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

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10    Abstract

11  The 'sibling effect' has been widely reported in studies examining a breadth of topics in the

12  academic literature, suggesting firstborn children are advantaged across a range of

13  cognitive, educational and health-based measures compared with their later-born peers.

14  Expanding on this literature using naturalistic home-recorded data and parental

15  vocabulary report, we find that early language outcomes vary by number of siblings.

16  Specifically, we find that children with two or more older siblings - but not one - had

17  smaller vocabularies at 18 months, and heard less input from caregivers across several

18  measures. We discuss implications regarding what infants experience and learn across a

19  range of family sizes in infancy.

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

21    Word count: X

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

23    The 'sibling effect' - that is, the apparent advantage for earlier-born versus later-born

24  children - was noted as far back as the 1800s, when Galton (1874) observed that notable

25  'English men of science' were often firstborns. Galton (1874, p. 35) posited that these men

26  "would generally have more attention in [their] infancy... than [their] younger brothers and

27  sisters," thereby giving them more of a chance of later success. Current research finds some

28  evidence to support these claims, showing that those who have fewer older siblings are

29  more likely to do better than their laterborn siblings in a range of domains, including

30  educational outcomes (Esposito, Kumar, & Villaseñor, 2020; Monfardini & See, 2016),

31  overall earnings (Behrman & Taubman, 1986; Kantarevic & Mechoulan, 2006), and some

32  aspects of physical and mental health (Black, Devereux, & Salvanes, 2016). This work

33  suggests that there may be marked economic, social and physical advantages for children

34  with fewer older siblings.

35    In this paper, we consider the role of siblings in the early language environment.

36  Prior work finds that educational attainment is shaped by early language outcomes (R. C.

37  Anderson & Freebody, 1981; Marchman & Fernald, 2008); e.g., one study finds that

38  children with higher vocabulary scores at age 2 did better on a range of language and

39  literacy measures at age 10-11 (Lee, 2011). Given that the early linguistic input predicts

40  lexical advance (Cartmill et al., 2013; Ferjan Ramírez, Lytle, & Kuhl, 2020), it may be the

41  case that having more siblings has a negative effect on the early language environment.

42  With this in mind, we use naturalistic home-recorded data to measure input in earlier- and

43  later-born infants in relation to their lexical development over the first 18 months of life.

44    Many studies assume an optimum environment for early language development,

45  whereby the input is tailored to the infant's needs, changing over time as language capacity

46  develops (e.g. Soderstrom, 2007; Stern, Spieker, Barnett, & MacKain, 1983). However, for

47  many infants and for many reasons, language acquisition does not take place in such a

48 setting; various domestic and social factors are known to affect the learning environment,

49 including the presence of older siblings in the home (Fenson et al., 1994). According to the

50 United States Census Bureau (2010), around one third of children are born into households

51 with at least one other infant present, and one in every five infants is acquiring language in

52 a household shared with two or more other children. Similar statistics are reported for

53 British infants (Office for National Statistics, 2018), where the average household has 1.75

54 children, and 15% of households have three children or more.

55     There is already evidence to suggest that infants born to households with older

56 children may experience disruption to their linguistic trajectory. Fenson and colleagues

57 (1994) found that by 30 months of age, children with older siblings performed worse than

58 those with no siblings across measures of productive vocabulary, use of word combinations,

59 and mean length of utterance (MLU). This disadvantage may be manifested in input

60 differences between first- and later-born children: infants with older siblings hear less

61 speech aimed specifically at them, and what they do hear is understood to be linguistically

62 less supportive of early language development (Hoff-Ginsberg, 1998; Oshima-Takane &

63 Robbins, 2003). The sex of the older siblings may also have an effect on a child's

64 development: Havron and colleagues (2019) show that the 'sibling effect' is manifested

65 largely in the presence of an older brother. Children with an older brother had significantly

66 lower language skills than those with no siblings, while children with an older sister showed

67 no difference. Furthermore, some studies have noted linguistic *advantages* for later-borns,

68 who may have stronger social-communicative skills (Hoff, 2006), better understanding of

69 pronouns (Oshima-Takane, Goodz, & Derevensky, 1996), and better conversational abilities

70 (Dunn & Shatz, 1989).

71     Numerous studies have attempted to better understand the mechanisms behind this

72 issue, with comparisons of language acquisition across first- and later-borns, and analyses

73 of mothers' input in dyadic (infant + mother) and triadic (infant + mother + older sibling)

74 situations. Findings are mixed, but overall two general conclusions can be drawn. First,

75 analyses consistently show that there is a disadvantage in early language acquisition for

76 infants with older siblings (Berglund, Eriksson, & Westerlund, 2005; Fenson et al., 1994;

77 Pine, 1995; Zambrana, Ystrom, & Pons, 2012), but this is often marginal, and typical of

78 the earliest stages of language learning. Hoff-Ginsberg (1998) shows first-borns to have

79 better lexical and syntactic skills up until 2;5, but later-born infants had better

80 conversational abilities during the same time-period.

81      The second finding to appear consistently in the literature pertains to sibling-related

82 differences in the early linguistic environment: infants with no siblings receive not only

83 more input overall, but also higher-quality input. Indeed, the very presence of a sibling in

84 the linguistic environment changes the way language is used. When siblings are present

85 (i.e. triadic interactions), mothers' input is more focused on regulating behaviour, as

86 opposed to the language-focused speech that is common in dyadic contexts (Oshima-Takane

87 & Robbins, 2003). Infants with no siblings not only hear speech that is linguistically more

88 supportive, but they also hear more input overall. Reports show that MLU is longer in the

89 input of first-born infants (Hoff-Ginsberg, 1998; but see also Oshima-Takane & Robbins,

90 2003 for a comparison of dyadic and triadic contexts) who also hear more questions

91 directed at them than later-borns. Both Jones and Adamson (1987) and Oshima-Takane

92 and Robbins (2003) report no difference between the overall number of word types

93 produced by mothers in dyadic and triadic settings, but the proportion of speech directed

94 at the target infant is drastically reduced when input is shared with siblings.

