., the items did not have to appear in CS and CDS with the *same* verb). We then established how many of the verbs each item appeared with for the child and then how many verbs each appeared with in the CDS sample. We repeated this for all shared items and calculated an average specificity score for each item type (subjects, objects) at each time point (T1, T2), for each speaker (CS, CDS). As in previous analyses, randomized data reduction was necessary to equate the number of tokens of each verb. Therefore, to avoid the possibility of using unrepresentative samples, this process was repeated 10 times with different randomly generated matched samples where data reduction was required. Ideally we would have included the same set of shared nouns in CS and CDS across samples, and taken an average for the number of verbs each individual subject and object item combined with. However, with the data we had, this criterion was too strict and would have resulted in too few NVN frames to analyze. This is because if a particular subject or object form is found in both CS and CDS in randomly reduced sample 1, or at T1, but not in sample 2 or at T2 as is often the case for low-frequency forms, then strict matching would mean these items would be excluded from analysis. Nouns were therefore matched between the child and CDS at T1 and between the child and CDS at T2, and matching was done independently for each randomly reduced sample. We then used the data from these 10 repeated analyses to compare the degree of specificity in the verbs used with subjects and objects in CS and CDS and between the two time points T1 and T2.

3.4.2. Results and discussion

To determine whether particular subjects and objects were used with a wider range of verb types in CDS than in CS, or in CS at T2 in comparison to T1 (see Fig. 4), mixed

effects models were fitted to the data. Random effects of Sample (10 samples) and Dyad (Eleanor, Fraser, Thomas), and fixed effects of Time (T1, T2), Speaker (CS, CDS), and the interaction between them were entered into the model. In Analyses 1–3, Verb was entered into the model as a random factor because each verb was repeatedly randomly sampled, with each data point representing the mean across samples for that verb. However, in Analysis 4, the outcome variable was the mean number of verbs combined with the subjects or objects produced in any given random sample. Because the subject and object forms differed between samples, Sample was entered as a random variable, rather than the specific subject or object form. For subjects, there was no interaction between Speaker and Time ($\beta = 0.15$, $t = 0.63$, $p = .53$). There was a significant effect of Time with both children and mothers showing greater flexibility in the number of verbs used with individual subject forms across development for children, and in the samples matched to T1 versus T2 for mothers (T1, M no. of verbs in CS = 3.41, CDS = 4.07; T2, CS = 3.97, CDS = 4.77; $\beta = 0.56$, $t = 3.40$, $p < .001$), and a significant effect of Speaker, with mothers using their subjects with more different verbs than their children at both time points ($\beta = 0.66$, $t = 4.00$, $p < .001$). For objects, there was a significant effect of Time ($\beta = 0.25$, $t = 2.70$, $p < .01$) and of Speaker ($\beta = 0.54$, $t = 5.78$, $p < .001$), but there was also a significant interaction between Time and Speaker ($\beta = -0.53$, $t = -4.02$, $p < .001$). This reflects the fact that the mothers used their objects with a wider range of verbs than their children at T1, but the children showed an increase in flexibility across development such that there was no difference between CS and CDS at T2 (T1, M no. of verbs in CS = 2.56, CDS = 3.11; T2, CS = 2.82, CDS = 2.83).

