

Supplementary Material

This supplemental material contains a data link and additional information on the following: instructions to the parent; how we coded parents' referential speech; the statistical models we used, along with their R code and a few notes about those models; and two supplementary tables containing sample transcripts of parent speech.

Data link: The data reported in this paper (utterance onsets, offsets, and reference coding for both studies; learning scores for study 2) are available on the OSF [https://osf.io/dzru7/?view_only=e6b44a6f86a14ec2a5b74cf75e687967].

Instructions to parents (Study 2): The parent was given two laminated cards, each containing the pictures and novel names of one set of three objects. The experimenter pronounced the names of each of the objects and the parents repeated the names back, with feedback if needed to correct their pronunciation. The novel names were those used in Pereira et al. (2014) and were pronounced as follows (IPA), all with stress on the first syllable: habble (/ˈhæbl/), mapoo (/ˈmæpu/), wawa (/ˈwawa/), zeebee (/ˈzibi/), tema (/ˈtimə/), and dodi (/ˈdodi/). Parents were instructed to use these names when talking about the objects, but were not told that the purpose of the study was for them to teach their toddler these names.

Coding referential speech: All coders were first trained in how to code verbal references to objects from sample videos and transcripts of parent-child interactions. This included the use of contextual cues from the videos and audio recordings. As part of this process, new coders' coding was compared with that of an experienced coder and disagreements between the coders were discussed as part of the training process. Trained coders then coded the data presented in this manuscript by reviewing the transcript utterance by utterance as they watched the video recording of the interaction and listened to the audio recording of parent speech. Any utterance in the transcript that contained one or more nouns or pronouns that could refer to one or more of the objects was coded with the ID numbers of any objects referenced, in the order that they were referenced, or was coded as "NA" if no object was referenced (see the supplementary material for an example). A second coder independently coded 25% of the recordings in order to calculate inter-rater reliability, but these secondary codings were not used to amend the primary coding.

Statistical models (Study 2): Statistical models were conducted using the lmer and glmer functions of the R package lme4 (Doran, Bates, Bliese, & Dowling, 2007) in RStudio Version 1.4.1717 and took the general form: `lmer(dependentVariable ~ fixedEffect1 + ...fixedEffectN + randomEffect1 + ... randomEffectN, data=dataFile)`. Below are the formulas for the four models reported in the manuscript:

Linear mixed effects null model:

```
lmer(propNamesLearned ~ meanNumberOfIOIs + childAge + (1 | subject), data = data_perSubject, REML = FALSE)
```

Linear mixed effects alternate model:

```
lmer(propNamesLearned ~ meanNumberOfIOIs + childAge + B_category + (1 | subject), data = data_perSubject, REML = FALSE)
```

Generalized linear mixed effects null model:

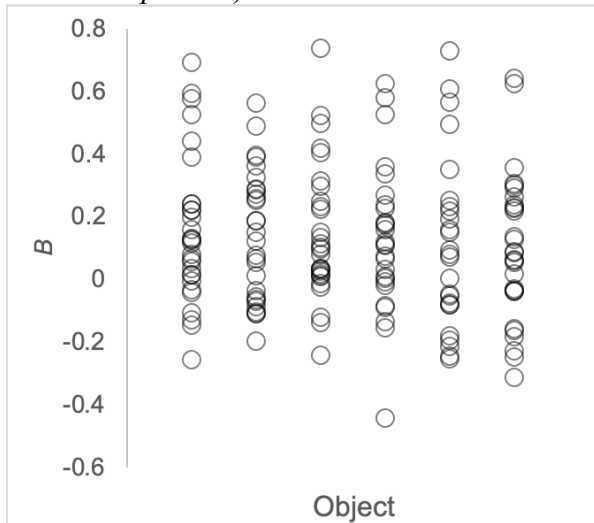
```
glmer(binaryLearningOutcome ~ numberOfIOIs + childAge + (1 | subject),  
family=binomial, data = data_perObject)
```

Generalized linear mixed effects alternate model:

```
glmer(binaryLearningOutcome ~ numberOfIOIs + childAge + B_value + (1 | subject),  
family=binomial, data = data_perObject)
```

Modeling notes:

1. We began with GLM null model with the most complex (maximal) random effect structure permitted by the design: `glmer(binaryLearningOutcome ~ numberOfIOIs + childAge + (1 + B_value | subject) + (1 + B_value | object), family=binomial, data = data_perObject)`; however, by-subject random slopes and by-object random intercepts and slopes were removed to allow a non-singular fit (Barr et al., 2013). We did check for potential systematic variability across items in terms of both burstiness and learnability, and found none. For visual reference, burstiness (B) values are shown in the figure below by object, with each circle representing B for one parents' talk about the object, for all 6 objects. In terms of learnability, the best learned object name (9 out of the 30 children learned the name) and the worst learned object name (5 out of the 30 children learned the name) did not significantly differ in their learning rates (one-tailed Fisher's exact test: $p=0.18$).



