Analysing the effect of sibling number on input and output in the first 18 months

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Abstract

Prior research suggests that across a wide range of cognitive, educational, and health-based measures, first-born children outperform their later-born peers. Expanding on this literature using naturalistic home-recorded data and parental vocabulary report, we find that early language outcomes vary by number of siblings in a sample of 43 English-learning U.S. children from mid-to-high socioeconomic status homes. More specifically, we find that children in our sample with two or more - but not one - older siblings had smaller productive vocabularies at 18 months, and heard less input from caregivers across several measures than their peers with two or more siblings. We discuss implications regarding what infants experience and learn across a range of family sizes in infancy.

Keywords: Siblings, Lexical Development, Input Effects, Language Acquisition

Word count: X

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A common simplifying assumption in research on language development is that there is a theoretical "optimum" environment for early language, whereby the input is tailored to a single infant's needs, changing over time as language capacity grows (e.g. Soderstrom, 2007; Stern, Spieker, Barnett, & MacKain, 1983). However, for many infants and for many reasons, language acquisition occurs across diverse social contexts that can influence the learning environment, including the presence of older siblings in the home (Fenson et al., 1994). According to the United States Census Bureau (2010), around one third of children are born into households with at least one other infant present, and one in every five infants is acquiring language in a household shared with two or more other children. Similar statistics are reported for British infants (Office for National Statistics, 2018), where the average household has 1.75 children, and 15% of households have three children or more. In this paper, we consider the role of siblings in the early language environment of English-learning infants. We use naturalistic home-recorded data to measure input in earlier- and later-born infants in relation to their productive vocabulary over the first 18 months of life.

Prior research suggests that infants born to households with older children may be slower to learn language. Fenson and colleagues (1994) found that by 30 months of age, children with older siblings performed worse than those with no siblings across parent-reported measures of productive vocabulary, use of word combinations, and mean length of utterance. This 'sibling effect' may be the result of differences in input between first- and later-born children: some research finds that infants with older siblings hear less speech aimed specifically at them, and what they do hear is understood to be linguistically less supportive of early language development (Hoff-Ginsberg, 1998; Oshima-Takane & Robbins, 2003). In contrast, some studies have noted linguistic *advantages* for later-borns, who may have stronger social-communicative skills (Hoff, 2006), better understanding of pronouns (Oshima-Takane, Goodz, & Derevensky, 1996), and better conversational abilities (Dunn & Shatz, 1989). Overall, while the particulars differ across studies, prior work suggests that the presence of siblings in the home leads to differences in infants' early linguistic experiences and skills, though the direction of these differences varies depending on what aspects of language are being measured.

Numerous studies have attempted to better understand how siblings affect the language development trajectory, with comparisons of language acquisition across first- and later-borns, and analyses of mothers' input in dyadic (infant + mother) and triadic (infant + mother + older sibling) situations. Here again, findings are mixed, but overall two general conclusions can be drawn. First, analyses consistently show that infants with older siblings generally have slower *vocabulary development* (Berglund, Eriksson, & Westerlund, 2005; Fenson et al., 1994; Pine, 1995; Zambrana, Ystrom, & Pons, 2012), though effect sizes tend to be small, with significant differences more typically found in the earliest stages of language learning. Hoff-Ginsberg (1998) shows first-borns to have better lexical and syntactic skills up until 2;5, but later-born infants had better conversational abilities during the same time-period. Relatedly, using a large longitudinal dataset of French-learning 2-5 year olds, Havron and colleagues (2019) find no effect of age gap between siblings, but lower standardized language scores in children with older brothers (but not sisters) relative to those without siblings, based on parental report and direct battery assessments. Some of these differences across studies may relate to insufficient power to detect relatively small effects or simultaneous contributing factors that are difficult to disentangle.

The second general finding pertains to sibling-related differences in the early linguistic *environment*: infants with no siblings receive more input overall, and this more closely reflects what is typically considered to be 'high quality' input in the extant literature. Indeed, the very presence of a sibling in the linguistic environment changes the way language is used. When siblings are present (i.e. triadic interactions), mothers' input has been found to be more focused on regulating behaviour, as opposed to the language-focused speech that is common in dyadic contexts (Oshima-Takane & Robbins, 2003). Reports show that the mean length of utterance is longer in the input of first-born infants (Hoff-Ginsberg, 1998; but see also Oshima-Takane & Robbins, 2003 for a comparison of dyadic and triadic contexts), who also hear more questions directed at them than later-borns. Both Jones and Adamson (1987) and Oshima-Takane and Robbins (2003) report no difference between the overall number of word types produced by mothers in dyadic and triadic settings, but the proportion of speech directed at the target infant is drastically reduced when input is shared with siblings.

As Hoff (2006) explains, infants with siblings have less experience of speech directed at them, but they do have an advantage over their first-born peers in that they are subject to more overheard speech. Barton and Tomasello (1991) show that by as early as 19 months, infants with siblings are already able to take part in triadic conversations, which were almost three times longer than dyadic conversations. The authors suggest that the presence of siblings may shift the learning context, and facilitate infants' participation in communicative interactions: infants are under less pressure to participate in a triadic interaction, meaning the conversation can continue even when the infant is unable to respond. As a result, the infants in Barton and Tomasello's study took more conversational turns in triadic interactions than dyadic ones.

There thus may be a trade-off in development between highly supportive one-to-one input from a caregiver (cf. Ramírez-Esparza, García-Sierra, & Kuhl, 2014) and the potential benefits drawn from communicating with (or overhearing communication with) a sibling. In the present study, we test the extent to which having more versus fewer siblings in the home environment may lead to differences in vocabulary development and the early linguistic environment over the course of the first 18 months of life. In analyzing infants' growing productive vocabulary in relation to the presence of older siblings in their household, the present work expands on the extant literature in two key ways. First, prior work generally considered birth order as a binomial factor (i.e. comparing first-born infants with second-borns, e.g. Oshima-Takane & Robbins, 2003), or 'later-borns' (e.g. Hoff-Ginsberg, 1998), potentially missing graded effects. Instead of this approach, we consider how having *more versus fewer siblings* is linked to an infant's lexical development and their early linguistic environment. Second, much of the existing literature in this area is drawn from questionnaire data or brief interactions recorded in the lab (but see Dunn & Shatz, 1989 for a study of naturalistic home-recorded data), rather than naturalistic day-to-day interactions in the home. In contrast, we analyze an existing corpus of home recordings in concert with vocabulary checklists. Based on work summarized above, we expect that both the language environment and infants' early productive vocabulary will vary as a function of how many older siblings they have.

