Language Acquisition by Identical vs. Fraternal SLI Twins*

Karin Stromswold & Jay I. Rifkin

Dept. of Psychology & Ctr. for Cognitive Science, Rutgers University, New Brunswick, NJ

Abstract

This paper investigates the role that genetic factors play in language and language disorders through an ongoing in-depth longitudinal study of language acquisition by sets of identical (monozygotic, MZ) and fraternal (dizygotic, DZ) twins with specific language impairment (SLI). In addition to providing an in-depth picture of language development in 4 SLI children, the results of this study suggest:

- Genetic factors may play an important role in the acquisition of all aspects of language (morphosyntax, phonology, and the lexicon).
- Genetic factors may affect not only whether a child is language-impaired, but also the nature of the impairment.
- Genetic factors may play an increasing role in language acquisition as SLI children get older.

Overview

Longitudinal Study:

- In-depth study of syntax, morphology, phonology & the lexicon via analyses of spontaneous speech and tests of comprehension and production.
- Monthly sessions of 30-60 minutes

Subjects: 4 male SLI twins

Child	Birth Weight	Age	# Sessions Analyzed	# Utterances Analyzed
JES^{m}	5 lbs, 6 oz.	2;8;20-4;2;24	10	2073
JOS^{m}	5 lbs, 1 oz.	2;8;20-4;2;24	10	2404
MAL^{d}	6 lbs, 13 oz.	4;0;7 - 5;1;25	15	3666
RYL^{d}	6 lbs, 14.5 oz.	4;0;7 - 5;1;25	15	4158

* **Acknowledgment.** This research was supported by a grant from the John Merck Foundation. We are indebted to the twins and their families for graciously agreeing to participate in this study. We would like to thank Karen Arnold, Krystene Boyle, Meghan Coughlin, Bill Donnelly, Gabrielle Dorland, Patricia Estrada, Michael Giovanniello, Eileen Grob, Samantha Holt, Sony Kishin, Mark Leone, Leila Rauf, and Ryan Rumage for their help in collecting and transcribing the data. We are grateful to the staff at the Rock Brook School and the JFK Medical Center for referring the twins and providing testing facilities. Correspondence may be sent to Karin Stromswold, M.D., Ph.D., Department of Psychology & Center for Cognitive Science, Rutgers University, New Brunswick, NJ 08903 or via e-mail to karin@ruccs.rutgers.edu.

Developmental Milestones

Child	Smiled*	Sat*	Walked*	Hand preference*
JES^m	4 mos	8 mos	12 mos	24 mos (R)
JOS^m	4 mos	8 mos	17 mos	24 mos (R)
MAL^d	4 mos	6 mos	12 mos	~ 24 mos (R)
RYL^d	4 mos	6-7 mos	13 mos	ambidex.

Language History:

Child	Age of First Word*	Age of First 2-Word Utterance*	Family history of language disorder*
JES^m	~ 2 years	~ 2 years	older brother
JOS^m	~ 2 years	~ 2 years	older brother
MAL^d	~ 2 years	~ 2.5 years	older brother, aunt, 3 first cousins
RYL^d	1.5 years (but stopped)	~ 2.5 years	older brother, aunt, 3 first cousins

key: ^{m} = Monozygotic twin, ^{d} = Dizygotic twin, * = Parental report

Morphosyntax

Morphosyntactic Measures of Speech of Spontaneous Speech:

MLU (see graphs)

In morphemes: MZ $r = .92$, $p < .001$; DZ $r = .36$, $p > .20$
In words: MZ $r = .85$, $p < .002$; DZ $r = .07$, $p > .80$

Brown's 14 grammatical morphemes (see table)

Although the twins occasionally used some of these morphemes, they do not use them in 90% of obligatory contexts. The order in which the twins began using Brown' s morphemes regularly (= 4 times/transcript) was similar to the order of mastery reported for normally developing children.

Subject-Aux Inversion in questions (see graphs)

Like normally developing children, the SLI twins rarely failed to invert.

Overregularization (Past tense & plural) (see graphs and tables)

The twins overregularized more frequently than is generally reported for normally developing children. If lexical versions of *be*, *do*, and *have* and "no change" past tense verbs are included in the denominator, the overall regularization rates were:

JES: 10.2% (4/39) JOS: 14.9% (7/47)
MAL: 17.7% (53/229) RYL: 23.1% (24/104)

(Pronominal) Case

Pronominal case errors were fairly frequent. Most of the errors involved using accusative case in non-accusative settings. Only RYL made an appreciable number of errors using non-accusative case in accusative settings.

Plurality (see graphs)

The rate of including a plural morpheme that was not allowed (e.g., *a cats*, *this cats*, *one cats*) was greater than the rate of omitting an obligatory plural morpheme (e.g., **two cat*, *these cat*, *many cat*). The overall error rates were:

Singular:	JES: 3.0% (5/198)	JOS: 5.7% (12/210)
	MAL: 2.4% (11/468)	RYL: 0.1% (1/803)
Plural:	JES: 27.8% (11/40)	JOS: 10.3% (3/29)
	MAL: 22.2% (30/135)	RYL: 38.2% (42/110)

Tense/Agreement

Omitting the past tense morpheme in obligatory contexts was much more common than supplying it when it wasn't required. Both types of agreement errors were found (e.g., *the cats eats this*, *a cat eat this*). This probably is partially a reflection of children's problems with plural inflection.

