

Supplemental Material S3.

Growth Curve Model Results

Estimates of Fixed Effects for Empty Model

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	-0.66	0.07	86.48	-9.80	< .001	-0.79	-0.53

Covariance Parameters for Empty Model

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.58	0.06	9.10	< .001	0.47	0.72
Intercept	0.19	0.06	3.01	< .01	0.10	0.36

Estimates of Fixed Effects for Random Intercept Fixed Slope Model

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	0.01	0.07	132.26	0.11	.92	-0.14	0.15
Time	0.11	0.01	167.98	20.49	< .001	0.10	0.12

Covariance Parameters for Random Intercept Fixed Slope Model

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	9.10	< .001	0.13	0.20
Intercept	0.31	0.06	5.57	< .001	0.22	0.45

The following models are random intercept, fixed slope models with one vocal variable as a predictor variable.

Estimates of Fixed Effects for Model with Number of Total Vocalizations as Predictor Variable

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	0.21	0.09	119.83	2.36	.02	0.03	0.38
Time	0.11	0.01	167.02	20.51	< .001	0.10	0.12
Number of total vocalizations	0.26	0.07	88.57	3.74	< .001	0.12	0.40

Covariance Parameters for Model with Number of Total Vocalizations as Predictor Variable

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	9.08	< .001	0.13	0.20
Intercept	0.26	0.05	5.36	< .001	0.18	0.38

Estimates of Fixed Effects for Model with Automated Quantity of Vocalizations as Predictor Variable

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	-0.47	0.13	95.74	-3.57	.001	-0.72	-0.21
Time	0.11	0.01	163.29	20.23	< .001	0.10	0.12
Automated quantity of vocalizations	2.9×10^4	6.8×10^5	83.89	4.25	< .001	1.5×10^4	4.3×10^4

Covariance Parameters for Model with Automated Quantity of Vocalizations as Predictor Variable

Parameter	Estimate	SE	Wald Z	<i>p</i>	Lower CI	Upper CI
Residual	0.16	0.02	8.98	< .001	0.13	0.20
Intercept	0.25	0.05	5.29	< .001	0.18	0.37

Estimates of Fixed Effects for Model with Number of Communication Acts with a Vocalization as Predictor Variable

Parameter	Estimate	SE	<i>df</i>	<i>t</i>	<i>p</i>	Lower CI	Upper CI
Intercept	0.63	0.09	112.58	6.82	< .001	0.45	0.81
Time	0.11	0.01	168.00	20.59	< .001	0.10	0.12
Number of communication acts with a vocalization	0.86	0.10	86.16	8.64	< .001	0.66	1.05

Covariance Parameters for Model with Number of Communication Acts with a Vocalization as Predictor Variable

Parameter	Estimate	SE	Wald Z	<i>p</i>	Lower CI	Upper CI
Residual	0.16	0.02	9.09	< .001	0.13	0.20
Intercept	0.14	0.03	4.62	< .001	0.09	0.22

Estimates of Fixed Effects for Model with Proportion of Communicative Vocalizations as Predictor Variable

Parameter	Estimate	SE	<i>df</i>	<i>t</i>	<i>p</i>	Lower CI	Upper CI
Intercept	0.56	0.08	118.55	6.84	< .001	0.40	0.72
Time	0.11	0.01	168.63	20.54	< .001	0.10	0.12
Proportion of communicative vocalizations	0.69	0.07	85.55	9.35	< .001	0.55	0.84

Covariance Parameters for Model with Proportion of Communicative Vocalizations as Predictor Variable

Parameter	Estimate	SE	Wald Z	<i>p</i>	Lower CI	Upper CI
Residual	0.16	0.02	9.11	< .001	0.13	0.20
Intercept	0.13	0.03	4.49	< .001	0.08	0.20

Estimates of Fixed Effects for Model with Diversity of Key Consonants Used in Communication Acts as Predictor Variable

Parameter	Estimate	SE	<i>df</i>	<i>t</i>	<i>p</i>	Lower CI	Upper CI
Intercept	0.67	0.09	115.54	7.43	< .001	0.49	0.85
Time	0.11	0.01	166.38	20.62	< .001	0.10	0.12
DKCC	0.59	0.06	85.86	9.41	< .001	0.47	0.72

Note. DKCC = diversity of key consonants used in communication acts (Wetherby et al., 2007; Woynaroski et al., 2017).