95      As Hoff (2006) explains, infants with siblings have less experience of speech directed

96 at them, but they do have an advantage over their first-born peers in that they are subject

97 to more overheard speech. Indeed, the input of first-borns may be explicitly tailored to

98 their needs, but equally this means it might be less varied. Indeed, Barton and Tomasello

99 (1991) show that by as early as 19 months, infants with siblings are already able to take

100 part in triadic conversations, which were almost three times longer than dyadic

101 conversations. The authors suggest that siblings may shift the learning context, and

102 facilitate infants' participation in communicative interactions: infants are under less

103 pressure to participate in a triadic interaction, meaning the conversation can continue even

104 when the infant is unable to respond. As a result, the infants in Barton and Tomasello's

105 study took more conversational turns in triadic interactions than dyadic ones.

106       Taken together, it seems that there is an early disadvantage in lexical development

107 for laterborn children, which may be redressed when it comes to syntactic and

108 communicative development. However, given that vocabulary size is a known key predictor

109 of later educational success (Lee, 2011; Marchman & Fernald, 2008), combined with studies

110 showing that laterborns have lower educational attainment by high school (Esposito et al.,

111 2020; Monfardini & See, 2016), it is crucial to understand the disadvantage in early lexical

112 development amongst laterborns.

113       In analyzing infants' lexical development in relation to the presence of older siblings

114 in their household, the present work expands on the extant literature in two key ways.

115 First, while prior work generally considered birth order as a binomial factor (i.e. comparing

116 first-born infants with second-borns (e.g. Oshima-Takane & Robbins, 2003), or

117 'later-borns' (e.g. Hoff-Ginsberg, 1998), potentially missing graded effects, we consider how

118 *discrete sibling number* (i.e. how many siblings a child has) is linked to an infant's lexical

119 development and their early linguistic environment. Second, much of the existing literature

120 in this area is drawn from questionnaire data or brief interactions recorded in the lab (but

121 see Dunn & Shatz, 1989 for a study of naturalistic home-recorded data), rather than

122 naturalistic day-to-day interactions in the home. In contrast, we analyze an existing corpus

123 of daylong audio-recordings in concert with vocabulary checklists. Based on work

124 summarized above, we expect that both the language environment and infants' early

125 vocabulary will vary as a function of how many older siblings they have.

<sup>126</sup> **Hypotheses**

<sup>127</sup> Research has already shown that early lexical development is more advanced among

<sup>128</sup> first-born infants (e.g. Hoff-Ginsberg, 1998). We expect to see the same effect in our data,

<sup>129</sup> but we hypothesize that the closer granularity of this analysis will show a gradient decline

<sup>130</sup> in infants' lexical abilities in relation to an increasing number of siblings. With regard to

<sup>131</sup> the infants' linguistic environment, we hypothesize that increased sibling number will have

<sup>132</sup> a negative effect on factors of the early input that are known to support language

<sup>133</sup> development. To test this, we adopt three input measures, established in the literature as

<sup>134</sup> being important for early language learning:

<sup>135</sup> 1) **Amount of input** will decline as sibling number increases. Mothers' attention will

<sup>136</sup> be divided across a larger group of children, and as a result the proportion of input

<sup>137</sup> from the mother will be lower for infants with more siblings. In addition, these

<sup>138</sup> infants will experience more input from other children in the home. Amount of

<sup>139</sup> overall input is an important predictor of language development in the longer term

<sup>140</sup> (Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991), as is amount of one-to-one

<sup>141</sup> input from the caregiver (Ramírez-Esparza, García-Sierra, & Kuhl, 2014), while

<sup>142</sup> overall speech in the environment (i.e. including speech not necessarily directed at

<sup>143</sup> the infant) does not appear to support lexical development (*ibid*). We thus expect

<sup>144</sup> amount of input directed towards the child to be an important determiner of infants'

<sup>145</sup> lexical production skills at 18 months.

<sup>146</sup> 2) **More 'learnable' words** (words that tend to be acquired earlier, Fenson et al.,

<sup>147</sup> 1994) will occur in the input of infants with fewer siblings, and this will decrease as

<sup>148</sup> sibling number increases. Input from older children will generate a wider variety of

<sup>149</sup> lexical items in the input, including words directed to and produced by siblings, some

<sup>150</sup> of whom will still be young language learners themselves. As a result, in homes with

151  older siblings, we predict that the lexical items in the input will be less typical of

152  words acquired earlier on in development.

153  3) **Amount of object presence** (word + object co-occurrence, e.g. mother says 'cat'

154  when there is a cat in the room) will decrease as sibling number increases. As

155  caregivers' attention is drawn away from one-to-one interactions with the infant,

156  there will be less opportunity for contingent talk. Moreover, less learnable words are

157  also expected to be less imageable, and thus less likely to be presented alongside

158  caregivers' utterances. The co-occurrence of words alongside their associated objects

159  is thought to contribute to the earlier learning of nouns over verbs (E. Bergelson &

160  Swingley, 2013), as it supports the word learning process through the concrete

161  mapping of word to referent (Gleitman, Cassidy, Nappa, Papafragou, & Trueswell,

162  2005). Furthermore, object presence is more suited to instances of joint visual

163  attention with the caregiver, which is less likely to occur in households where

164  caregiver attention is shared between multiple children.

## Methods

166  We analyze data from the SEEDLingS corpus (Elika Bergelson, Amatuni, Dailey,

167  Koorathota, & Tor, 2019), a longitudinal set of data incorporating home recordings,

168  parental reports and experimental studies from the ages of 0;6 to 1;6. The present study

169  draws on the parental report data, and annotations of hour-long home video recordings,

170  taken on a monthly basis during data collection.

### Participants

172  Forty-four families in New York State completed the year-long study. Infants (21

173  females) were from largely middle-class households; 33 mothers had attained a B.A. degree

174  or higher. All infants had normal birthweight with no reported speech or hearing problems.

175  Forty-two infants were Caucasian; two were from multi-racial backgrounds.

**Materials**

177     **Parental report data** The present analyses draw on data from vocabulary

178 checklists [Macarthur-Bates Communicative Development Inventory, hereafter CDI; Fenson

179 et al. (1994)], administered monthly from 0;6 to 1;6, along with a demographics

180 questionnaire. Because the majority of infants did not produce their first word until around

181 0;11 according to CDI reports (M=10.70, SD=2.22)[1], we use CDI data from 0;10 onwards

182 in our analysis. CDI production data for each month is taken as a measure of the infants'

183 lexical development over the course of the analysis period.