Hypotheses

In broad strokes, given prior research showing that early lexical development is more advanced among first-born infants (e.g. Hoff-Ginsberg, 1998), our prediction regarding infants' productive vocabulary is that if this effect is gradient, then children with more siblings will have lower productive vocabularies than their peers with fewer siblings. With regard to the infants' linguistic environment, we hypothesize that infants' with more siblings will experience lower prevalence of two aspects of the language input previously shown to support language development: **amount of input** and **amount of object presence.** To unpack each of these input aspects, following previous studies that show infants with siblings to receive less speech directed at them (Jones & Adamson, 1987; Oshima-Takane & Robbins, 2003), we expect to see the same effect in our sample. By object presence we mean word and object co-occurrence, e.g. mother saying "cat" when the child is looking at a cat. We predict object presence will decrease as sibling number increases, because as caregivers' attention is drawn away from one-to-one interactions with the infant, there is likely less opportunity for contingent talk and joint attention. Prior research suggests links between object presence and early word learning (Bergelson &

Aslin, 2017; Cartmill et al., 2013), though to our knowledge this has not been examined in relation to sibling number.

Methods

We analyze data from the SEEDLingS corpus (Bergelson, Amatuni, Dailey, Koorathota, & Tor, 2019), a longitudinal set of data incorporating home recordings, parental reports and experimental studies from the ages of 0;6 to 1;6. The present study draws on the parental report data to index child vocabulary size, and annotations of hour-long home video recordings, taken on a monthly basis during data collection, to index input. We also ran our input analysis using data sub-sampled from day-long audio recordings taken on a different day from the video data reported below; all results were consistent with those outlined below (see Supplementary Materials). We note at the outset that with such a multidimensional dataset there are always alternative ways of conducting analyses of input and output; our goal here is to make motivated decisions that we clearly describe, provide some alternative analytic choices in the supplementals, and to share the data with readers such that they are free to evaluate alternative approaches.

Participants

Forty-four families in New York State completed the year-long study. Infants (21 females) were from largely middle-class households; 33 mothers had attained a B.A. degree or higher. Based on parental report, no infants had speech- or hearing-relevant diagnoses; none were low birth weight (all >2,500g); 42 were white, two were from multi-racial backgrounds. All infants heard >75% English on a regular basis. Two participants were dizygotic twins; we retain one twin in the current sample, considering the other only as a sibling. Thus our final sample size was 43 infants.

Sibling Details. Sibling number was computed based on parental report in the demographics questionnaires completed at 0;6 (R: 0-4). Siblings were on average 4.11 years older than the infants in this study (Mdn days: 1,498.50, SD: 1465, R: 0-17 years).[1] All siblings lived in the household with the infant full time, apart from one infant who had two older half siblings (and no other full siblings) who lived with their other parent part of the time. Both older siblings were present for at least some of the monthly recordings. One family had a foster child live in the home for 2 months of data collection, who is not accounted for in our data; the target infant had one sibling. All siblings were older than or of the same age as the infant in question.

Materials

Parental report data. To index each child's language abilities, we draw on data from vocabulary checklists [MacArthur-Bates Communicative Development Inventory, hereafter CDI; Fenson et al., -Fenson et al. (1994)], administered monthly from 0;6 to 1;6, along with a demographics questionnaire; each month's CDI survey came pre-populated with the previous month's answers to save on reduplicated effort. Because the majority of infants did not produce their first word until around 0;11 according to CDI reports (M=10.67, SD=2.23), we use CDI data from 0;10 onwards in our analysis. CDI production data for each month is taken as a measure of the infants' lexical development. CDI data for production has been well validated by prior work, including work in this sample (Frank, Braginsky, Yurovsky, & Marchman, 2021; Moore, Dailey, Garrison, Amatuni, & Bergelson, 2019). Of the 13 CDIs collected for each infant (559 CDIs in total), 26 were missing across 11 infants. 4 infants had 4 CDI data-points missing, while the majority (n = 5) had only one missing data-point.

Home-recorded video data. Every month between 0;6 and 1;5, infants were video-recorded for one hour in their home, capturing a naturalistic representation of each

[1] For six infants, siblings' exact birthdates were not provided, and so age difference was estimated by subtracting the infant's age (6 months) from the sibling's age in years, as listed on the questionnaire (e.g. if a sibling was 5 years old, they were classed as being 4.5 years older than the infant).

infant's day-to-day input. Infants wore a hat with two small Looxcie video cameras attached, one pointed slightly up, and one pointed slightly down; this captured the scene from the infants' perspective. In the event that infants refused to wear the hats, caregivers wore the same kind of camera on a headband. Additionally, a camcorder on a tripod was set up in the room where infants and caretakers were interacting to capture a broader view; families were asked to move this camcorder if they changed rooms.

Object words (i.e. concrete nouns) deemed to be said to, by, or loudly and clearly near the target child were annotated by trained coders for several properties of interest to the broader project on noun learning. Here we examine annotations for speaker, i.e. who produced each noun, and object presence, i.e. whether the noun's referent was present and attended to by the infant (see "Derived Input Measures" below). See Bergelson et al. (2019) for further details on the full set of home-recorded data and its annotations.

Derived Input measures. Two input measures were derived based on the annotations of concrete nouns in this corpus, each pertaining to an aspect of the input that is established as important in early language learning: **overall household input** (how many concrete nouns does each infant hear?) and **object presence** (how much of this input is referentially transparent?), detailed below. We note that neither of these measures are, in our view, interpretable as "pure" quality or quantity input measures; we hold that quality and quantity are inextricably linked in general, and specifically we include (by design) only object words that the recordings suggest were possible learning instances for the infants who heard them, wherein quantity and quality are conflated.