Covariance Parameters for Model with Diversity of Key Consonants Used in Communication Acts as Predictor Variable

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.17	0.02	9.05	< .001	0.13	0.21
Intercept	0.13	0.03	4.35	< .001	0.08	0.20

Estimates of Fixed Effects for Model with Proportion of Vocalizations with a Canonical Syllable as Predictor Variable

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	0.38	0.08	122.95	4.76	< .001	0.22	0.54
Time	0.11	0.01	167.90	20.55	< .001	0.10	0.12
Proportion of vocalizations with a canonical syllable	0.38	0.05	86.20	7.26	< .001	0.28	0.48

Covariance Parameters for Model with Proportion of Vocalizations with a Canonical Syllable as Predictor Variable

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	9.10	< .001	0.13	0.20
Intercept	0.18	0.04	4.90	< .001	0.12	0.26

Estimates of Fixed Effects for Model with ACPU-C+V as Predictor Variable

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	0.19	0.10	103.79	1.93	.06	−0.01	0.40
Time	0.11	0.01	163.23	20.20	< .001	0.10	0.12
ACPU-C+V	0.27	0.10	86.50	2.71	< .01	0.07	0.46

Note. ACPU-C+V = average count per utterance – consonants + vowels (Woynaroski et al., 2017; Xu et al., 2014).

Covariance Parameters for Model with ACPU-C+V as Predictor Variable

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	8.98	< .001	0.13	0.20
Intercept	0.29	0.05	5.43	< .001	0.20	0.42

Note. ACPU-C+V = average count per utterance – consonants + vowels (Woynaroski et al., 2017; Xu et al., 2014).

The following models are used for the incremental validity analyses. They continue to use a random intercept, fixed slope model but with two vocal variable predictors rather than one.

Estimates of Fixed Effects for Model with Number of Total Vocalizations

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	0.21	0.09	119.83	2.36	.02	0.03	0.38
Time	0.11	0.01	167.02	20.51	< .001	0.10	0.12
Number of total vocalizations	0.26	0.07	88.57	3.74	< .001	0.12	0.40

Covariance Parameters for Model with Number of Total Vocalizations

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	9.08	< .001	0.13	0.20
Intercept	0.26	0.05	5.36	< .001	0.18	0.38

Estimates of Fixed Effects for Model with Number of Total Vocalizations and Communicative Quality Composite

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	0.69	0.08	117.88	8.26	< .001	0.53	0.86
Time	0.11	0.01	168.65	20.59	< .001	0.10	0.12
Number of total vocalizations	-0.01	0.06	89.15	-0.25	.80	-0.13	0.10
Communicative quality composite	0.91	0.10	85.43	9.29	< .001	0.72	1.11

Covariance Parameters for Model with Number of Total Vocalizations and Communicative Quality Composite

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	9.11	< .001	0.13	0.20
Intercept	0.10	0.03	4.14	< .001	0.06	0.17

Estimates of Fixed Effects for Model with Number of Total Vocalizations and Phonological Quality Composite

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	0.55	0.08	121.01	6.64	< .001	0.39	0.71
Time	0.11	0.01	167.74	20.60	< .001	0.10	0.12
Number of total vocalizations	-0.11	0.07	87.00	-1.50	.14	-0.25	0.04
Phonological quality composite	0.60	0.08	84.71	7.74	< .001	0.44	0.75

Covariance Parameters for Model with Number of Total Vocalizations and Phonological Quality Composite

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	9.09	< .001	0.13	0.20
Intercept	0.13	0.03	4.49	< .001	0.09	0.20

Estimates of Fixed Effects for Model with Number of Total Vocalizations and ACPU-C+V

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	0.38	0.10	103.67	3.62	< .001	0.17	0.59
Time	0.11	0.01	163.29	20.28	< .001	0.10	0.12
Number of total vocalizations	0.27	0.07	87.07	3.93	< .001	0.13	0.40
ACPU-C+V	0.24	0.09	86.67	2.69	< .01	0.06	0.42

Note. ACPU-C+V = average count per utterance – consonants + vowels (Woynaroski et al., 2017; Xu et al., 2014).