Morphosyntactic Tests

Berko plural production test ("wug" test)

JES (4;0.16): 56% (10/18); JOS (4;0.16): 6% (1/18)
MAL (5;0.25): 69% (11/16); RYL (5;0.25): 69% (11/16)

Singular/Plural comprehension test:

JES (4;2.24): 44% (7/16); JOS (4;2.24): 38% (6/16)
MAL (4;8.21): 81% (13/16); RYL (4;11.22): 50% (8/16)

Preposition comprehension test (semantically reversible)

JES (3;8.9): 75% (6/8); JOS (3;8.9): 68% (5/8)
MAL (4;7.25): 100% (8/8); RYL (4;9.21): 38% (3/8)

Active/Passive comprehension test (semantically reversible)

JES (4;4.13)	Actives: 93% (14/15)	Passives: 80% (12/15)
JOS (4;4.13)	Actives: 87% (13/15)	Passives: 73% (11/15)
MAL (4;7.25)	Actives: 100% (11/11)	Passives: 94% (16/17)
RYL (4;9.21)	Actives: 100% (14/14)	Passives: 15% (2/13)

***Wh*-question comprehension test**

JES (4;0.16): 60% (18/30); JOS (4;0.16): 73% (22/30)
MAL (5;8.12): 100% (30/30); RYL (5;8.12): 90% (27/30)

The Lexicon

Type/Token Ratios

MZ $r = .77$, $F(1, 8) = 11.80$, $p < .009$; DZ $r = .01$, $F(1, 12) = 0.00$, $p > .90$

Rescorla (1989) Parental Checklist

JES (3;0): 277/309; JOS (3;0): 263/309 (Concordance rate = 93%)
MAL (4;7): 293/309; RYL (4;7): 66/309 (Concordance rate = 88%)

Lexical Retrival (Animal naming task)

JES (4;4.13): 6 animals; JOS (4;4.13): 4 animals
MAL (5;4.3): 13 animals; RYL (5;4.3) : 6 animals

Phonology

Minimal Pairs Test Indiana University School of Medicine Minimal Pairs Test:

JES (4;1.10 & 4;2.24): 98% (78/80); JOS (4;1.10 & 4;2.24): 95% (76/80)
MAL (5;2.27): 100% (80/80); RYL (5;2/27): 90% (72/80) (confused /k/ and /g/)

Phonetic Inventory Concordance Rates (see Table)

The phonetic inventories of the MZ twins do not appear to be more concordant that the DZ twins. This may reflect the relatively small number of utterances analyzed (25).

Major Phonological Processes Common to MZ and DZ Twins

- Simplification of Liquids (liquid gliding, liquid vocalization, and liquid deletion)
- Consonant Cluster Reduction (syllable onsets and codas)
- Final Consonant Deletion
- Stopping (fricative or affricate replaced by a stop, usually its homorganic counterpart)
- Unstressed Syllable Deletion (often with compensatory lengthening of previous stressed vowel, or incorporation of the syllable's consonants into surrounding syllable structure)

Primarily Phonological MZ Twin Processes

- Initial Consonant Deletion (Appears to be more common in JOS's speech. Occurs primarily before high front vowels /i/ and /I/.)
- Onset Creation (Insertion of a onset or replacement of a glide in onset position with a consonant, usually the same as one in a later coda position.)

Primarily Phonological DZ Twin Process

- Velar Fronting: Shift of place of articulation of an onset from velar to alveolar or sometimes labial. Though all the twins do some fronting, velar fronting is particularly prevalent in MAL and RYL's onsets.

Examples of Less Common Phonological Processes

- Substitutions
  - Dental -> Alveolar, less commonly Alveolar -> Dental.
  - Stop -> Fricative, Affricate -> Fricative.
- Cluster Creation (addition of a segment to an onset or coda)

Summary & Conclusions

- For the most part, the SLI twins make similar types of errors as normally developing children. In general, the SLI twins' make more omission errors than normally developing children (e.g., Brown's grammatical morphemes). For most types of errors that are not errors of omission, the SLI twins' error rates are similar to those reported for normal children (e.g., subject-auxiliary inversion errors). However, for some types of non-omission errors (e.g., overregularization errors such as *mouses*, subject verb agreement errors such as *they eats*, and plurality errors such as *that boys*), the SLI twins make more errors than normally developing children.