Household Input reflects how many nouns infants heard in the recordings from their mother, father and (where relevant) siblings. Other speakers' input was relatively rare during video recordings, accounting for 11.42% of input overall (SD=22.82%), and is excluded from our analysis. This measure of the early language environment is based on evidence showing strong links between the amount of speech heard in the early input and later vocabulary size (Anderson, Graham, Prime, Jenkins, & Madigan, 2021). This analysis considers only nouns produced by speakers in the child's environment (which is what was annotated in the broader SEEDLingS project); concrete nouns are acquired earlier in development in English and cross-linguistically (Braginsky, Yurovsky, Marchman, & Frank, 2019). In this corpus (as in any sample of naturalistic interaction) the number of nouns correlates highly with the number of words overall [e.g. based on automated analyses of adult word counts vs. manual noun-only annotations; Bulgarelli & Bergelson, -Bulgarelli & Bergelson (2020)]. Thus, noun count in the monthly hour of video data serves as our household input proxy.

Object Presence was coded as "yes", "no", or "unsure" for each object word annotated in the home recordings based on trained annotators' assessment of whether the referent of the word (i.e. the object) was present and attended to by the child. In the video data, 169 instances (0.25% on average per infant) of object presence were marked as unsure; these instances were not included in this analysis.

In the following analyses, we consider infants' total productive vocabulary[2] alongside these two input measures – nouns in household input and extent of object presence in the input – as a function of sibling number. Since the raw data are highly skewed, log-transformed data and/or proportions are used for statistical analysis (1 was added to the raw infant production data of all infants before log-transformation to retain infants with vocabularies of 0.) All figures display non-transformed data for interpretive ease.

Results

Vocabulary development was highly variable across the 43 infants, according to the CDI data we had available. By 18 months, 2 infants produced no words (taken from 36

[2] While in principle we could have just used noun productive vocabulary, in practice noun and total vocabulary is correlated >.95 in this age range; we opted to retain the overall total vocabulary, as lexical class is not a straightforward notion in the early lexicon.

Table 1

Sibling number by female and male infants.

n Siblings	Female	Male	Total
0	9	12	21
1	7	6	13
2	2	3	5
3	2	0	2
4	0	2	2
Total	20	23	43

available CDIs at this time-point), while mean productive vocabulary size was 60.28 words (SD=78.31, Mdn=30.50). Three infants had substantially larger-than-average (3SDs above the mean monthly vocabulary score) vocabularies at certain time-points in the data; we opted to count one of these infants as an outlier and remove her data from the CDI analysis, owing to vocabulary being higher for multiple consecutive months (1;1-1;6). The other two infants had higher vocabularies at 10-11 months only. This left 42 infants (19 females) in the analysis of vocabulary size. Infants had one sibling on average (M=0.86, Mdn=1, SD=1.10). See Table 1.

Model structure for fixed and random effects

All reported models were generated in R (R Core Team, 2019) using the *lmerTest* package to run linear mixed-effects regression models (Kuznetsova, Brockhoff, & Christensen, 2017). *P*-values were generated by likelihood ratio tests resulting from nested model comparison. All models include infant as a random effect. All post-hoc tests are two-sample, two-tailed Wilcoxon Tests; given that all of our variables of interest (CDI score, household input and object presence) differed significantly from normal by Shapiro tests, we opted to run non-parametric tests for all post-hoc comparisons. Where multiple post-hoc comparisons are run on the same dataset, Bonferroni corrections are applied (e.g. with an adjusted p-value threshold of .025 for 2 between-group comparisons are done). While we have a substantial amount of data for each participant, our limited n means we are under-powered to consider multiple demographic variables simultaneously given the data distribution (e.g. sibling number and sex, see Table 1; see Supplementary Data for correlations between sibling number and maternal age/education).

Effect of siblings on infants' productive vocabulary

We first modeled the effect of siblings on reported productive vocabulary. We explored three possible variations on how to represent the sibling effect: a binary variable (0 vs. >0 siblings), aggregated groups (None vs. One vs. 2+ siblings), and discrete sibling number (0 vs. 1 vs. 2 vs. 3 vs. 4 siblings), comparing the following nested model structures, where (1) is the baseline model, (2) includes siblings as the variable of interest, and (3) considers the extent to which the infant's sex improves model fit:

1. vocabulary size (log-transformed) ~ age (months) + (1|subject)
2. vocabulary size (log-transformed) ~ siblings [binary, group or discrete] + age (months) + (1|subject)
3. vocabulary size (log-transformed) ~ siblings [binary, group or discrete] + age (months) + sex + (1|subject)

In our sample, simply having siblings (i.e. as a binary variable) did not predict CDI productive vocabulary size, while both discrete sibling number and sibling group did. See Table 2. Sex did not improve model fit over and above the effect of siblings in any of the three comparisons (ps all >0.68).

Table 2

Output from likelihood ratio tests comparing regression models that predict the effects of sibling number (binary, grouped and discrete variables) on vocabulary size. Month was included in each model as a fixed effect; subject was included as a random effect.

Model	Df	Chisq	p value
0 vs. >0 siblings	1.00	2.04	0.15
Sibling group	2.00	7.03	0.03
Sibling number	1.00	5.26	0.02

Table 3

Full model output from linear mixed effects regression model comparing language development over time in relation to sibling group. Age in months was included as a fixed effect; subject was included as a random effect.

Effect	Estimate	Std. Error	df	t value	p
Intercept	-1.92	0.17	95.77	-11.38	<0.001
SibGroupOne	-0.03	0.23	42.11	-0.11	0.911
SibGroup2+	-0.66	0.25	42.90	-2.64	0.011
month	0.29	0.01	479.07	34.37	<0.001

Having more siblings was associated with a smaller vocabulary size over the course of early development. This is consistent with previous findings (Hoff-Ginsberg, 1998; Pine, 1995). We find that for each additional sibling, infants were reported to have produced

21.14% fewer words. The 'sibling effect' is thus present in our data.

In terms of our grouped sibling variable (i.e. 0 vs. 1 vs. 2+ siblings) infants with one sibling acquire only 3% fewer words than firstborns over the course of our analysis, while infants with two or more siblings produce 66% fewer words. See Table 3 and and Figure 1. Post-hoc Wilcoxon Rank Sum tests comparing reported productive vocabulary at 18 months (where there's the widest vocabulary range) revealed significantly larger vocabularies for infants with one sibling compared to those with two or more siblings (W=5, p = .004), but no difference between infants with one sibling and those with no siblings (W=79.50, p = .631). See 4.