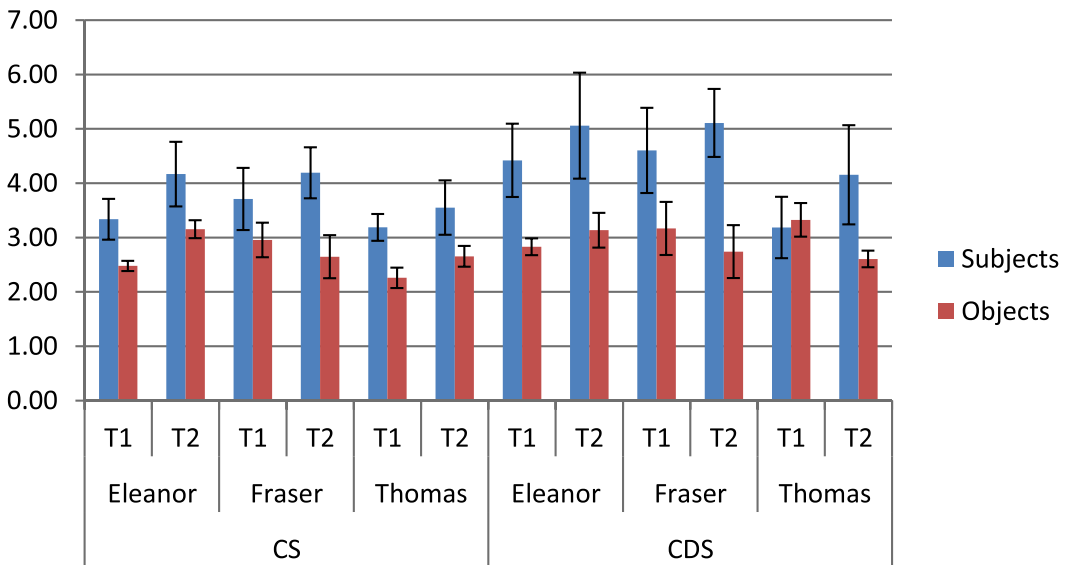


Fig. 4. Mean no. of verbs (& SD) combined with each subject and object form in CS and CDS.

These results demonstrate that even when children and their caregivers use exactly the same subject and object items, and the sample size and verb identity are controlled, caregivers show greater flexibility, or relatively less verb specificity, in their use of these items. For subjects, this difference can still be observed at T2, whereas for objects the effect only holds at T1 with children showing equal productivity as is seen in CDS in their use of particular objects across verbs at T2. An analysis of the items used in these slots reveals that the effects we see for subjects are largely driven by pronoun use. For example at T2, Eleanor shares the item *we* with her CDS, but it is used with an average of 3.8 verbs in CS compared to 6.1 verbs in CDS, in part accounting for the greater flexibility seen in CDS. This can also explain why we see greater flexibility in the CDS sample matched to CS at T2 than in the CDS sample matched to CS at T1. Although pronouns such as *we* appear in Eleanor's vocabulary at T1 and are potentially available for use with the target verbs, some are not in fact used with these verbs until T2. In this analysis, CS and CDS were matched according to the subject types appearing in CS with the target verbs. Thus, many pronouns were not included in the matched T1 CDS sample. Because the child had begun to use these forms with her target verbs by T2, these forms were included in the matched T2 CDS sample, boosting apparent flexibility of subject use. In contrast, items that are shared at T1 are more likely to be proper names (e.g., *Mummy*, *Dada*) and used with relative verb specificity in CDS, presumably because parents more often use pronominal forms, and the contexts of occurrence of some named individuals may be semantically restricted (e.g., names for family pets, TV characters).

4. General discussion

Productivity has been of long-standing theoretical interest in linguistics and language acquisition research, but it is a complicated concept and one that raises the issue of how best to measure it. What we have tried to do here is systematically look at different facets of productivity with four different measures using a methodologically rigorously controlled sample of CS and CDS. We found differences between CS and CDS productivity that were dependent on the particular analysis used and the stage of development we were looking at. Before summarizing these findings and discussing them in terms of language acquisition more generally, we briefly underline the methodological and theoretical improvements our paper offer to the existing debate on productivity.