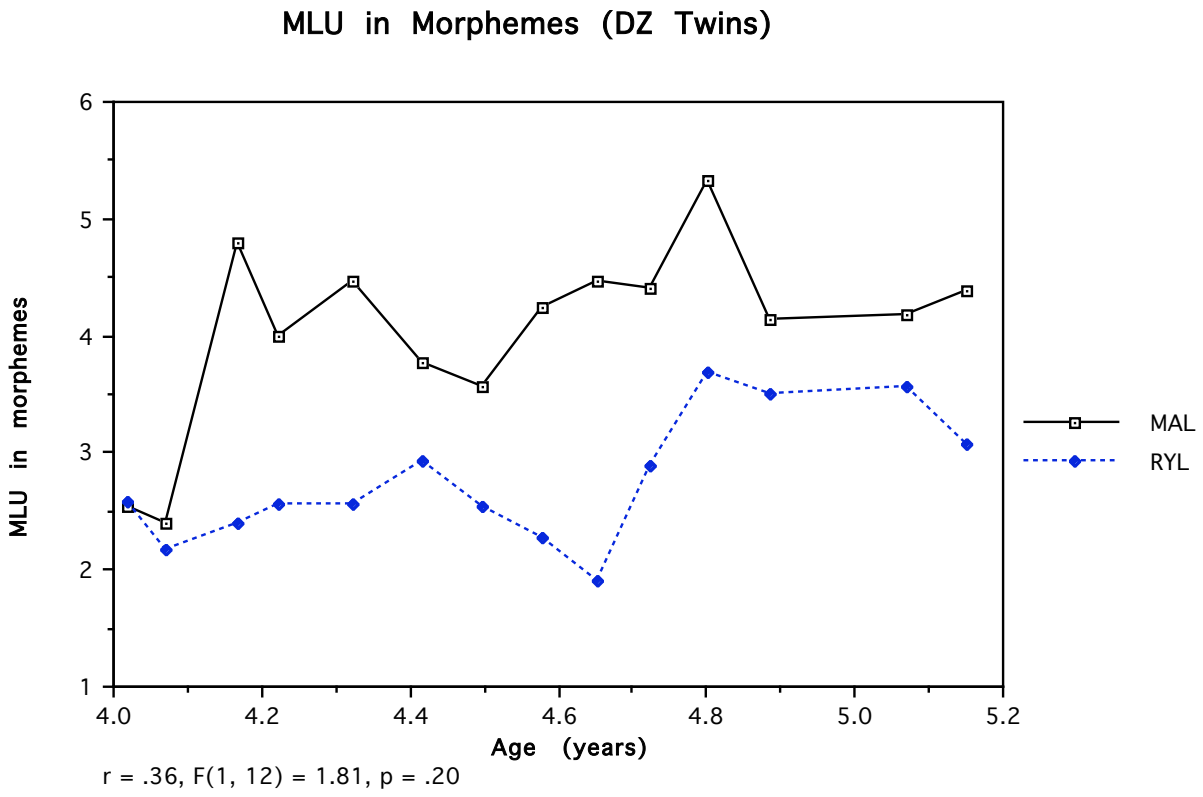
- Generally, the order in which the SLI twins acquire aspects of morphosyntax, phonology, and the lexicon is similar to that of normal children, though the time course is slowed considerably.

- Genetic factors may play an important role in the acquisition of many aspects of language (morphosyntax, phonology, and the lexicon). The MZ-DZ discrepancies seem to be greater for morphosyntax and the lexicon than for phonology, but this may reflect the smaller sample sizes for phonological analyses.

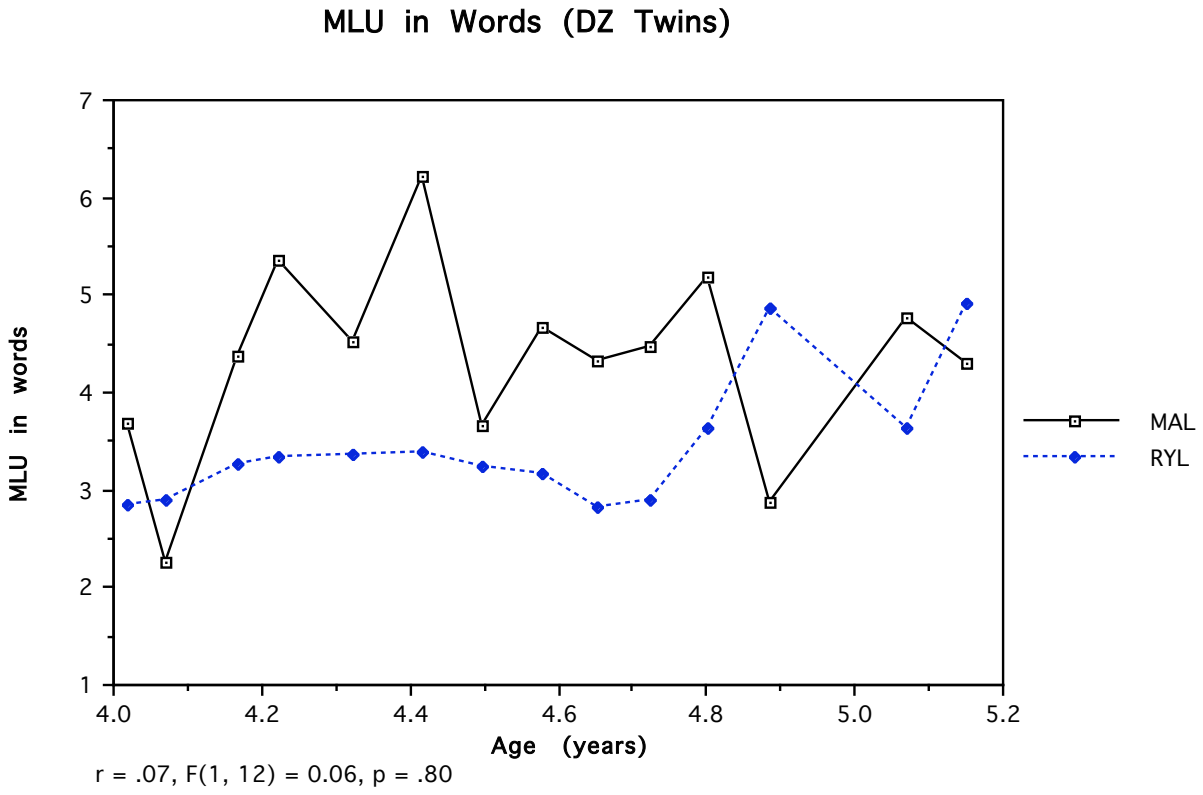
- Genetic factors may affect not only whether a child is language-impaired, but also the nature of the impairment. This is relevant for interpretting the results of twin studies in which twins are classified as either concordant or disconcordant. Even though both sets of twins are concordant for SLI, the MZ twins are more similar to one another than are the DZ twins.