Effect of siblings on infants' input

Having established that infants' productive vocabulary varied as a function of how many siblings they had across two of our three sibling measures, we turn to our input measures to test whether input varied by a child's sibling status. To keep relatively similar Ns across groups we used the 0 vs. 1 vs. 2+ siblings division, with the one outlier from above included back into the analysis given that input and vocabulary are not tested in the same model. Using this grouping as our sibling measure also lets us consider the role of sex, which was not possible for sibling number given the (random) gender and sibling distribution (see Table 1). We ran the same analyses with discrete sibling number as a fixed effect; reported model outcomes hold for object presence, but not for overall household input. See Supplementary Data.

We first tested for the effect of infant sex and age on our two input measures. Models of nouns in the input were a better fit when both age and sex were included alongside a random effect of infant, relative to a model with only this random effect (ps $<$ .042), while age (p = .002) but not sex (p = .172) improved model fit for object presence. Significant variables will be added to the relevant models below. See Supplementary Data for

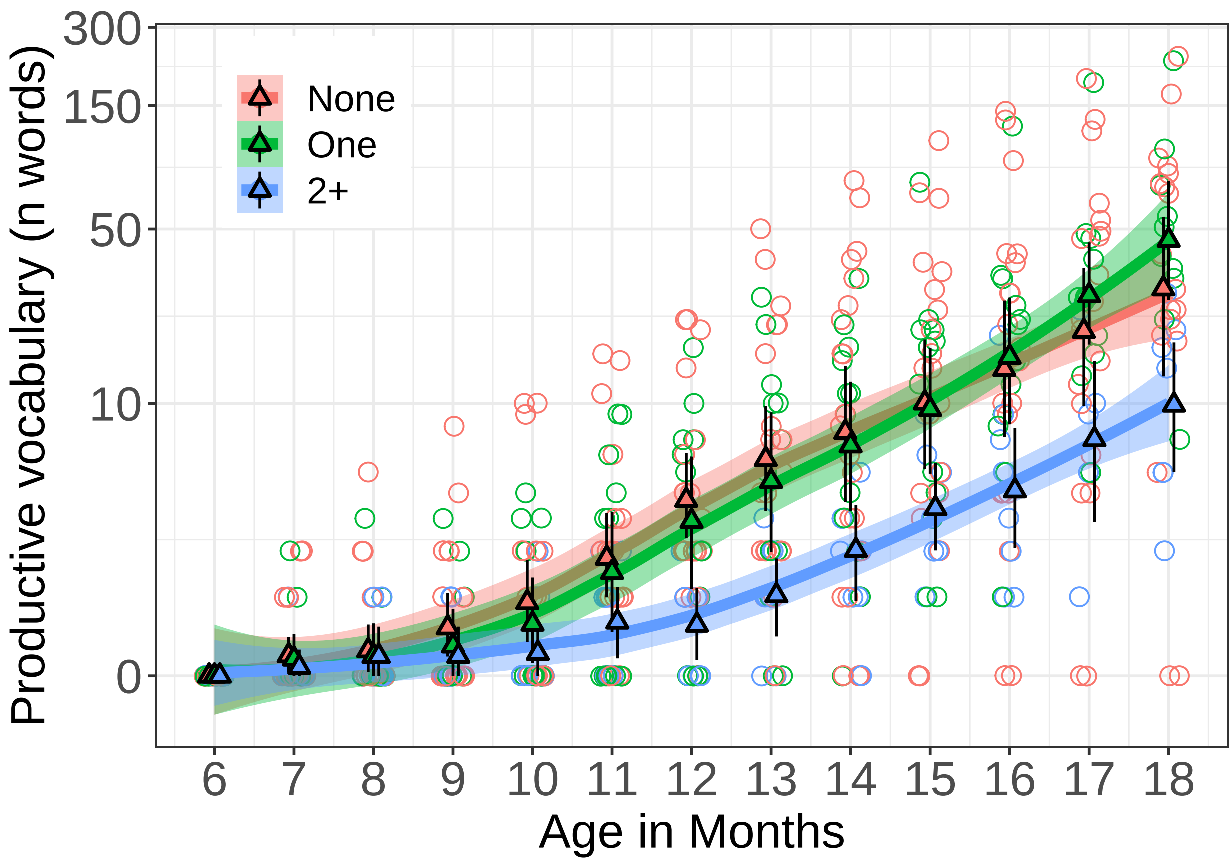

Figure 1. Reported productive vocabulary acquisition (CDI) over time. Colors denote sibling group; line with colored confidence band reflects local estimator (loess) fit over individual infants' vocabulary at each month. Triangles indicate mean with bootstrapped CIs computed over each month's data. Points (jittered horizontally) show individual infants' vocabulary size at each month. Y-axis utilizes log-transformed vertical spacing for visual clarity.

correlations between input and maternal education/age.

Parental Input. Mothers provided the largest proportion of the infants' overall input across the sample (81%, M=136.71 object words, Mdn=115, SD=112.16). Fathers accounted for an average of 13% (M=18.81, Mdn=0, SD=43.37), while infants with siblings received around 6% of their input from their brothers and sisters (M=15.84, Mdn=10, SD=19.19). See Table 4 and Figure 2. We tested overall quantity of input (aggregated across mothers, fathers, and siblings) in our model alongside age, sex and subject, as

Table 4

Data summary of our two input measures and reported vocabulary size at 18 months.

	No siblings		1 sibling		2+ siblings	
Variable	Mean	SD	Mean	SD	Mean	SD
% object presence in input, 10-17 months	0.67	0.15	0.56	0.15	0.46	0.18
N Input utterances, 10-17 months	180.63	124.85	184.43	84.76	100.19	52.80
Productive Vocabulary 18m (CDI)	58.89	60.76	92.64	111.42	13.00	9.49

reported above, and a significant effect was found for the effect of sibling group ($\chi^2(2) = 14.66$, p=.001).

We then ran post-hoc tests to compare mean amount of input across sibling groups; these showed a significant difference in average input received between infants with one sibling versus those with two or more siblings (W=4, $p<$ .001; Bonferroni-corrected p-threshold = .025 for all reported Wilcoxon tests) while amount of input did not differ between infants with no siblings and those with one sibling (W=117, p = .506). On average, in any given hour-long recording, infants with no siblings heard 0.50 *fewer* object words in their input than those with one sibling, and 80 more than those with two or more siblings. Infants with one sibling heard 80 more object words than those with two or more siblings. See Table 4 for overall group differences (M and SD) in amount of input.