184     **Home video data** Every month between 0;6 and 1;5, infants were recorded for one

185 hour in their home, capturing a naturalistic representation of each infant's day-to-day

186 input. Infants wore a hat with two small Looxcie video cameras attached, one pointed

187 slightly up, and one pointed slightly down; this allowed us to record the scene from the

188 infants' perspective. In the event that infants refused to wear the hats, caregivers wore the

189 same kind of camera on a headband. Additionally, a camcorder was set up in the home.

190 Object words (i.e. concrete nouns) deemed to be directed to or attended by the child were

191 annotated by trained coders. Here we examine annotations for speaker, i.e. who produced a

192 word, and object presence, i.e. whether the word's referent was present and attended to by

193 the infant.

**Procedure**

195     We analyzed number of siblings based on parental report in the demographics

196 questionnaires completed at 0;6 (R: 0-4). Siblings were on average 4.05 years older than the

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[1] Note that reported word production began earlier than observed word production (i.e. in the video recordings) but this difference was not statistically significant (see Moore, Dailey, Garrison, Amatuni, & Bergelson, 2019).

infants in this study (Mdn days: 1477, SD: 1477, R: 0-17 years).[2] All siblings lived in the household with the infant, and all were older than or of the same age as the infant in question.[3]

**Input measures**

Three input measures were derived based on the annotations of concrete nouns in this corpus, each pertaining to aspects of the input that are established as important in early language learning: **overall household input** (how many concrete nouns does each infant hear?), **early-acquired words** (how much of this input is *early-learned* nouns?), and **object presence** (how much of this input is referentially transparent?). Each is described in further detail below.

*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 0.09% of input overall (SD=0.24, 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 (N. J. Anderson, Graham, Prime, Jenkins, & Madigan, 2021). This analysis considers only nouns produced by speakers in the child's environment, as concrete nouns are acquired earlier in development in English and cross-linguistically (Braginsky, Yurovsky, Marchman, & Frank, 2019). Note that Bulgarelli and Bergelson (2020) found that, for the same corpus of data, noun production correlated strongly with automated adult word count estimates; we can thus assume that higher noun count in this data indicates higher input across the board.

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[2] 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).

[3] Two infants in the dataset were dizygotic twins; our pattern of results holds with or without these infants.

*Early-acquired words* reflects the proportion of object word lemmas in the parental input that appeared on the "Words & Gestures" communicative development inventory (CDI, Fenson et al., 1994). This CDI form offers an inventory of words typically acquired by infants from the United States between the ages of 8 and 18 months (Fenson et al., 2007). The CDI items were established based on a sample of over 1,700 infants (~50% firstborn, 73% White, 44% of mothers with a college diploma), and so the CDI is taken as a standardized proxy of words typically acquired by infants in early development. Words found on the CDI are, by definition, early-learned, though somewhat variable in their age of acquisition and in the reasons underlying their learnability. Thus, CDI words like *foot* and *banana* are acquired earlier than non-CDI words like *jet ski* or *wheel.* Frank and colleagues (2021) show that the earliest-learned words are very similar across languages, suggesting a conceptual bias towards some words over others in early acquisition (though many factors, e.g. frequency, concreteness, phonological complexity, are relevant as well). Note also that our measure of early-acquired words in the input is the same as our measure of infant vocabulary development (i.e., the CDI wordlist), and so captures broad parallels between the words parents say and the words their infants are reported to have acquired.

*Object Presence* was coded for each object word in the home recordings based on whether or not the annotator determined the object in question as present and attended to by the child. This is a metric of referential transparency, which has been suggested to aid in learning (E. Bergelson & Swingley, 2013). Bergelson and Aslin (Elika Bergelson & Aslin, 2017) found that word-object co-presence in the home correlated with infants' ability to recognise the same words in an eye-tracking experiment, suggesting an advantage for object labeling in word learning. This is consistent with findings from Cartmill and colleagues (2013), who found that more referentially-transparent interactions with the caregiver (as judged by adult speakers observing videos where target words were blanked out) predicted larger vocabulary size at 54 months. Indeed, presence of the labelled object decreases the ambiguity of the learning environment (Yurovsky, Smith, & Yu, 2013), and may be a crucial

²⁴⁶ component of supportive contingent talk (McGillion, Pine, Herbert, & Matthews, 2017).

²⁴⁷    In the following analyses, we consider infants' productive vocabulary alongside our

²⁴⁸ three input measures: amount of household input, number of early-acquired nouns in the

²⁴⁹ input, and extent of object presence in the input, as a function of sibling number. These

²⁵⁰ measures index established measures of both input quality and quantity (though we make

²⁵¹ no distinction between quality/quantity of input here), and will be analysed in relation to

²⁵² infants' reported productive vocabulary (all word types included) as our dependent

²⁵³ measure. Since the raw data are highly skewed, log-transformed data[4] and/or proportions

²⁵⁴ are used for statistical analysis. All figures display non-transformed data for interpretive

²⁵⁵ ease.


# Results

²⁵⁷    Vocabulary development was highly variable across the 44 infants. By 18 months, 2

²⁵⁸ infants produced no words, while mean productive vocabulary was 60.28 words (SD=78.31,

²⁵⁹ Mdn=30.50). One female infant had a substantially larger reported vocabulary (3SDs

²⁶⁰ above the mean monthly vocabulary score) between 1;1 and 1;6 and was classed as an

²⁶¹ outlier. We removed her from our data, leaving 43 infants (20 females) in the present

²⁶² analysis. Infants had one sibling on average (M=0.86, Mdn=1, SD=1.09). See Table **??**.


**Model structure for fixed and random effects**

²⁶⁴    All reported models were generated in R (R Core Team, 2019) using the *lmerTest*

²⁶⁵ package to run linear mixed-effects regression models (Kuznetsova, Brockhoff, &

²⁶⁶ Christensen, 2017). P-values were generated by likelihood ratio tests resulting from nested

²⁶⁷ model comparison. All models include infant as a random effect. All post-hoc tests are

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[4] 1 was added to the raw infant production data of all infants before log-transformation to retain infants
with vocabularies of 0.

two-sample, two-tailed Wilcoxon Tests, given that all but one of our variables differed

significantly from normal by Shapiro tests. We thus 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 with an adjusted threshold of $a$=0.02,

accounting for two between-group comparisons (no siblings vs. one sibling, one sibling

vs. multiple siblings; see below).