- As the twins have gotten older, the MZ twins continue to resemble each other to a considerable extent, whereas the DZ twins are becoming increasingly different (e.g., one DZ twin has even been mainstreamed much of the day and the

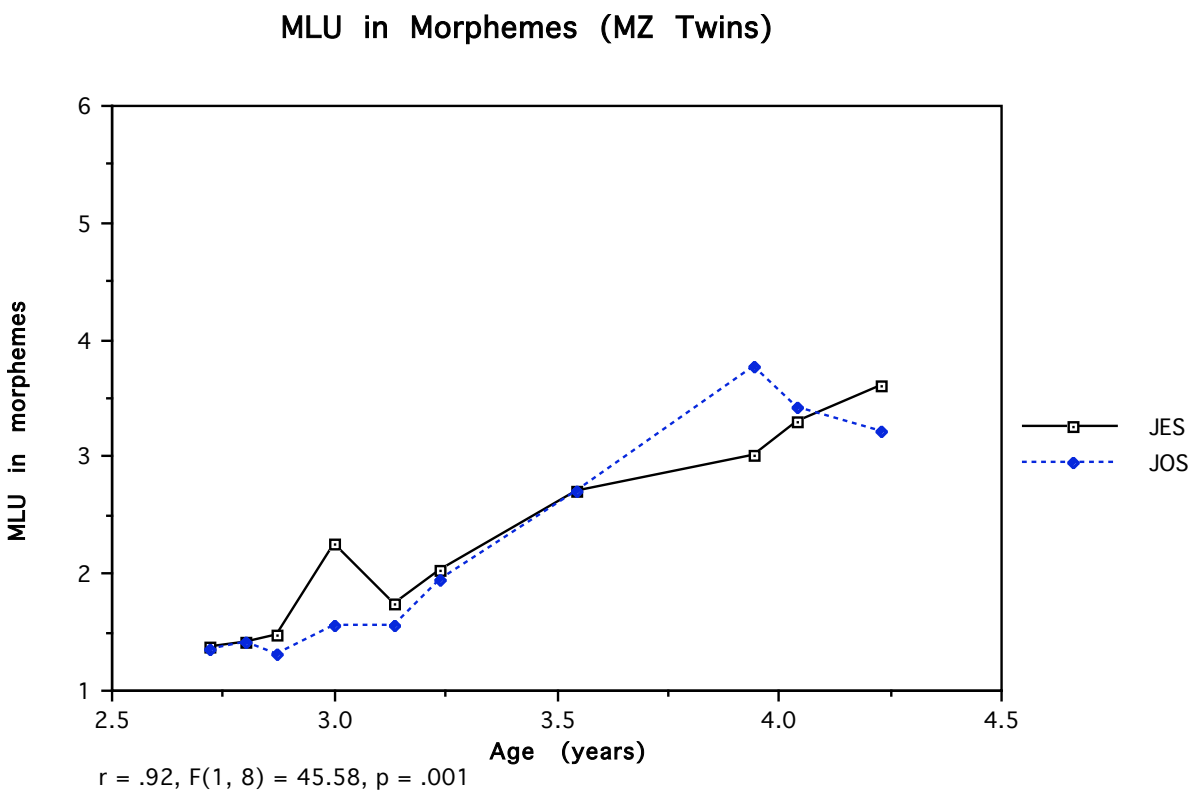
other remains in a school for language-impaired children). This suggests that genetic factors may play an increasing role in language acquisition as SLI children get older.