2. The manuscript describes a possible interaction between burstiness and age as a direction for future research. We were not able to explore this possibility directly because adding this interaction term into the model resulted in the model failing to converge. Moreover, our relatively small sample size -- Study 2 contained 30 participants that spanned the age range of 15 months to 26 months -- likely provided insufficient power to detect an interaction between age and burstiness, even if it did exist.

Supplementary tables: Supplementary tables provide transcripts and referential coding of the sample utterance sequences that are visually portrayed in Figure 2D-E. Details of the referential coding process are provided below. Table S1 provides one parent's bursty utterance sequence (B

= .48; see Figure 2D) and Table S2 provides a different parent’s non-bursty utterance sequence ($B = -.16$; see Figure 2D). Tables include all utterances that intervened between the parent’s first and last utterances to the target object – the helmet (object 1) in Table S1 and the turtle (object 9) in Table S2. Calculation of the inter-onset-intervals (IOIs) of utterances about the target object begins at the second utterance about the target object, by subtracting the onset time of the previous utterance about the target object (see final column). Parent speech occasionally included syllables that were not words (e.g., “lalala”, “mwah”), which were coded as langplayx, or sounds that were not clearly language syllables (e.g., whistling, humming), which were coded as vocplayx.

Table S1

Timing, Transcription, Referential Coding, and Inter-Onset-Interval (IOI) Coding of a Sample Utterance Sequence Containing Bursty Speech About the Helmet (Object 1) from Parent A.

| Utterance Onset (s) | Utterance Offset (s) | Utterance Transcript | First Object Referenced | Referential Term(s) | IOI (s) for Object 1 |
|---------------------|----------------------|--|-------------------------|---------------------------|----------------------|
| 442.7 | 443.3 | you want this one | 1 | this one | |
| 443.7 | 445.6 | this is red too look red | 1 | this | 1.03 |
| 446.1 | 447.6 | red and | NA | | |
| 449.1 | 450.2 | red | NA | | |
| 450.8 | 454.7 | that is a red ladybug and that is a red ladybug do they look the same look | 11 | that; ladybug; they | |
| 455.3 | 455.5 | look | NA | | |
| 456.1 | 458.1 | red ladybug red ladybug | 11 | ladybug | |
| 459.4 | 461.0 | except one is a bug toy | NA | | |
| 461.5 | 462.1 | that is squeaky | 11 | that | |
| 462.9 | 464.6 | and one a little drum toy | NA | | |
| 468.7 | 470.8 | this is a helmet it goes on your head | 1 | helmet | 24.94 |
| 471.5 | 473.0 | should we put it on our doll head | 1 | it | 2.87 |
| 473.8 | 474.5 | hi babyname | NA | | |
| 475.1 | 476.3 | how are you doing today | NA | | |
| 477.4 | 479.5 | should we put the helmet on her head she going to play football | 1 | helmet | 5.89 |