Covariance Parameters for Model with Number of Total Vocalizations and ACPU-C+V

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	8.98	< .001	0.13	0.20
Intercept	0.24	0.05	5.25	< .001	0.17	0.35

Note. ACPU-C+V = average count per utterance – consonants + vowels (Woynaroski et al., 2017; Xu et al., 2014).

Estimates of Fixed Effects for Model with Automated Quantity of Vocalizations

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	−0.47	0.13	95.74	−3.57	.001	−0.72	−0.21
Time	0.11	0.01	163.29	20.23	< .001	0.10	0.12
Automated quantity of vocalizations	2.9×10^4	6.8×10^5	83.89	4.25	< .001	1.5×10^4	4.3×10^4

Covariance Parameters for Model with Automated Quantity of Vocalizations

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	8.98	< .001	0.13	0.20
Intercept	0.25	0.05	5.29	< .001	0.18	0.37

Estimates of Fixed Effects for Model with Automated Quantity of Vocalizations and Communicative Quality Composite

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	0.48	0.14	94.78	3.49	< .01	0.21	0.75
Time	0.11	0.01	164.67	20.39	< .001	0.10	0.12
Automated quantity of vocalizations	9.8×10^5	5.2×10^5	83.81	1.89	.06	-5.0×10^6	2.0×10^4
Communicative quality composite	0.83	0.09	83.88	9.39	< .001	0.66	1.01

Covariance Parameters for Model with Automated Quantity of Vocalizations and Communicative Quality Composite

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	8.99	< .001	0.13	0.20
Intercept	0.10	0.02	3.99	< .001	0.06	0.16

Estimates of Fixed Effects for Model with Automated Quantity of Vocalizations and Phonological Quality Composite

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	0.35	0.15	94.78	2.30	.02	0.05	0.64
Time	0.11	0.01	163.51	20.39	< .001	0.10	0.12
Automated quantity of vocalizations	9.5×10 ⁵	6.9×10 ⁵	83.77	1.62	.11	−2.2×10 ⁵	2.1×10 ⁴
Phonological quality composite	0.47	0.06	85.03	7.42	< .001	0.35	0.60

Covariance Parameters for Model with Automated Quantity of Vocalizations and Phonological Quality Composite

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	8.97	< .001	0.13	0.20
Intercept	0.13	0.03	4.44	< .001	0.08	0.20

Estimates of Fixed Effects for Model with Automated Quantity of Vocalizations and ACPU-C+V

Parameter	Estimate	SE	df	t	p	Lower CI	Upper CI
Intercept	−0.29	0.16	92.12	−1.78	.08	−0.61	0.03
Time	0.11	0.01	163.45	20.21	< .001	0.10	0.12
Automated quantity of vocalizations	2.6×10 ⁴	6.9×10 ⁵	84.41	3.69	< .001	1.2×10 ⁴	3.9×10 ⁴
ACPU-C+V	0.17	0.09	87.01	1.84	.07	−0.01	0.36

Note. ACPU-C+V = average count per utterance – consonants + vowels (Woynaroski et al., 2017; Xu et al., 2014).

Covariance Parameters for Model with Automated Quantity of Vocalizations and ACPU-C+V

Parameter	Estimate	SE	Wald Z	p	Lower CI	Upper CI
Residual	0.16	0.02	8.98	< .001	0.13	0.20
Intercept	0.24	0.05	5.25	< .001	0.17	0.35

Note. ACPU-C+V = average count per utterance – consonants + vowels (Woynaroski et al., 2017; Xu et al., 2014).

References

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