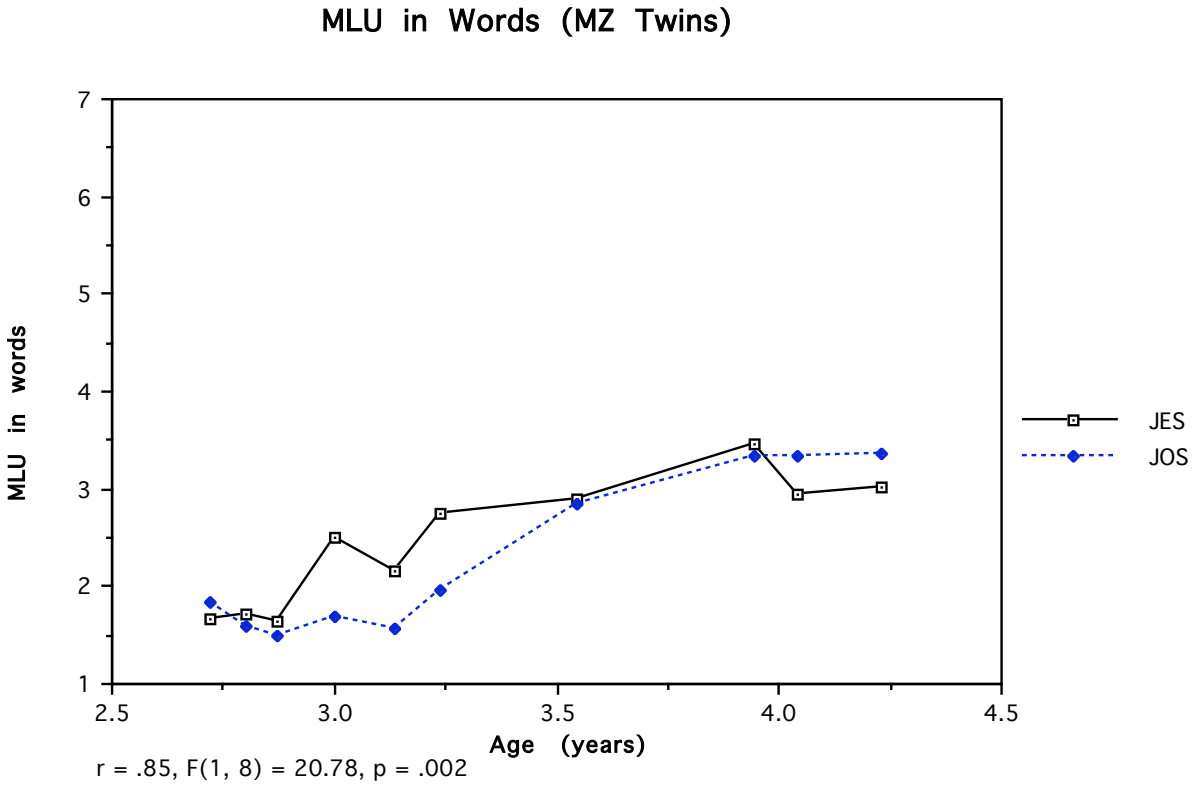


r = .36, F(1, 12) = 1.81, p = .20



r = .07, F(1, 12) = 0.06, p = .80


MLU in Morphemes (MZ Twins)
MLU in morphemes
6
5
4
3
2
1
2.5
3.0
3.5
4.0
4.5
Age (years)
JES
JOS
r = .92, F(1, 8) = 45.58, p = .001

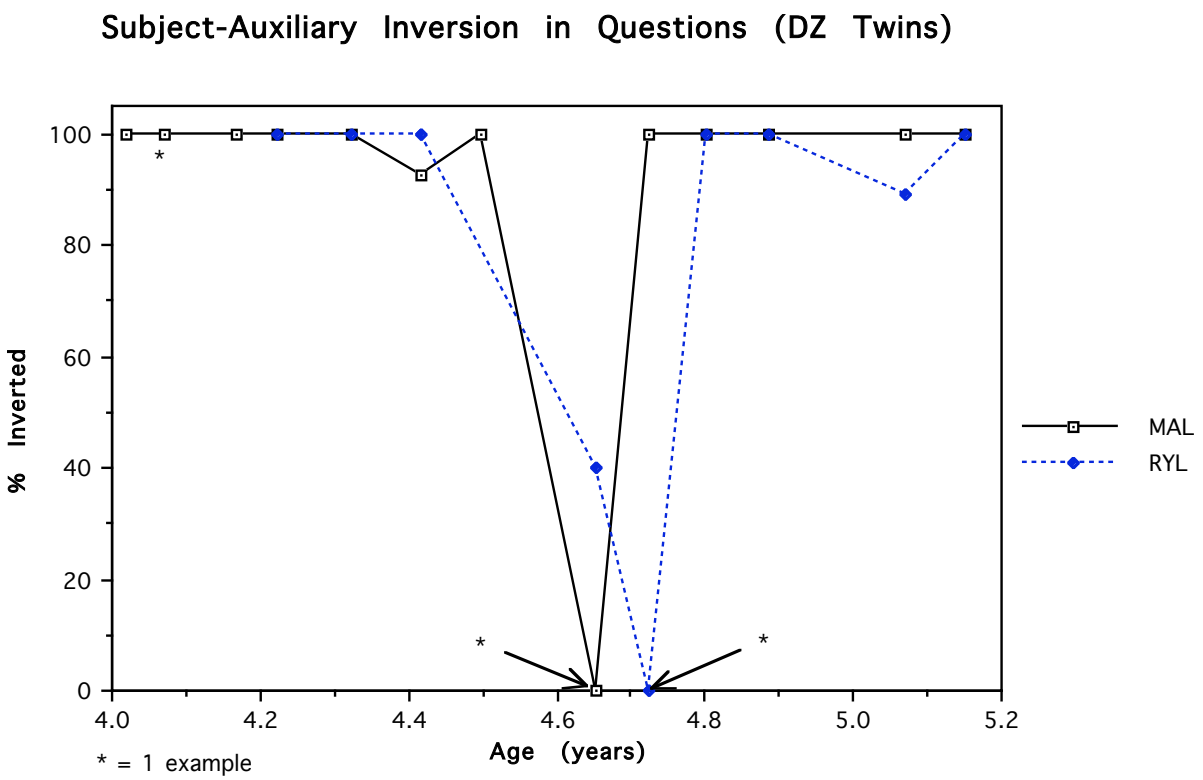

MLU in Words (MZ Twins)
MLU in words
7
6
5
4
3
2
1
2.5
3.0
3.5
4.0
4.5
Age (years)
JES
JOS
r = .85, F(1, 8) = 20.78, p = .002