Next, we tested how much of that input came from siblings (for infants who had them). Overall, for infants who had siblings, at least one other child was present in 70.72% of recordings (n = 263). Wilcoxon Rank Sum tests showed no difference between the amount of sibling input received by infants with one sibling compared with those with two or more siblings (W=43, p=.316). Looking at caregivers individually, infants with two or more siblings heard significantly less input from their mothers than those with one sibling (W=12, p=.001), while there was no difference between those with one vs. no siblings

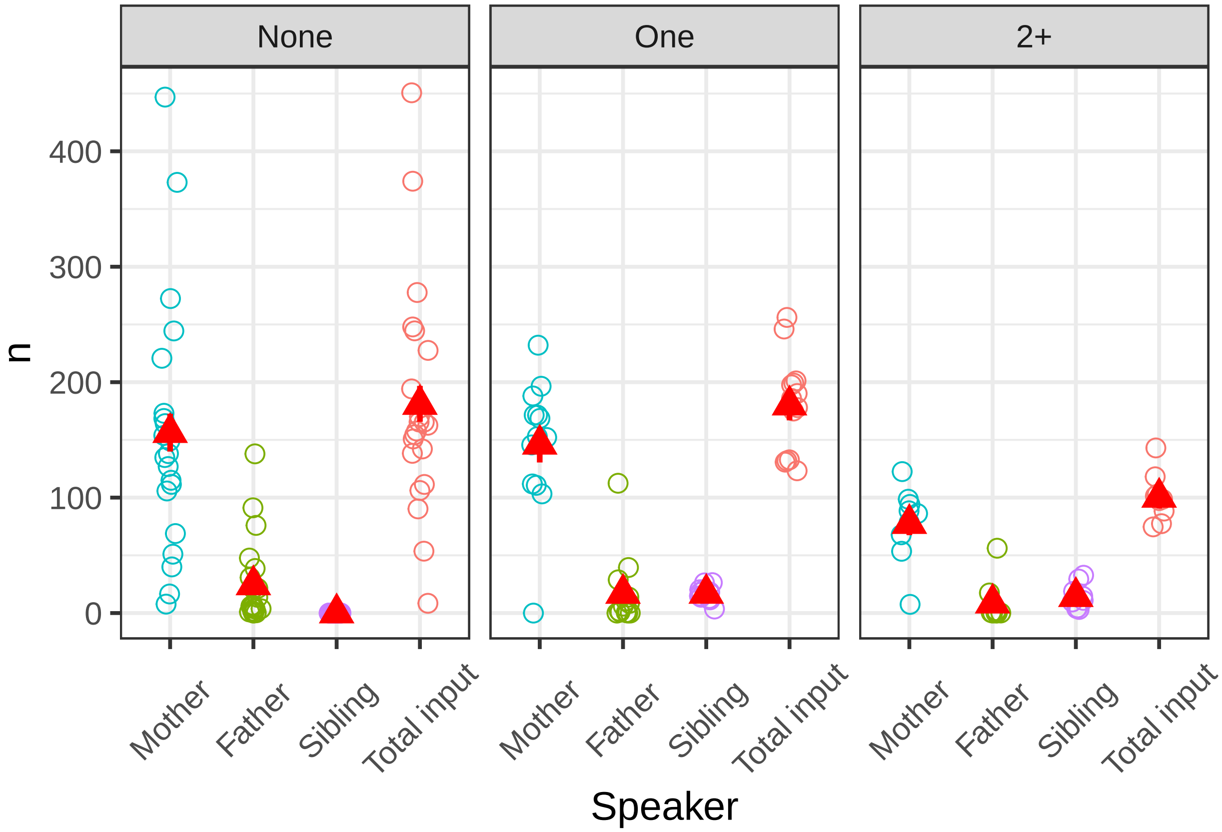

Figure 2. Mean number of words produced by Mothers, Fathers and Siblings, as well as total family input (mother + father + sibling(s)), across sessions recorded between 10-17 months. Circles represent values for individual infants; red triangles show group means.

(W=126, p = .727). Finally, amount of paternal input did not differ between groups (one vs. none: W=161, p = .395; one vs. 2+: W=45, p=.382).

Object presence. On average, 59% of annotated utterances included a referent that was present and attended to by the infant (Mdn=0.59, SD=0.14). See Table 4. We hypothesized that infants with more siblings would hear fewer words in referentially transparent conditions (i.e. they would experience lower object presence) than those with fewer siblings. Indeed, modelling the quantity of object present tokens that infants heard, we find a significant effect for sibling group on object presence ($\chi^2(2) = 25.17$, $p < .001$). See Figure 3. Infants with no siblings experienced 20% more object presence in their input