| | | | | | |
|-------|-------|--|----|----------|------|
| 480.3 | 481.4 | can you put her head in the helmet | 15 | her | |
| 482.4 | 483.3 | or the helmet on her head | 1 | helmet | 5.00 |
| 486.2 | 487.2 | oh almost | NA | | |
| 488.7 | 489.0 | vocplayx | NA | | |
| 490.4 | 492.4 | langplayx oh she has got poofy hair | 15 | she | |
| 493.0 | 495.8 | she has got pigtails like you do see if we cannot get her in there | 15 | she; her | |
| 496.3 | 498.2 | oh her pigtail want to stick out | 15 | her | |
| 500.7 | 507.7 | langplayx | NA | | |
| 510.5 | 510.8 | oh | NA | | |
| 511.4 | 512.9 | she has got a helmet on her head | 15 | she; her | |
| 513.4 | 514.1 | does she not | 15 | she | |
| 515.2 | 517.9 | say blue forty one blue forty two hut hut | NA | | |
| 518.6 | 519.4 | keep play football | NA | | |
| 520.1 | 521.4 | alright let us see what else we have | NA | | |
| 524.2 | 525.7 | she looks funny in there does she not | 15 | she | |
| 526.4 | 527.8 | she looks silly in there | 15 | she | |
| 530.4 | 532.2 | is she tired should we put her to bed | 15 | she; her | |
| 532.7 | 533.9 | do you see a bed anywhere | 23 | bed | |
| 535.2 | 536.0 | hmm | NA | | |
| 536.5 | 537.3 | where is her bed | 23 | bed | |
| 538.3 | 538.7 | oh | NA | | |
| 539.3 | 540.8 | way over here | NA | | |

| | | | | | |
|-------|-------|--|----|-------------------|-------|
| 541.9 | 542.7 | is that her bed | 15 | her | |
| 543.1 | 544.6 | can you put the baby doll in her bed | 15 | baby doll; her | |
| 546.0 | 546.8 | can you put her in her bed | 15 | her | |
| 547.7 | 550.0 | we got lots of car over here let us move some of those | 20 | car | |
| 551.0 | 551.3 | langplayx | NA | | |
| 553.6 | 554.6 | want to put her in her bed | 15 | her | |
| 558.0 | 558.4 | yes | NA | | |
| 560.1 | 561.6 | oh she has got to take the helmet off right | 15 | she | |
| 562.5 | 563.3 | oh can you get it | 1 | it | 80.05 |
| 563.9 | 564.6 | pull | NA | | |
| 565.5 | 566.5 | pull | NA | | |
| 570.1 | 571.7 | can you get it say i got it | 1 | it | 7.58 |
| 572.9 | 573.3 | yes | NA | | |
| 574.3 | 574.9 | help please | NA | | |
| 577.3 | 577.8 | there you go | NA | | |
| 579.2 | 580.9 | it pop it is off oh | 1 | it | 9.12 |

Table S2

Timing, Transcription, Referential Coding, and Inter-Onset-Interval (IOI) Coding of a Sample Utterance Sequence Containing Non-Bursty Speech About the Turtle (Object 9) from Parent B.

| Utterance Onset (s) | Utterance Offset (s) | Utterance Transcript | First Object Referenced | Referential Term(s) | IOI (s) for Object 1 |
|---------------------|----------------------|---|-------------------------|---------------------|----------------------|
| 540.32 | 545.09 | oh hi babynome will you play with me today i am just coming out of my house | 9 | me; i | NA |
| 546.36 | 547.55 | will you play with me | 9 | me | 6.04 |
| 549.41 | 549.69 | huh | NA | | |
| 550.10 | 551.20 | i will climb up here | 9 | i | 3.74 |
| 551.74 | 553.30 | langplayx vocplayx | NA | | |
| 554.90 | 556.40 | uh oh did he fall | 9 | he | 4.80 |
| 557.28 | 557.95 | langplayx | NA | | |
| 559.35 | 560.53 | i will help you | 5 | i | |
| 561.00 | 561.93 | langplayx | NA | | |
| 563.56 | 564.32 | he fell off | 9 | he | 8.66 |
| 565.48 | 566.68 | mister elephant | 5 | elephant | |
| 567.17 | 568.23 | that did not help me | 9 | me | 3.61 |
| 569.57 | 570.46 | can you help me | 5 | you | |
| 571.36 | 572.83 | i need help getting down | 9 | i | 4.18 |
| 573.55 | 575.20 | okay grab my trunk | NA | | |
| 575.60 | 576.06 | oh | NA | | |
| 576.49 | 577.31 | langplayx | NA | | |
| 578.57 | 580.19 | thank you mister elephant | 5 | elephant | |
| 582.59 | 583.73 | langplayx | NA | | |
| 585.99 | 587.28 | yeah it is a turtle | 9 | it; turtle | 14.63 |
| 589.01 | 589.93 | yeah you want to pet him | 9 | him | 3.02 |
| 590.64 | 591.86 | oh good turtle | 9 | turtle | 1.63 |
| 593.65 | 594.57 | is that a good turtle | 9 | that; turtle | 3.01 |