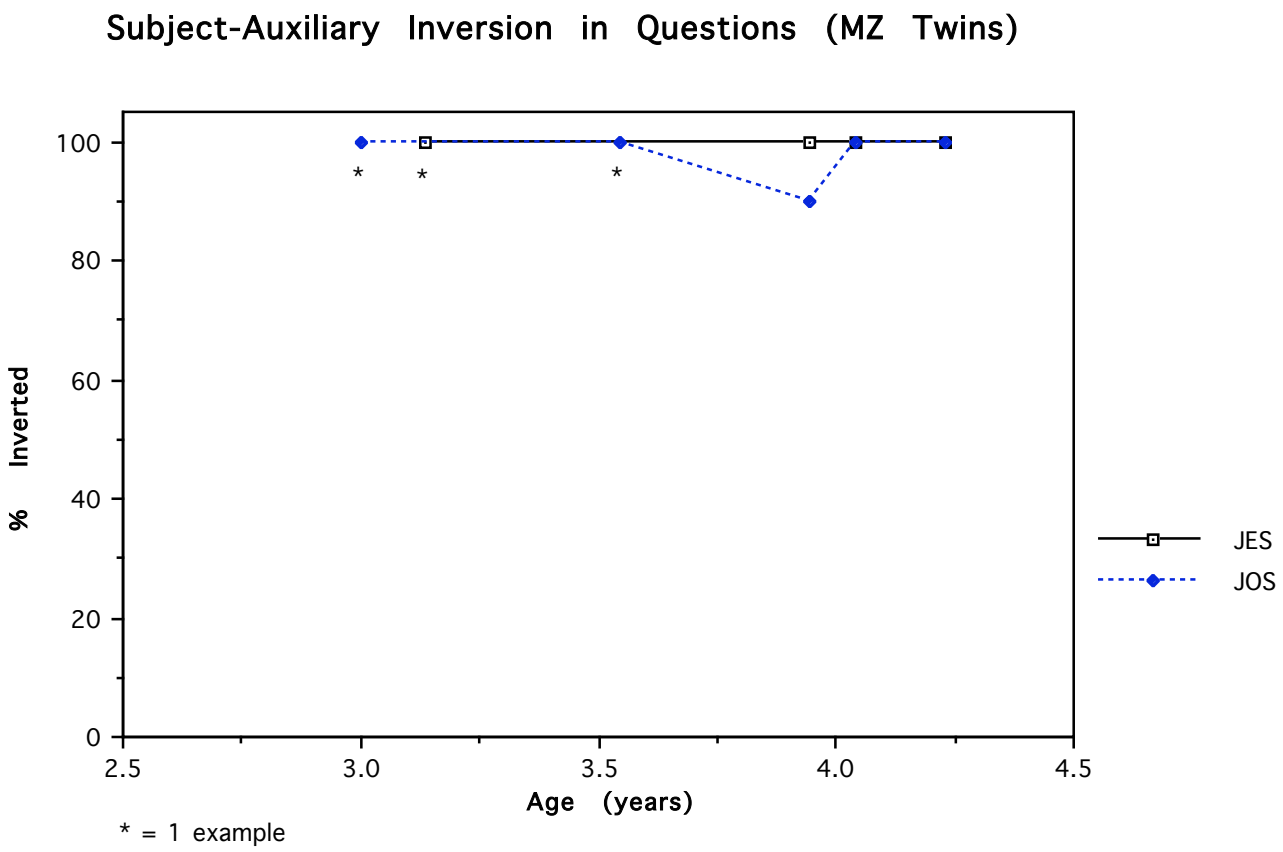
Brown's 14 Grammatical Morphemes

	MZ		DZ	
Morpheme	**JES***	**JOS***	**MAL***	**RYL***
-ing	3;1.20	3;6.16	≤ 4;0.7	≤ 4;0.7
plural	2;10.13	3;1.20	≤ 4;0.7	≤ 4;0.7
in	3;11.9	3;11.9	≤ 4;0.7	≤ 4;0.7
on	4;2.24	3;11.9	≤ 4;0.7	4;2.0
possessive	3;11.9	2;9.18	≤ 4;0.7	4;2.0
regular past	NA by 4;2.24	3;11.9	≤ 4;0.7	4;0.26
irregular past	3;11.9	3;11.9	≤ 4;0.7	≤ 4;0.7
regular 3rd person singular	NA by 4;2.24	3;11.9	≤ 4;0.7	NA by 4;10.18
a, the	≤ 2;8.20	≤ 2;8.20	≤ 4;0.7	≤ 4;0.7
contractible copula be	3;1.20	3;6.16	≤ 4;0.7	≤ 4;0.7
contractible auxiliary be	4;0.16	3;11.9	4;2.0	≤ 4;0.7
uncontractible copula be	3;11.9	3;11.9	≤ 4;0.7	4;0.26
uncontractible auxiliary be	4;2.24	NA by 4;2.24	4;2.22	NA by 4;10.18
irregular 3rd person singular	NA by 4;2.24	NA by 4;2.24	≤ 4;0.7	4;3.27

≤ = At or beforeNA = Not Acquired

* Acquisition = 4 uses in a single transcript


Subject-Auxiliary Inversion in Questions (DZ Twins)
% Inverted
100
80
60
40
20
0
4.0
4.2
4.4
4.6
4.8
5.0
5.2
Age (years)
MAL
RYL
* = 1 example