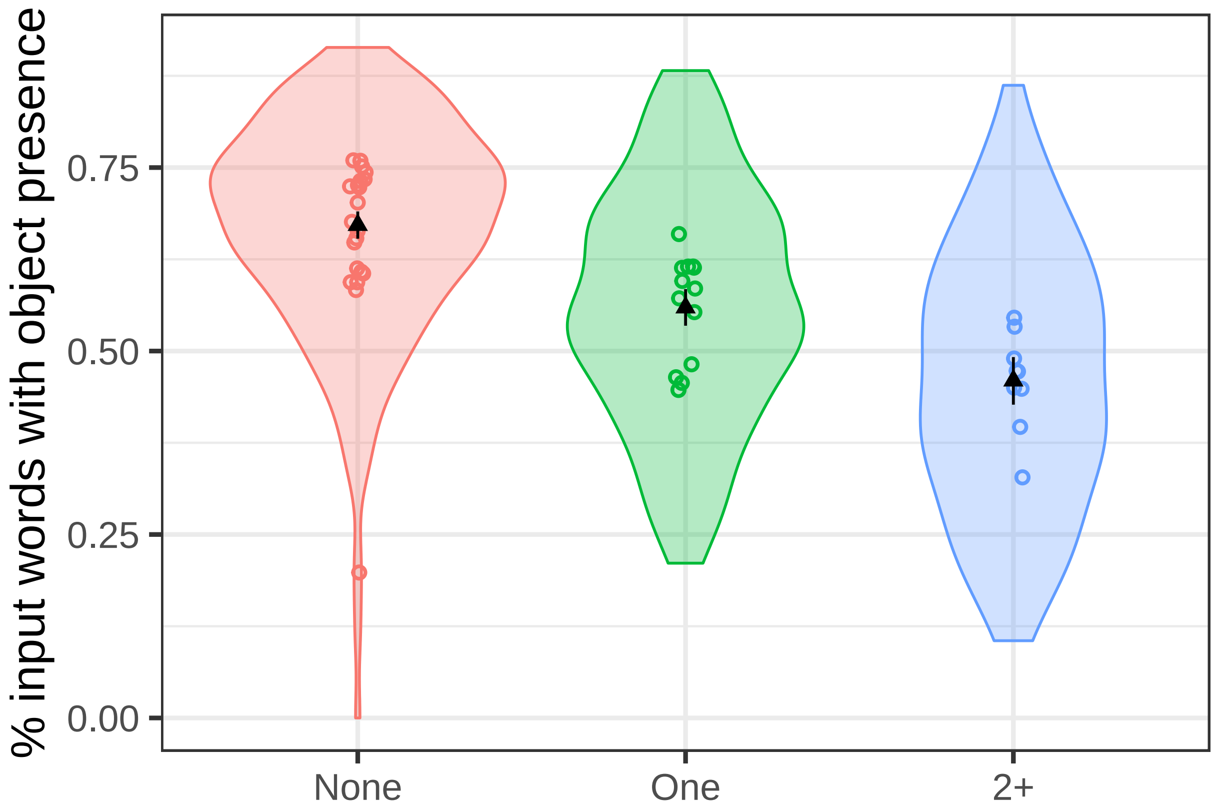

Figure 3. Proportion of input words produced with object presence across sibling groups. Error bars and black triangles show 95% CIs and mean proportion of object presence across sibling groups. Dots indicate mean proportion of object presence per infant, collapsing across age and jittered horizontally for visual clarity.

than those with two or more siblings, and 10% more than those with one sibling. Post-hoc comparisons revealed significant between-group differences: infants with no siblings experienced significantly more object presence than those with one sibling (W=224, p=.001; Bonferroni-corrected p-threshold = .025). Likewise, infants with one sibling experienced significantly more object presence those with two or more siblings (W=20, p=.009).

Discussion

We investigated the nature of infant language development in relation to number of children in the household. Previous research found a delay in lexical acquisition for later-born infants (Fenson et al., 1994; Hoff, 2006), with differences in input across birth order reported as a root cause. Our results add several new dimensions to this, by testing for differences across more vs. fewer older siblings, and by looking at input during child-centered home recordings. Infants with more siblings were reported to say fewer words by 18 months, heard fewer nouns from their parents, and experienced less ‘object co-presence’ when hearing them.

Importantly, and in contrast with some previous research (Hoff-Ginsberg, 1998; Oshima-Takane & Robbins, 2003), infants with one sibling showed no decrement in lexical production and minimal reduction in input in comparison to first-born infants. That is, our results suggest that simply having a sibling does not contribute to input or vocabulary differences across children (as measured here), while having more than one siblings seems to do so. Indeed, infants with zero and one sibling had similar results for productive vocabulary, and parental noun input overall (though not object presence). In contrast, infants with two or more siblings said fewer words, and also heard fewer input words overall, with proportionally less object co-presence, compared with their peers.

The sibling effect. When we considered the effect of sibling status – that is, whether or not infants had any siblings, disregarding specific sibling number – our findings showed that having siblings made no difference to infants’ lexical production capacities. This contrasts with Hoff-Ginsberg (1998), who found that, by 18 months, laterborns exhibit lower language skills. However, Oshima-Takane and colleagues (1996) found no overall differences between first- and second-born children across a range of language measures taken at 21 months. Our finer-grained results suggest a greater role for *sibling quantity* over first- vs. later-born status. The more older siblings a child had, the lower their reported productive vocabulary at 18 months. This adds to findings from Fenson and colleagues (1994), who found a weak but significant negative correlation between birth order and production of both words and gestures. Controlling for age, our model showed that for each additional older sibling, infants produced more than 30% fewer words by 18 months.

While infants with more siblings heard less input speech overall, having one sibling did not significantly reduce the number of nouns in an infant's input. This is in direct contrast with reports from the literature; Hoff (2006) states that "when a sibling is present, each child receives less speech directed solely at…her *because mothers produce the same amount of speech whether interacting with one or two children*" (p.67, italics added). While this does not appear to be the case in the present dataset, it may be due to the circumstances of the home-recorded data: while siblings were present in many of the recordings (70.72% of recordings in which the target child had a sibling), given the focus of the data collection, parents may have had a tendency to direct their attention - and consequently their linguistic input - more towards the target child; of course our samples also differed in other ways (e.g. sociocultural context) that may have influenced the results as well. Alternatively, our results may diverge from those of Hoff (2006) due to the nature of our input measure, which only took nouns into account. We find this explanation unlikely given work by Bulgarelli and Bergelson (2020) showing that nouns are a reliable proxy for overall input in this dataset, thus suggesting that this measure provides an appropriate representation of overall input directed at the target child.

In contrast to the other results, our analysis of object presence showed a more linear 'sibling effect'. In this case, even having one sibling led to fewer word-object pairs presented in the input. Presence of a labeled object with congruent input speech is known to be supportive in early word learning: Bergelson and Aslin (2017) combined analysis of this home-recorded data at six months with an experimental study to show that word-object co-presence in naturalistic caregiver input correlated with comprehension of nouns when tested using eye-tracking. Gogate and colleagues (2000) state that contingent word production supports the learning of novel word-object combinations, as “multimodal motherese” - whereby a target word is produced in synchrony with its referent, often involving movement or touch of the object - supports word learning by demonstrating novel word-object combinations. Indeed, lower rates of referential transparency in children’s input have also been proposed to explain why common non-nouns like *hi* and *uh-oh* are learned later than concrete nouns (Bergelson & Swingley, 2013).