Before considering sibling status, we first modelled infants' productive vocabulary as

a function of age, sex, and mother's education. There was no effect of sex on productive

vocabulary at 18 months ($p$=.632), and no correlation with mothers' education level

(across five categories from High School to Doctorate; $r$ = -0.01, $p$=.139). As expected, age

had a significant effect on productive vocabulary ($p <$ .001), and so we include age as a

fixed effect in all subsequent models. Because we expected that maternal age and

education might have an effect on both sibling number and infant productive vocabulary,

we ran further correlations to test these variables. There was no correlation between

mother's education and number of siblings ($r$ = -0.01, $p$=.928), and a marginal positive

correlation between mother's age and number of siblings (Spearman's $r$ = 0.28, $p$=.069);

older mothers tended to have more children. However, no correlation was found between

mothers' age and productive vocabulary at 18 months ($r$ = -0.04, $p$=.822).

**Effect of siblings on infants' productive vocabulary**

We next modeled the effect of siblings on productive vocabulary. Starting with a

binary variable (0 vs. >0 siblings), our model revealed no effect for the presence of siblings

on productive vocabulary when we included month as a fixed effect ($\chi^2(1) = 2.27$, $p$=.132).

We then modelled aggregated groups (None vs. One vs. 2+) and discrete sibling number (0

vs. 1 vs. 2 vs. 3 vs. 4 siblings). In both cases, models with siblings accounted for more

variance in productive vocabulary than models without it (see Table **??**).