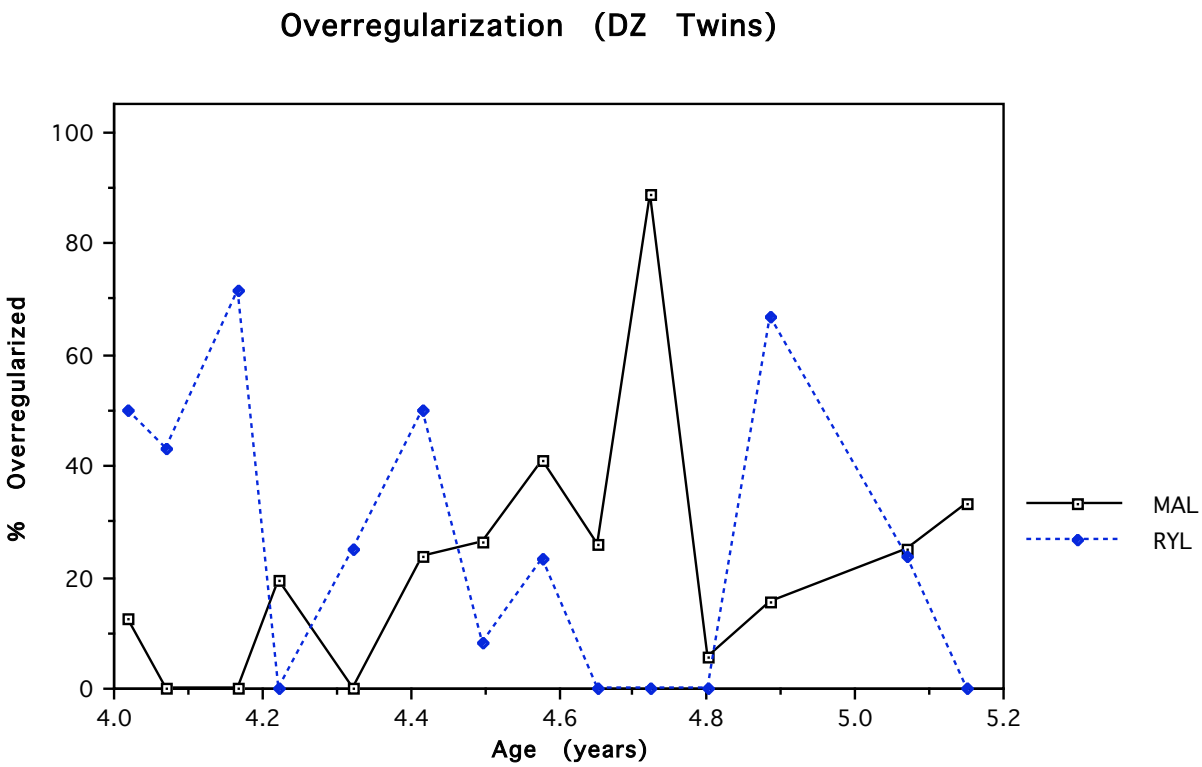

Subject-Auxiliary Inversion in Questions (MZ Twins)
% Inverted
100
80
60
40
20
0
2.5
3.0
3.5
4.0
4.5
Age (years)
JES
JOS
* = 1 example

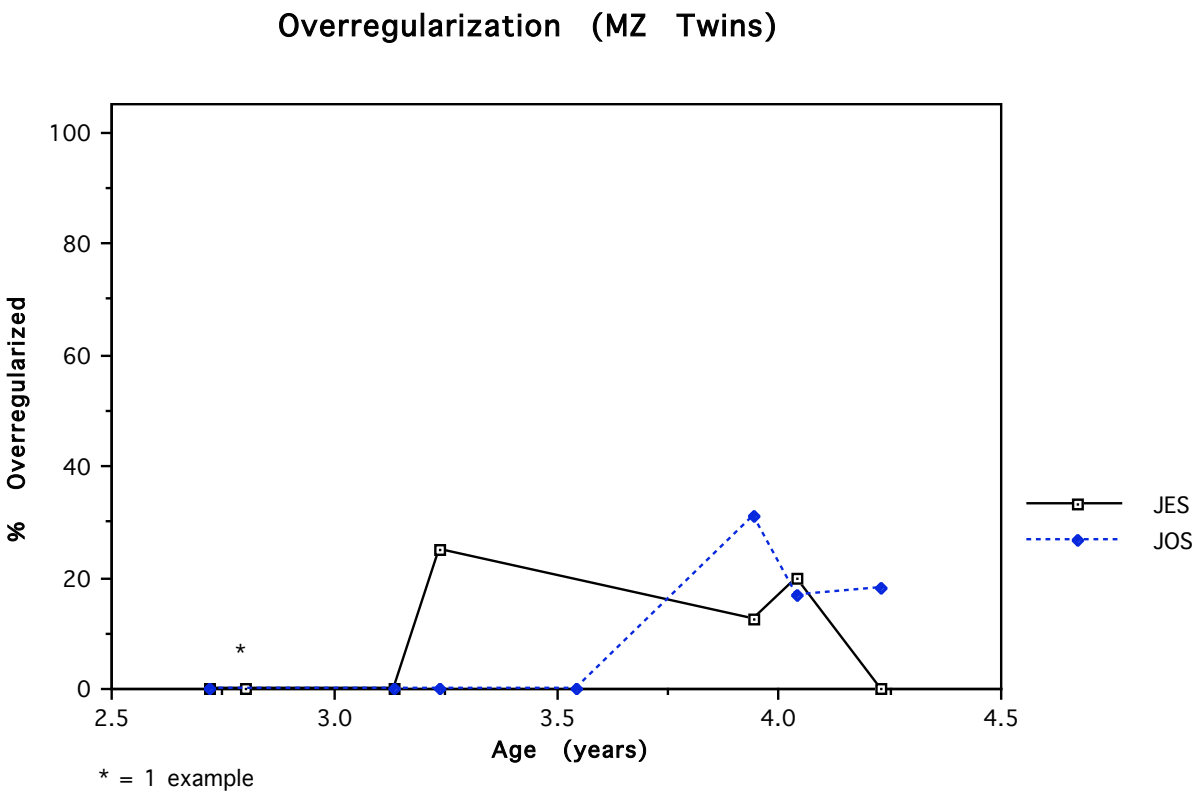
Past Tense & Plural Regularization (DZ Twins)