Siblingese as a learning opportunity? We also found that infants with siblings did not hear much speech from their older brothers and sisters. Similar findings are reported in a lab-based interaction study by Oshima-Takane and Robbins (2003), who found that older siblings rarely talked directly to the target child; instead, most input from siblings was overheard speech from sibling-mother interactions. However, results from Havron and colleagues (2019) indirectly suggest that speech from siblings may affect language development, and not necessarily in a negative direction. They found that children with older brothers had lower verbal skills than children with no siblings; children with older sisters did not show this effect. The authors propose that this differential effect could be due sisters having positive effects on language development (i.e., the effect is derived from supportive sibling input), or perhaps due to brothers’ additional demands on caregiver time and attention, thus directing caregiver attention away from the target child (i.e., the effect is derived from changes to caregiver input). We did not analyse sibling sex in our data, but future analyses could consider input speech in relation to sibling sex.

One possibility raised by these results is that perhaps parents are able to compensate or provide relatively similar input and learning support for one or two children, but once children outnumber parents, this balancing act of attention, care, and time, becomes unwieldy. While the current sample is relatively limited and homogeneous in the family structures and demographics it includes, future work could fruitfully investigate this possibility by considering whether (controlling for other potential contributors like SES, Hoff-Ginsberg, 1998) the presence of more caregivers (whether parents, relatives, or other adults) helps foster language development.

Alternatively, second-borns might 'even out' with children with no siblings due to a trade-off between direct attention from the caregiver and the possibility of more sophisticated social-communicative interactions. For these infants there is still ample opportunity to engage with the mother in one-to-one interactions, allowing a higher share of her attention than is available to third- or later-borns. Furthermore, triadic interactions can benefit the development of a number of linguistic and communication skills (Barton & Tomasello, 1991; Dunn & Shatz, 1989). Second-borns may also benefit from overheard speech in their input, supporting the acquisition of nouns and even more complex lexical categories (Floor & Akhtar, 2006; Oshima-Takane et al., 1996). For infants with one sibling, the benefits of observing/overhearing interactions between sibling and caregiver, as well as the possibility for partaking in such interactions, may outweigh the decrease in some aspects of the input (i.e., in our data, only observed in object presence). Having more than one sibling may throw this off-balance.

Importantly, the present results make no claims about eventual outcomes for these children: generally speaking, regardless of sibling number, all typically-developing infants reach full and fluent language use. Indeed, some research suggests that sibling effects, while they may be clear in early development, are not always sustained into childhood; e.g. twins are known to experience a delay in language development into the third year, but are quick to catch up thereafter (Dales, 1969; Tomasello, Mannle, & Kruger, 1986). This demonstrates the cognitive adaptability of early development, which brings about the acquisition of language across varying and allegedly 'imperfect' learning environments. Infants' capacity to develop linguistic skills from the resources that are available to them – whether that is infant-directed object labels or overheard abstract concepts – highlights the dynamic and adaptable nature of early cognitive development, and a system that is sufficiently robust to bring about the same outcome across populations.

Limitations. Of course, the 'success' of early language development is defined by how success is measured. Here we chose word production as our measure of linguistic capability; we did not consider other equally valid measures such as language comprehension or early social-interaction skills. Similarly, our input measures focused on nouns; other lexical classes may reveal different effects, though they are generally far sparser in production until toddlerhood. There is also some imbalance in group sizes across our data; our sample was not pre-selected for sibling number, and so group sizes are unmatched across the analysis. Including a larger number of infants with 2+ siblings may have revealed a different pattern of results. Finally, more work across wider and larger populations is necessary to unpack the generalizability of the present results. Our sample is reflective of average household sizes in middle-class families across North America and Western Europe (Office for National Statistics, 2018; United States Census Bureau, 2010), but it is not unusual in some communities and parts of the world for households to include between three and six children on average (Institute for Family Studies & Wheatley Institution, 2019). Adding to this, it is also necessary to consider cross-cultural differences in the way children are addressed by their parents. Casillas, Brown and Levinson (2019) found that almost all of Tseltal Mayan children's input came from speech directed at other people (21 minutes per hour, compared with just under 4 minutes/hour of specifically child-directed input), while Shneidman and Goldin-Meadow (2012) found that 69% of speech directed at Mayan children came from siblings (in comparison with 10% for children in the USA).

Conclusion. In conclusion, our results support the general findings from the literature showing that later-born infants have slower lexical acquisition than their first-born peers. However, we highlight an important difference from previous findings, namely that in the present sample, second-born infants show no such effect, while infants with more than two siblings have significantly smaller productive vocabularies at age 18 months. We related this directly to the infants' input over a period of one year, showing differences as a function of sibling for both overall noun input and object presence. We look forward to future studies considering the granularity of more versus fewer siblings, and how this relates to language abilities over the course of development.

References

Anderson, N. J., Graham, S. A., Prime, H., Jenkins, J. M., & Madigan, S. (2021). Linking Quality and Quantity of Parental Linguistic Input to Child Language Skills: A Meta-Analysis. *Child Development*, *92*(2), 484–501. https://doi.org/10.1111/cdev.13508

Barton, M. E., & Tomasello, M. (1991). *Joint Attention and Conversation in Mother-Infant-Sibling Triads*. *62*(3), 517–529.

Bergelson, E., Amatuni, A., Dailey, S., Koorathota, S., & Tor, S. (2019). Day by day, hour by hour: Naturalistic language input to infants. *Developmental Science*, *22*(1), e12715. https://doi.org/10.1111/desc.12715

Bergelson, E., & Aslin, R. N. (2017). Nature and origins of the lexicon in 6-mo-olds. *Proceedings of the National Academy of Sciences*, *114*(49), 12916–12921. https://doi.org/10.1073/pnas.1712966114

Bergelson, E., & Swingley, D. (2013). The Acquisition of Abstract Words by Young Infants. *Cognition*, *127*(3), 391–397. https://doi.org/10.1038/jid.2014.371

Berglund, E., Eriksson, M., & Westerlund, M. (2005). Communicative skills in relation to gender, birth order, childcare and socioeconomic status in 18-month-old children. *Scandinavian Journal of Psychology*, *46*(6), 485–491. https://doi.org/10.1111/j.1467-9450.2005.00480.x

Braginsky, M., Yurovsky, D., Marchman, V. A., & Frank, M. C. (2019). Consistency and Variability in Children's Word Learning Across Languages. *Open Mind*, *3*, 52–67. https://doi.org/10.1162/opmi_a_00026

Bulgarelli, F., & Bergelson, E. (2020). Look who's talking: A comparison of automated and human-generated speaker tags in naturalistic day-long recordings. *Behavior Research Methods*, *52*(2), 641–653. https://doi.org/10.3758/s13428-019-01265-7

Cartmill, E. a., Armstrong, B. F., Gleitman, L. R., Goldin-Meadow, S., Medina, T.