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293  cap = "Output from regression models comparing language development over time in relatio
294  apa_table(table.sibling.model.output, caption = cap, col_spanners = NULL, digits = 2, pl
```

In short, having more siblings was associated with a smaller productive vocabulary over the course of early development. This is consistent with previous findings (Hoff-Ginsberg, 1998; Pine, 1995). Moreover, for each additional sibling, infants acquired 31% fewer words. Looking at differences between sibling groups (0 vs. 1 vs. 2+ siblings), we see that infants with one sibling produce only 5% fewer words than firstborns over the course of our analysis, while infants with two or more siblings produce 94% fewer words. See Table 1 and Figure 1. Post-hoc Wilcoxon Rank Sum tests comparing reported productive vocabulary at 18 months 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, $p = .631$; Bonferroni corrections applied).

**Effect of siblings on infants' input**

Having established that infants' productive vocabulary varied as a function of how many siblings they had, we turn to our three 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. That said, with the exception of household input (see Supplementary Data) all reported results hold if we model discrete sibling number as a fixed effect instead.

As with our previous analysis, we first modeled infants' input (maternal input only) as a function of age, sex and maternal education. This time, there was no effect for age, nor sex or maternal education ($p$s all>.260) on the amount of input produced by mothers. We therefore excluded all three variables from our models.
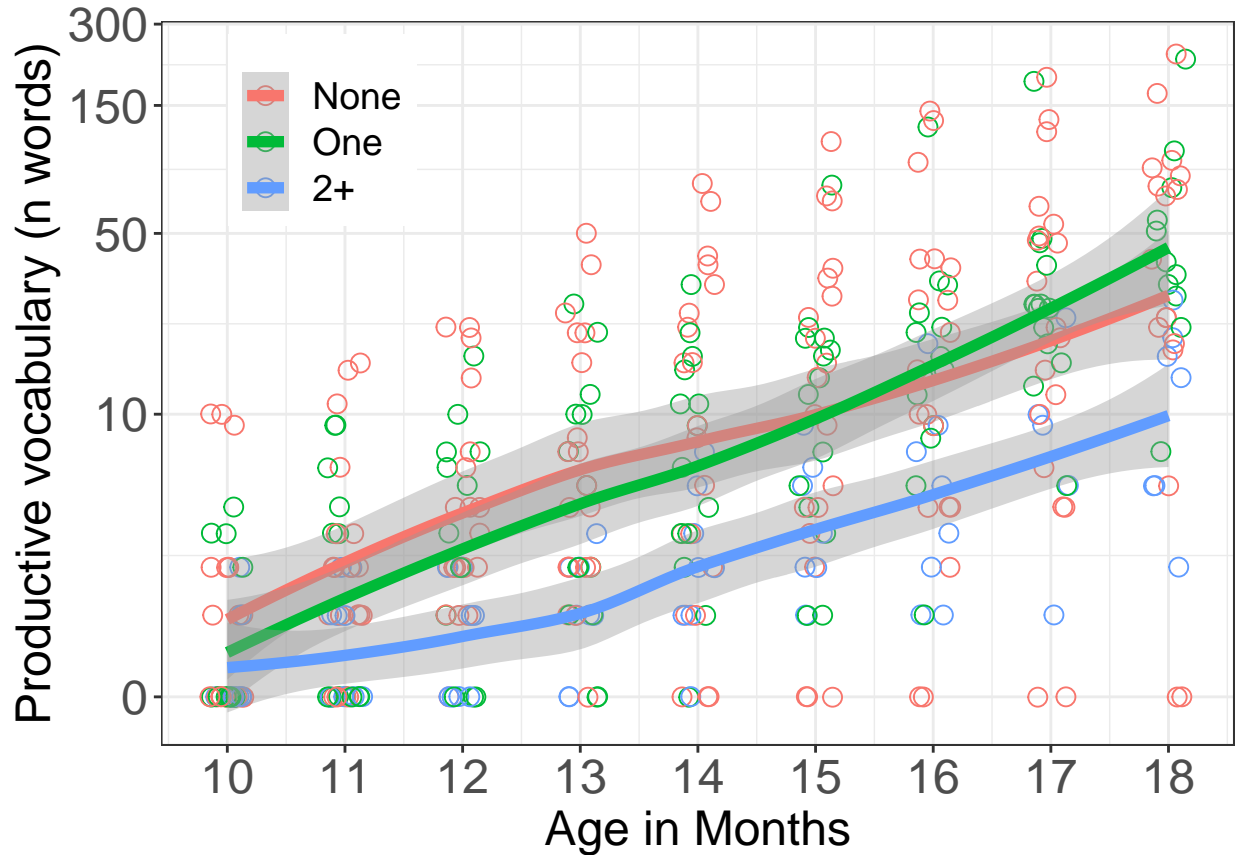
*Figure 1*. Productive vocabulary acquisition over time. Colors denote sibling group; line with grey confidence band reflects local estimator (loess) fit over individual infants' vocabulary at each month. Triangles indicate mean with bootstrapped CIs computed over each month's data. Points (jittered horizontally) show individual infants' vocabulary size at each month. Y-axis utilizes log-transformed vertical spacing for visual clarity.

317     **Parental Input.**     Mothers provided the largest proportion of the infants' overall

318     input across the sample (83%, M=146.10 object words, Mdn=125, SD=119.97). Fathers

319     accounted for an average of 13% (M=22.13, Mdn=0, SD=48.31), while infants with siblings

320     received around 5% of their input from their brothers and sisters (M=16.18, Mdn=11,

321     SD=18.51). See Table 1 and Figure 2. We tested overall quantity of input (aggregated

322     across mothers, fathers, and siblings) in our model, and a significant effect was found $(\chi^2(2)$

323     $= 18.48$, $p< .001)$. We then ran post-hoc tests to compare mean amount of input across

Table 1

*Data summary of all three input variables and reported vocabulary size at 18 months.*

| | No siblings | | 1 sibling | | 2+ siblings | |
|---|---|---|---|---|---|---|
| Variable | none m | none sd | 1 m | 1 sd | 2 m | 2 sd |
| % early-acquired words in input | 0.64 | 0.13 | 0.61 | 0.13 | 0.62 | 0.14 |
| % object presence in input | 0.67 | 0.15 | 0.56 | 0.15 | 0.46 | 0.18 |
| N Input utterances, 10-17 months | 60.21 | 106.52 | 61.48 | 87.23 | 33.40 | 47.26 |
| Productive Vocabulary 18m | 58.89 | 60.76 | 92.64 | 111.42 | 13.00 | 9.49 |

sibling groups. With Bonferroni corrections applied ($a$=0.02), these showed a significant difference in average input received between infants with one sibling versus those with two or more siblings ($W$=4032, $p <$ .001), while amount of input did not differ between infants with no siblings and those with one sibling ($W$=69120, $p =$ .004). On average, in any given hour-long recording, infants with no siblings heard -4 more object words in their input than those with one sibling, and 89 more than those with two or more siblings. Infants with one sibling heard 94 more object words than those with two or more siblings.

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 0.72% of recordings (n = 176. 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 ($W$=40, $p$=.235, Bonferroni corrections applied). Looking at caregivers individually, infants with two or more siblings heard significantly less input from their mothers than those with one sibling ($W$=15, $p$=.003), while there was no difference between those with one vs. no siblings ($W$=126, $p =$ .727). Finally, amount of paternal input did not differ between groups (one vs. none: $W$=152, $p =$ .606; one vs. 2+: $W$=42, $p$=.296).
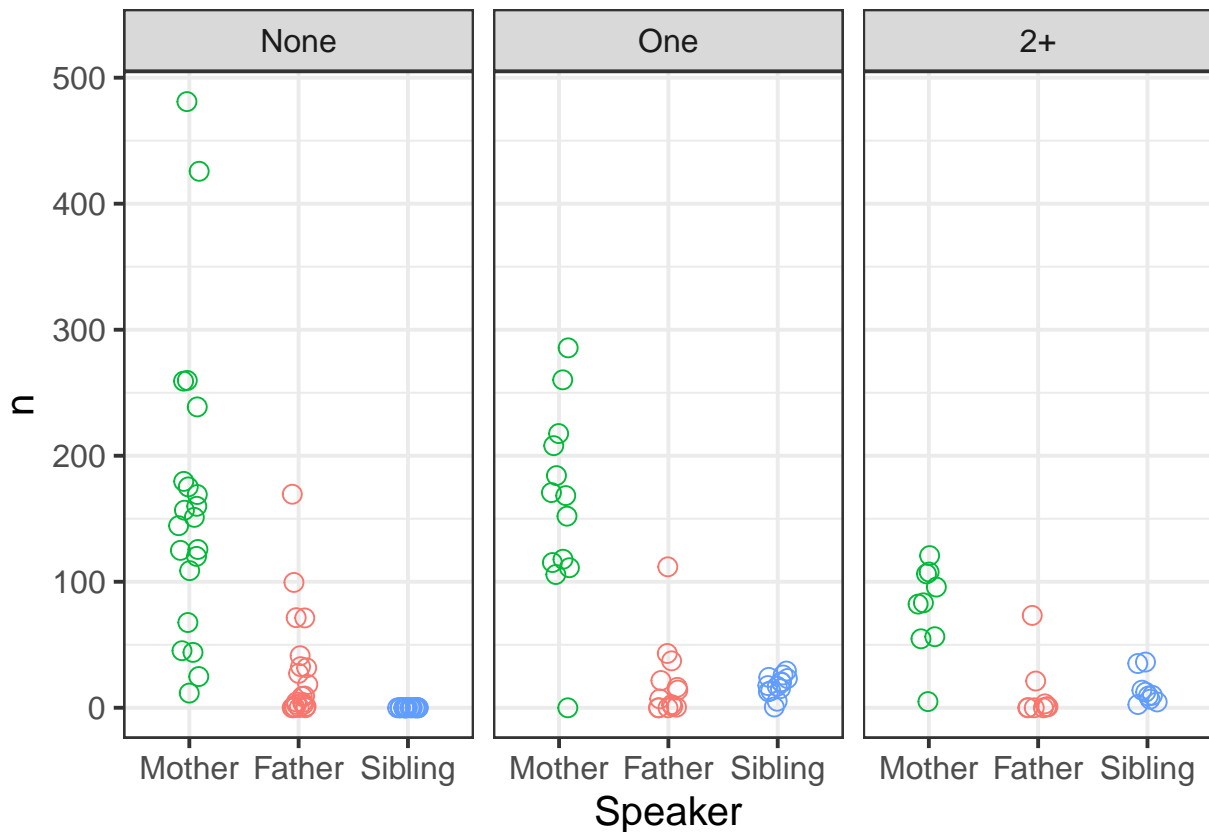
*Figure 2*. Mean number of words produced by Mothers, Fathers and Siblings across sessions recorded between 10-17 months. Circles represent values for individual infants; red triangles show group means.

341    **Early-acquired words.**    We expected infants with more siblings to hear fewer