First, every measure of CS productivity is explicitly compared with a matched sample of CDS (c.f. Naigles et al., 2009). It seems obvious that without examining the nature of what children hear (e.g., the flexibility and creativity of noun slots) it is difficult to make claims about the nature of what children say (e.g., the productivity of noun slots). Even when the CDS sample comprises only a subset of all that children actually hear, it is still better than no input comparison at all. When we examine the input, we have a proper benchmark to gauge the child's developmental stage, that is, if the samples are comparable, which brings us to the second point. Before comparing the productivity of CDS and child speech, samples were rigorously matched with one another in terms of sample size,

vocabulary, and verb identity. This means any differences in flexibility, creativity, or productivity between T1 and T2, or between CS and CDS cannot be attributed to the fact that there were more sentences in one sample than another (sample size control), nor can it be that the mother knows more words than the child, or that the child knows more words at T2 than at T1 (vocabulary control), nor can it be that the set of verbs in either the child or CDS samples combine more flexibly with nouns (semantic valency control). Finally, we have tried to move beyond the notion that productivity is roughly equivalent to type frequency by measuring not only flexibility (both in absolute and relative terms) but also by trying to capture the creative aspects of productivity as well.

What do the results tell us about how productive children are with respect to the language they hear? In Analysis 1, caregivers were found to combine their verbs with a greater number of subject types on average than their children at both time points, but no difference in absolute flexibility was observed for objects, although there was some suggestion that absolute levels of flexibility were lower at T1 than at T2. Fairly substantial differences were observed both between speakers and between verbs. In Analysis 2, we looked at whether variation in flexibility between verbs could be predicted by verb-specific patterns of use in CDS. We found clear evidence that this was the case, suggesting that the extent to which children are flexible with individual verbs depends on their experience of hearing those verbs used in the input. Analyses 1 and 2 did not take into account the identity of the subject and object forms produced, so it was impossible to determine whether the levels of flexibility observed reflected the particular items used in CDS, or a more creative pattern of language use by the children. In Analysis 3, we examined this issue by considering the extent to which the subject and object forms used with individual verbs overlapped between CS and CDS. The data revealed that the children showed an increase in overlap with CDS over development for both subject and object forms, suggesting that changes in flexibility (type frequency) are tightly related to the forms seen in CDS and a move toward greater conventionality. In addition, for objects but not subjects, there was also an increase in items found only in CS and not in the accompanying CDS, suggesting a higher level of creativity in the object slot by T2. In Analysis 4, we investigated whether, for subject and object forms that were found in both CS and CDS, there were any differences in specificity of use of those forms. That is, do children use their subjects and objects with a more restricted range of verbs than their caregivers? The data provide support for this suggestion for subject forms at both time points, but for objects, caregiver speech is more productive than CS at T1 only.

Overall, these results paint a fairly clear picture. Children's use of subject forms is more restricted, when measured in a number of different ways, than their CDS, even by T2. In contrast, their use of object forms is more adult-like from the beginning, and we only detect developmental change with some measures, namely the apparent increase in unique object forms used at T2, and the move to adult-like levels of verb flexibility at T2, in comparison to greater verb specificity at T1. Thus, simple measures of productivity based solely on type frequency counts fail to capture the developmental changes we see for object use, although they are able to detect differences in subject use over development. Of course, it is possible that with a larger number of children, or a larger number

of verbs, we may observe more differences in object use between CS and CDS, so our conclusions regarding object use from null results are necessarily tentative.

What can we learn about development? If the question is whether children show adult-like productivity early on in development with subject and object slots in NVN frames, the answer depends on what we mean by productivity. Based on the analyses here, it is possible to answer that question with a “no” but with the caveats; for some measures of flexibility, for some measures of creativity, at some time points, with some verbs and/or nouns, and in some argument slots. As least with regard to the productivity of noun slots in verb frames, there does not seem to be strong evidence to suggest that these CS samples show “avid generalization,” at least not in the sense that they are as “avid” as the CDS samples are. In general, CS was less flexible than CDS and these differences were more detectable early on in development (T1). On the other hand, the children were clearly sensitive to the different distributional characteristics of the subject and object slots, and to the semantic properties of these slots. Earlier productivity with the object slot is consistent with approaches advocating simple distributional learning from the ends of utterances, in which for English at least, objects are favored by virtue of their utterance-final position (e.g., Freudenthal et al., 2007).