N., & Trueswell, J. C. (2013). Quality of early parent input predicts child vocabulary 3 years later. *Proceedings of the National Academy of Sciences of the United States of America*. https://doi.org/10.1073/pnas.1309518110

Casillas, M., Brown, P., & Levinson, S. C. (2019). Early Language Experience in a Tseltal Mayan Village. *Child Development*, *EarlyView article*. https://doi.org/10.1111/cdev.13349

Dales, R. J. (1969). Motor and language development of twins during the first three years. *The Journal of Genetic Psychology; Provincetown, Mass., Etc.*, *114*(2), 263–271. Retrieved from https://search.proquest.com/docview/1297124434/citation/D928716F9A7E4AEFPQ/1

Dunn, J., & Shatz, M. (1989). Becoming a Conversationalist despite (Or Because of) Having an Older Sibling. *Child Development*, *60*(2), 399–410.

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, M., Stephen J. Tomasello, … Stiles, J. (1994). Variability in Early Communicative Development. *Monographs of the Society for Research in Child Development*, *59*. https://doi.org/10.2307/1166093

Floor, P., & Akhtar, N. (2006). Can 18-Month-Old Infants Learn Words by Listening In on Conversations? *Infancy*, *9*(3), 327–339. https://doi.org/10.1207/s15327078in0903_4

Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2021). *Variability and Consistency in Early Language Learning: The Wordbank Project*. MIT Press.

Gogate, L. J., Bahrick, L. E., & Watson, J. D. (2000). A Study of Multimodal Motherese: The Role of Temporal Synchrony between Verbal Labels and Gestures. *Child Development*, *71*(4), 878–894. https://doi.org/10.1111/1467-8624.00197

Havron, N., Ramus, F., Heude, B., Forhan, A., Cristia, A., Peyre, H., …

Thiebaugeorges, O. (2019). The Effect of Older Siblings on Language Development as a Function of Age Difference and Sex. *Psychological Science*, *30*(9), 1333–1343. https://doi.org/10.1177/0956797619861436

Hoff, E. (2006). How social contexts support and shape language development. *Developmental Review*, *26*(1), 55–88. https://doi.org/10.1016/j.dr.2005.11.002

Hoff-Ginsberg, E. (1998). The relation of birth order and socioeconomic status to children's language experience and language development. *Applied Psycholinguistics*, *19*(4), 603–629. https://doi.org/10.1017/S0142716400010389

Institute for Family Studies, & Wheatley Institution. (2019). *World family map 2019: Mapping family change and child well-being outcomes*. Charlottesville, VA: Institute for Family Studies. Retrieved from https://ifstudies.org/reports/world-family-map/2019/executive-summary

Jones, C. P., & Adamson, L. B. (1987). *Language Use in Mother-Child and Mother-Child-Sibling Interactions*. *58*(2), 356–366.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). {lmerTest} Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software*, *82*(13), 1–26. https://doi.org/10.18637/jss.v082.i13

Moore, C., Dailey, S., Garrison, H., Amatuni, A., & Bergelson, E. (2019). Point, Walk, Talk: Links Between Three Early Milestones, From Observation and Parental Report. *Developmental Psychology*. https://doi.org/10.1037/dev0000738

Office for National Statistics. (2018). *Families with dependent children by number of children, UK, 1996 to 2017* (No. 008855). Office for National Statistics. Retrieved from Office for National Statistics website: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/adhocs/008855familieswithdependentchildrenbynumberofchildrenuk1996to2017

Oshima-Takane, Y., Goodz, E., & Derevensky, J. L. (1996). *Birth Order Effects on*

Early Language Development : Do Secondborn Children Learn from Overheard Speech ? Author (s): Yuriko Oshima-Takane , Elizabeth Goodz and Jeffrey L . Derevensky Published by : Wiley on behalf of the Society for Research in Child De. *67*(2), 621–634.

Oshima-Takane, Y., & Robbins, M. (2003). Linguistic environment of secondborn children. *First Language*, *23*(1), 21–40. https://doi.org/http://dx.doi.org/10.1177/0142723703023001002

Pine, J. M. (1995). Variation in Vocabulary Development as a Function of Birth Order. *Child Development*, *66*(1), 272–281.

R Core Team. (2019). *R: A Language Environment for Statistical Computing*. R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

Ramírez-Esparza, N., García-Sierra, A., & Kuhl, P. K. (2014). Look who's talking: Speech style and social context in language input to infants are linked to concurrent and future speech development. *Developmental Science*, *17*(6), 880–891. https://doi.org/10.1016/j.surg.2006.10.010.Use

Shneidman, L. A., & Goldin-Meadow, S. (2012). Language input and acquisition in a Mayan village: How important is directed speech? *Developmental Science*, *15*(5), 659–673. https://doi.org/10.1111/j.1467-7687.2012.01168.x

Soderstrom, M. (2007). Beyond babytalk: Re-evaluating the nature and content of speech input to preverbal infants. *Developmental Review*, *27*(4), 501–532. https://doi.org/10.1016/j.dr.2007.06.002

Stern, D. N., Spieker, S., Barnett, R. K., & MacKain, K. (1983). The Prosody of Maternal Speech: Infant Age and Context Related Changes. *Journal of Child Language*, *10*(1), 1–15. https://doi.org/10.1017/S0305000900005092

Tomasello, M., Mannle, S., & Kruger, A. C. (1986). Linguistic environment of 1- to 2-year-old twins. *Developmental Psychology*, *22*(2), 169–176.

https://doi.org/10.1037/0012-1649.22.2.169

United States Census Bureau. (2010). *Household Type by Number of People Under 18 Years* (No. PCT16). Retrieved from https://data.census.gov/cedsci/table?q=number%20of%20children&hidePreview=false&tid=DECENNIALSF12010.PCT16&t=Children&vintage=2018

Zambrana, I. M., Ystrom, E., & Pons, F. (2012). Impact of Gender, Maternal Education, and Birth Order on the Development of Language Comprehension: A Longitudinal Study from 18 to 36 Months of Age. *Journal of Developmental & Behavioral Pediatrics*, *33*(2), 146–155. https://doi.org/10.1097/DBP.0b013e31823d4f83