342  early-acquired words (i.e. fewer words that occur on the CDI). We consider this with

343  regard to both amount and proportion of total household input. On average, 62% of the

344  object words heard in the infants' inputs were included on the CDI (Mdn=0.63, SD=0.11).

345  Infants with two or more siblings heard a lower proportion of these words overall (see See

346  Table 1 and Figure 3). Indeed, sibling group accounted for a significant amount of variance

347  on the proportion of early-acquired words heard in the input ($\chi^2(2) = 2.90$, $p$=.234).

348  Comparing proportion of early-acquired words in the object words produced by mothers,

349  fathers and siblings in the input, post-hoc Wilcoxon Rank Sum tests showed that infants

350  with two or more siblings heard significantly fewer early-acquired words ($W$=57, $p$=.948),

351  while there was no difference between infants with one vs. no siblings ($W$=168, $p$=.276,

352  Bonferroni corrections applied). All results were consistent when the same models were run

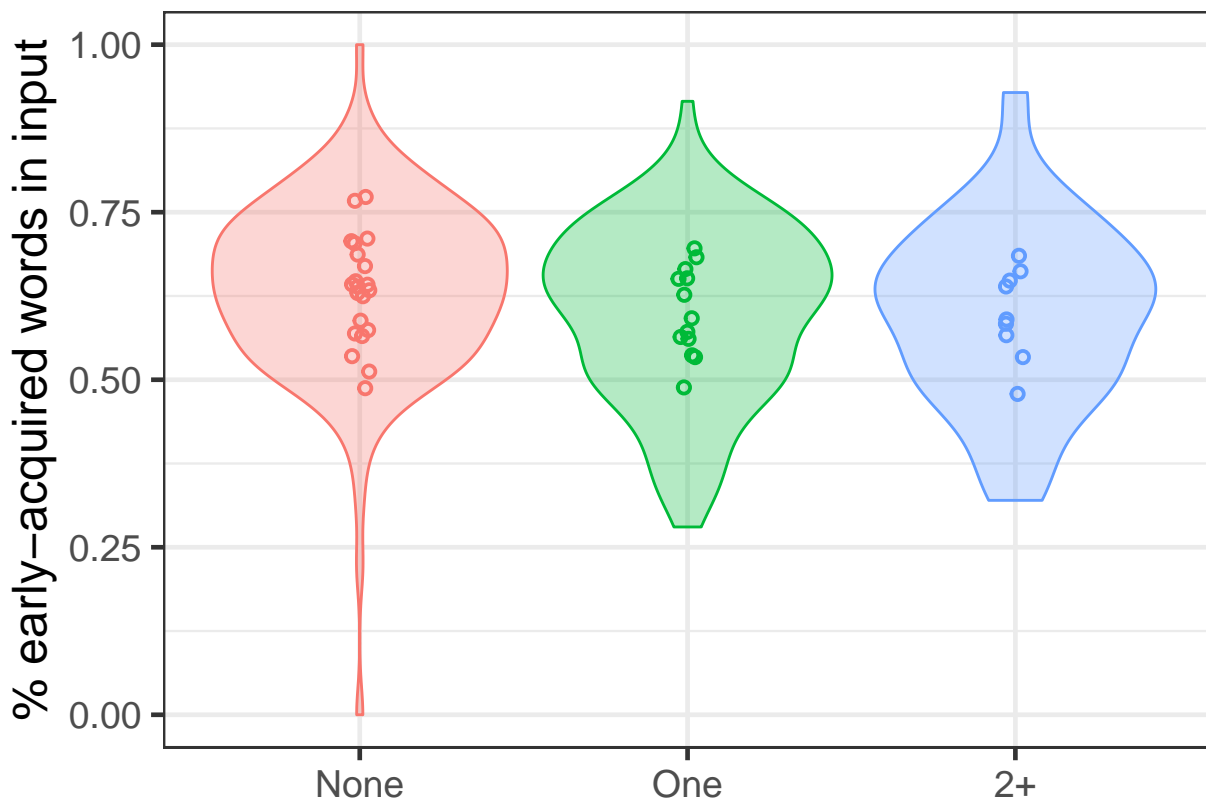353  on total number of early-acquired words heard in the input.



*Figure 3*. Proportion of early-acquired words in the input, across sibling groups. Error bars indicate mean learnable words heard across groups, with bootstrapped 95% CIs computed over all data. Dots indicate mean number of early-acquired words per infant, collapsed across age and jittered horizontally for visual clarity.

354  **Object presence.**   On average, 60% of utterances were produced in the presence of

355  the relevant object (Mdn=0.60, SD=0.12). We hypothesized that infants with more

356  siblings would hear fewer words in referentially transparent conditions (i.e. they would

357  experience lower object presence) than those with fewer siblings. Indeed, modelling the
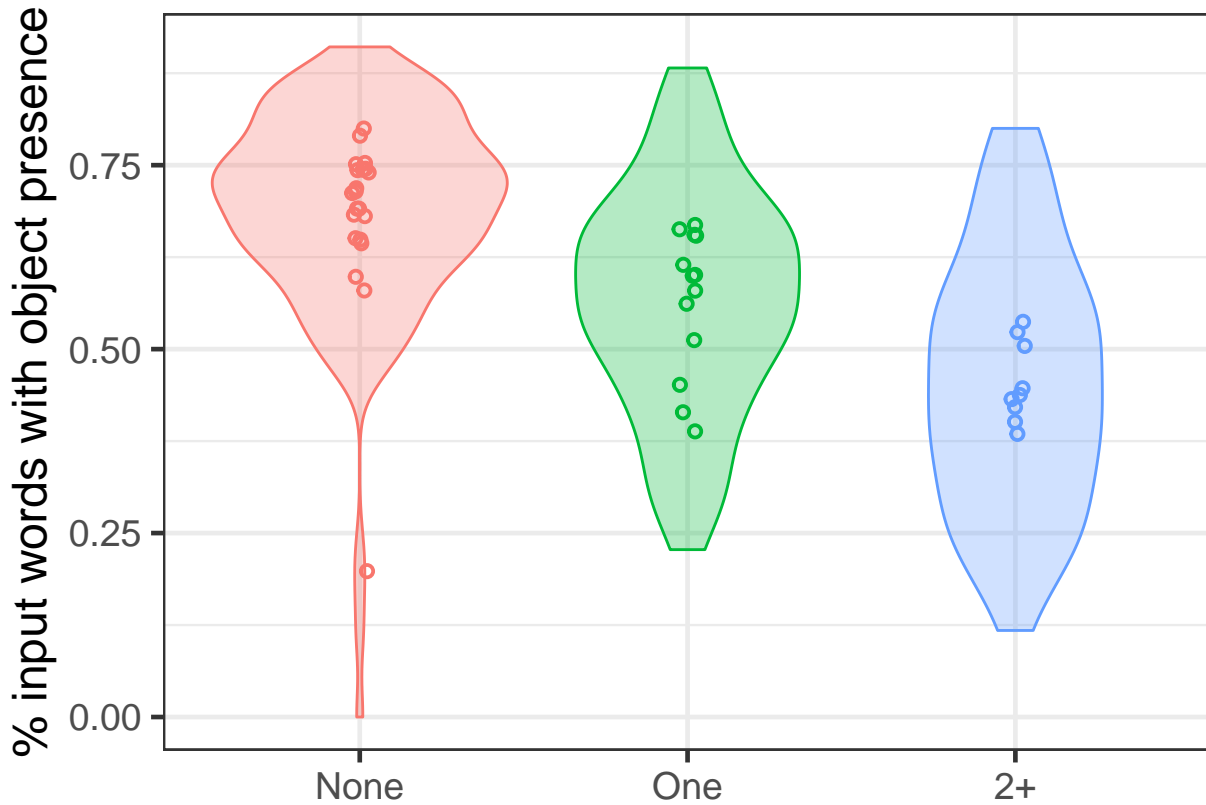
*Figure 4*. Proportion of input words produced with object presence in the input across sibling groups. Error bars and black triangles show 95% CIs and mean proportion of object presence across sibling groups. Dots indicate mean proportion of object presence per infant, collapsing across age and jittered horizontally for visual clarity.

358  quantity of object present tokens that infants heard, we find a significant effect for sibling

359  group on object presence ($\chi^2(2) = 26.09$, $p<$ .001). See Figure 4. Infants with no siblings

360  experienced 23% more object presence in their input than those with two or more siblings,

361  and 12% more than those with one sibling. Post-hoc comparisons revealed significant

362  between-group differences: infants with no siblings experienced significantly more object

363  presence than those with one sibling ($W$=234, $p$=< .001, Bonferroni corrections applied).

364  Likewise, infants with one sibling experienced significantly more object presence those with

365  two or more siblings ($W$=20, $p$=.009). See Table 1.

<sup>366</sup>                                        **Discussion**

<sup>367</sup>          We investigated the nature of infant language development in relation to number of

<sup>368</sup>   children in the household. Previous research found a delay in lexical acquisition for

<sup>369</sup>   later-born infants (Fenson et al., 1994; Hoff, 2006), with differences in input across birth

<sup>370</sup>   order reported as a root cause. Our results add several new dimensions to this, by testing

<sup>371</sup>   for differences across more vs. fewer older siblings, and by looking at input child-centered

<sup>372</sup>   home recordings. Infants with more siblings were reported to say fewer words by 18

<sup>373</sup>   months, heard fewer nouns from their parents, heard fewer early-acquired nouns, and

<sup>374</sup>   experienced less 'object presence' when hearing them.

<sup>375</sup>          Importantly, and in contrast with some previous research (Hoff-Ginsberg, 1998;

<sup>376</sup>   Oshima-Takane & Robbins, 2003), infants with one sibling showed no delay in lexical

<sup>377</sup>   production and minimal reduction in input in comparison to first-born infants. That is, our

<sup>378</sup>   results suggest that simply having a sibling does not contribute to input or vocabulary

<sup>379</sup>   differences across children (as measured here), while having more than one siblings seems

<sup>380</sup>   to do so. Indeed, infants with zero and one sibling had similar results for productive

<sup>381</sup>   vocabulary, parental noun input overall, and early-acquired nouns in the input (but not

<sup>382</sup>   object presence, which we return to below). In contrast, infants with two or more siblings

<sup>383</sup>   said fewer words and had lower rates of all of our input measures compared with their

<sup>384</sup>   peers.

<sup>385</sup>          When we considered the effect of sibling status – that is, whether or not infants had

<sup>386</sup>   any siblings, disregarding specific sibling number – our findings showed that having siblings