These are tentative conclusions based on the limited CDS–CS pairs with sufficiently dense data to support this kind of methodologically rigorous analysis. However, we should also note that in order to carry out this analysis, we ignored intervening material such as auxiliaries, negators, and determiners in NVN frames. If we had treated all of these forms differently, the process of matching vocabulary items across CS and CDS would have been much more difficult and we would have had to exclude even more data. On the other hand, it is important to consider how children might process these different kinds of input, and whether it is plausible to assume that when children hear complex noun phrases as the subjects or objects of verbs (e.g., *the big brown dog*), this serves as input for simpler forms (e.g., *dog*). Furthermore, another important issue that deserves greater consideration is the process by which children build up flexibility and productivity of more complex NP slots. This issue is examined briefly for Thomas’s early transitive utterances elsewhere (see Theakston et al., 2012). Thus, although our analyses by no means address the full complexity of the problem, what we can strongly advocate is looking at the notion of productivity from a number of different perspectives with properly matched samples.

Our measures, particularly Analysis 2, also emphasize the graded nature of productivity highlighted recently by studies in morphology and syntax showing how representations can be distributed, overlapping, and graded (e.g., Abbot-Smith & Tomasello, 2006; Abbot-Smith et al., 2008; Hay & Baayen, 2005; Ibbotson et al., 2012). Rather than use some arbitrary threshold at which a child or a NVN frame is considered either productive or not (an approach taken by some language acquisition researchers as a proxy for productivity, e.g., Naigles et al., 2009; Shirai, 1998), productivity can be measured along a continuum of flexibility and creativity, and, as productivity is a relative term, measured with respect to an appropriate control. The data from this study show that productivity can be sensibly analyzed as a graded phenomenon.

Of course, our four measures are not the only ways to measure productivity. The measures we have presented are insensitive to the difference between what might be called qualitative flexibility versus quantitative flexibility of a slot. In theory, two slots with the same number of lexical types could display different degrees of flexibility based on their semantic diversity. For example, in our quantitative approach *table*, *chair*, and *car* are simply counted as three types, as are *I*, *garage*, and *water*, yet the second set seems relatively more diverse; for example, it includes entities that are animate, inanimate, count, and mass nouns. Taking this as a starting point it is relatively easy to see how further work could integrate the quantitative and qualitative aspects of slot-filler category productivity. This is to some degree predicated on capturing how a child rates the semantic distance between objects at any given point in development (see Matthews & Bannard, 2010 for possible measures to capture this). We have also attempted to address methodological and theoretical issues regarding productivity in such a way that the implications go beyond the immediate concern of noun slot productivity in verb frames. Productivity is an issue that concerns developmental theorists and linguists alike—whether they are interested in phonological, morphological, or syntactic patterns. We need measures that capture both the flexible and creative aspects of productivity and to do this we need properly matched samples between the child and CDS.

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Notes

1. As might be expected, the evidence for graded representations is not limited to language. It has been invoked to explain feature detection, categorization, concept learning (e.g., Landauer & Dumais, 1997; Tenenbaum, 1999), visual processing (Poggio & Edelman, 1990), and motor control (Poggio, 1990).
2. It is important to note that maternal type frequency of subjects and objects with individual verbs correlates highly with the overall sample size for each verb at both time points (Range Pearson's $r = .58-.80$). Indeed, mixed models fitted with verb sample size rather than maternal subject and object type frequency as the principal predictor show the same pattern of results. However, the correlation between child type frequency and maternal type frequency is higher than that between child type frequency and sample size for subjects and objects at both time points, markedly so for objects, suggesting that for objects at least, maternal type frequency contrib-

utes to the pattern of use in the children's speech over and above sample size. (Subjects: child type frequency & (a) maternal type frequency T1 $r = .76$, T2 $r = .65$, (b) sample size T1 $r = .67$, T2 $r = .57$; Objects: child type frequency & (a) maternal type frequency T1 $r = .74$, T2 $r = .88$; (b) sample size T1 $r = .34$, T2 $r = .65$).

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