<sup>387</sup>   made no difference to infants' lexical production capacities. This contrasts with

<sup>388</sup>   Hoff-Ginsberg (1998), who found that, by 18 months, laterborns exhibit lower language

<sup>389</sup>   skills. However, Oshima-Takane and colleagues (1996) found no overall differences between

<sup>390</sup>   first- and second-born children across a range of language measures taken at 21 months.

<sup>391</sup>   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 vocablary 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 parental input, having one sibling did not significantly reduce an infant's noun input quantity. 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, 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.

Infants' exposure to early-acquired (CDI) words was affected by sibling number; again, infants with more siblings were at a disadvantage overall, but having one sibling did not affect the number of early-acquired words heard in the input compared to zero siblings. This qualitative measure takes into account a number of factors known to be important in early word learning. One such factor is input frequency (Ambridge, Kidd, Rowland, & Theakston, 2015): the more frequently an infant hears a word, the more likely she is to acquire that form early on. Given that 60% of over 83,000 noun tokens in the input data matched the 241 object words on the CDI form, we can reliably assume that word repetition was high. Words acquired early in development (and thus included on the CDI form) tend to be learnable in other important ways: they may be phonologically well-suited to infants' early production capacity Vihman (2016), they may be produced frequently in isolation [e.g. **mommy**, **baby**; Brent & Siskind (2001)], or they may be labels for concrete items that are common in the infant's surroundings [e.g. **bottle**, **mouth**; E. Bergelson &

Swingley (2012)]. It is perhaps unsurprising that infants with more siblings tended to hear fewer early-acquired words in our data: a higher number of older siblings in the household almost tautologically ensures more complex grammatical structures, fewer concrete words, and more pronouns spoken to and by these children (Oshima-Takane et al., 1996).

Input disadvantages were most marked in our analysis of object presence. In this case, even having one sibling led to fewer word-object pairs presented in the input. Presence of a labelled object with congruent input speech is known to be supportive in early word learning. Gogate and colleagues (2000) highlight the importance of object presence in relation to contingent word production, which supports the learning of novel word-object combinations. They report that "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 in their infant's input. 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 (E. Bergelson & Swingley, 2013).

Our results indicated a relatively close link between input and early production: children with two or more siblings said the fewest words and heard the lowest quantity and quality input, as operationalized by our measures. Similarly, infants with 0 or 1 sibling showed similar production levels, parental input, and presence of early-acquired words in the input. Object presence varied more linearly across sibling quantity, suggesting it may be a less critical driver of early word production. Alternatively, the reduced object presence for children with 1 sibling may have been compensated for in other ways we did not measure here, which in turn resulted in the indistinguishable vocabulary in the 0 and 1 sibling children at 17 months.

More generally, 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

445 children, but once children outnumber parents, this balancing act of attention, care, and

446 time, becomes unwieldy. While the current sample is relatively limited and homogenous in

447 the family structures and demographics it includes, future work could fruitfully investigate

448 this possibility by considering whether (controlling for other potential contributors like

449 SES, Hoff-Ginsberg, 1998) the presence of more caregivers (whether parents, relatives, or

450 other adults) helps foster language development.

451       Alternatively, second-borns might 'even out' with children with no siblings due to a

452 trade-off between direct attention from the caregiver and the possibility of more

453 sophisticated social-communicative interactions. For these infants there is still ample

454 opportunity to engage with the mother in one-to-one interactions, allowing a higher share

455 of her attention than is available to third- or later-borns. Furthermore, triadic interactions

456 can benefit the development of a number of linguistic and communication skills (Barton &

457 Tomasello, 1991; Dunn & Shatz, 1989). Second-borns may also benefit from overheard

458 speech in their input, supporting the acquisition of nouns and even more complex lexical

459 categories (Floor & Akhtar, 2006; Oshima-Takane et al., 1996). For infants with one

460 sibling, the benefits of observing/overhearing interactions between sibling and caregiver, as

461 well as the possibility for partaking in such interactions, may outweigh the decrease in

462 some aspects of the input (i.e., in our data, only observed in object presence). Having more

463 than one sibling may throw this off-balance.

464       Importantly, the present results make no claims about eventual outcomes for these

465 children: generally speaking, regardless of sibling number, all typically-developing infants

466 generally reach full and fluent language use. Indeed, some research suggests that sibling

467 effects, while they may be clear in early development, are not always sustained into

468 childhood; e.g. twins are known to experience a delay in language development into the

469 third year, but are quick to catch up thereafter (Dales, 1969; Tomasello, Mannle, &

470 Kruger, 1986). This demonstrates the cognitive adaptability of early development, which

471 brings about the acquisition of language across varying and allegedly 'imperfect' learning

472 environments. Infants' capacity to develop linguistic skills from the resources that are

473 available to them – whether that is infant-directed object labels or overheard abstract

474 concepts – highlights the dynamic and adaptable nature of early cognitive development,

475 and a system that is sufficiently robust to bring about the same outcome across

476 populations.

477      Of course, the 'success' of early language development is defined by the goals that we

478 set in this domain. Here we chose word production as our measure of linguistic capability;

479 we did not consider other, equally valid measures such as language comprehension or early

480 social-interaction skills. Similarly, our input measures focused on nouns; other lexical

481 classes may reveal different effects, though they are generally sparser until toddlerhood.

482 There is also some imbalance in group sizes across our data; our sample was not

483 pre-selected for sibling number, and so group sizes are unmatched across the analysis.

484 Including a larger number of infants with 2+ siblings may have revealed a different pattern

485 of results. Finally, more work across wider and larger populations is necessary to unpack

486 the generalizability of the present results. Our sample is refelective of average household

487 sizes in middle-class families across North America and Western Europe (Office for

488 National Statistics, 2018; United States Census Bureau, 2010), but it is not unusual in

489 some communities and parts of the world for couples to have between three and six children

490 in their household on average (Institute for Family Studies & Wheatley Institution, 2019).

491 Adding to this, it is also necessary to consider cross-cultural differences in the way children

492 are addressed by their parents. In a study of the early input experienced by children

493 growing up in a Tseltal Mayan village, Casillas, Brown and Levinson (2019) found that

494 almost all of children's input came from speech directed at other people (21 minutes per

495 hour, compared with just under 4 minutes/hour of specifically child-directed input).

496 However, they did not hear much input from siblings, which contrasts with findings from

497 Shneidman and Goldin-Meadow (2012), who found that 69% of speech directed at Mayan

498 children came from their siblings (in comparison with 10% for children in the USA).

In conclusion, our results support the general findings from the literature showing a disadvantage in lexical acquisition for later-born infants in relation to their first-born peers. However, we highlight an important difference from previous findings, namely that in the present sample, second-born infants are at no disadvantage overall, while infants with more than two siblings are. We related this directly to the infants' input over a period of one year: infants' productive vocabulary was reflective of the input quality in their home environment, and both were influenced by sibling number. As reported in longitudinal studies mapping early language outcomes with later educational success (Lee, 2011; Marchman & Fernald, 2008), the differences we observe in the early input here may have longer-term implications for children born into households with more older children. As has been noted in studies across a range of domains (e.g. Esposito et al., 2020; Kantarevic & Mechoulan, 2006), higher sibling number may have a detrimental effect across the lifespan. These finding point to the potential importance of the early language environment, which may be a key factor in the broader research that shows the 'sibling effect' to have negative economic and social implications.

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