	MAL		RYL	
Age	Overregularized	Irregular	Overregularized	Irregular
4;0;7	1 houses (hausiz) 1 ?snowmans	5 verbs 2 noun	1 reindeers	0 verbs 1 noun
4;0;26		2 verbs	1 blowed, 2 houses (howsiz, hausiz)	2 verbs 2 noun
4;2;0		12 verbs	1 food-ed, 1 firemans, 1 foots, 2 mouses	2 verbs
4;2;22	1 builded, 1 falled, 1 put-s-ed, 1 sawed, 2 signed-ed, 1 ?put-s-ed	28 verbs 3 nouns		2 verbs
4;3;27		12 verbs 3 nouns	1 holded	2 verbs 1 noun
4;4;30	5 lifes	15 verbs 1 noun	1 falled/falleded, 1 sleeped	0 verbs 2 nouns
4;5;30	2 beated, 1 helpeded, 1 wented, 2 houses (howsiz)	16 verbs 1 noun	1 house (hausiz)	11 verbs
4;6;28	1 breaked, 2 comed, 1 hurted, 1 maked, 1 shooted, 9 lifes, 1 elfs	21 verbs 2 nouns	1 snowmans, 1 firemans, 1 teeths	9 verbs 1 noun
4;7;25	1 buyed, 1 finded, 1 flanged, 1 flinged, 1 shooted, 1 taked, 1 lifes	20 verbs		7 verbs
4;8;21	1 hitted, 1 shooted, 1 fishes	30 verbs 1 noun		1 verb 9 nouns
4;9;18	1 cutted, 1 taked, 1 knifes	51 verbs 1 noun		4 verbs
4;10;18	1 gived, 1 spitted	10 verbs 1 noun	4 mans	1 verb 1 noun
5;0;26	1 beated	1 verb 2 nouns	1 downed, 1 sayed, 1 mans, 1 policemans	10 verbs 3 nouns
5;1;25	1 comed, 1 drowneding, 1 shooted	5 verbs 1 noun		9 verbs
Totals	32 verbs 21 nouns	228 verbs 18 nouns	7 verbs 17 nouns	60 verbs 20 nouns

Past Tense & Plural Regularization (MZ Twins)

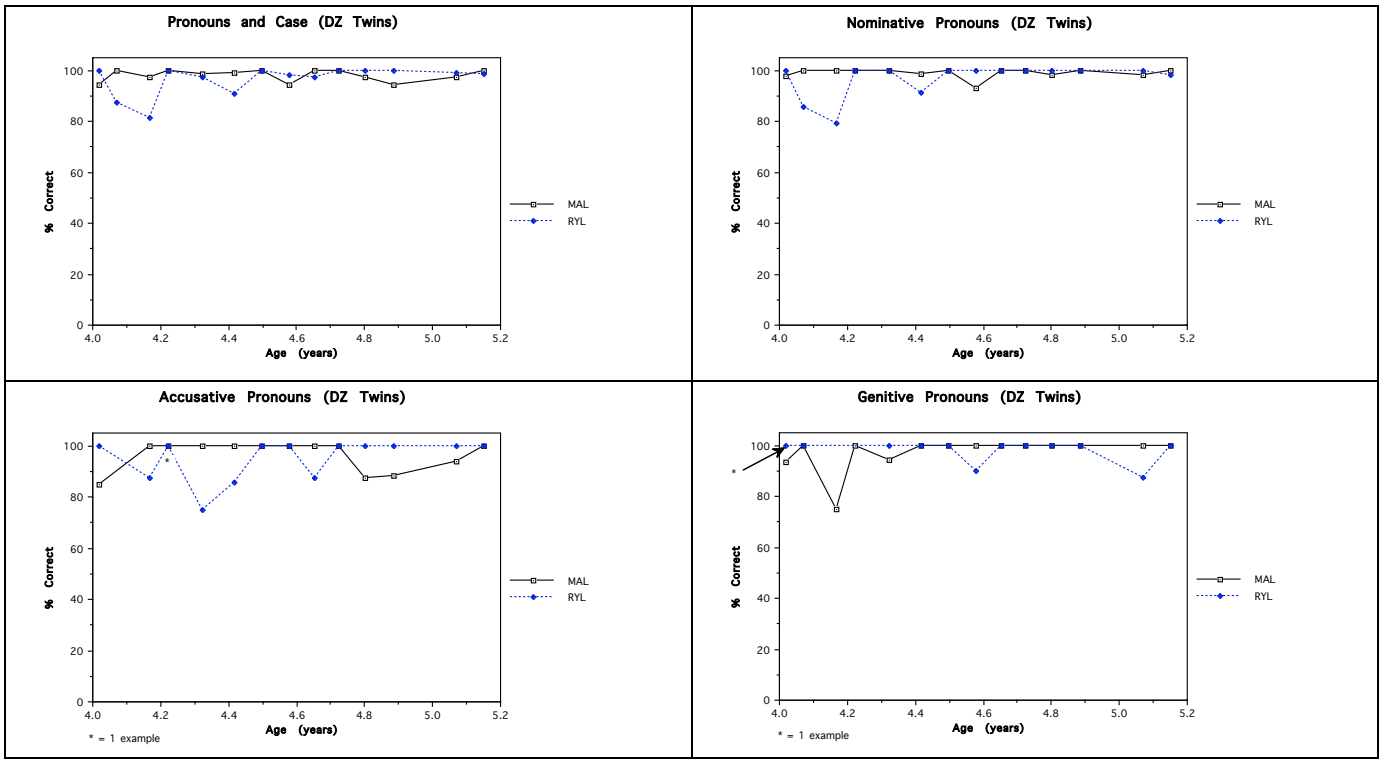
	JES		JOS	
Age	Overregularized	Irregular	Overregularized	Irregular
2;8;20		1 noun		4 nouns
2;9;18		1 noun		
2;10;13				
3;0;1				
3;1;20		10 nouns		1 verb
3;2;27	2 persons	6 nouns		5 verbs 6 nouns
3;6;16				1 verb 4 nouns
3;11;9	1 mans	5 verbs 2 nouns	2 mens 2 policemans	7 verbs 2 nouns
4;0;16	1 knifes	2 verbs 2 nouns	1 mans	5 verbs
4;2;24		9 verbs 3 nouns	1 broked 1 falleded	6 verbs 3 nouns
Total	0 verbs 4 nouns	16 verbs 19 nouns	2 verbs 5 nouns	25 verbs 15 nouns

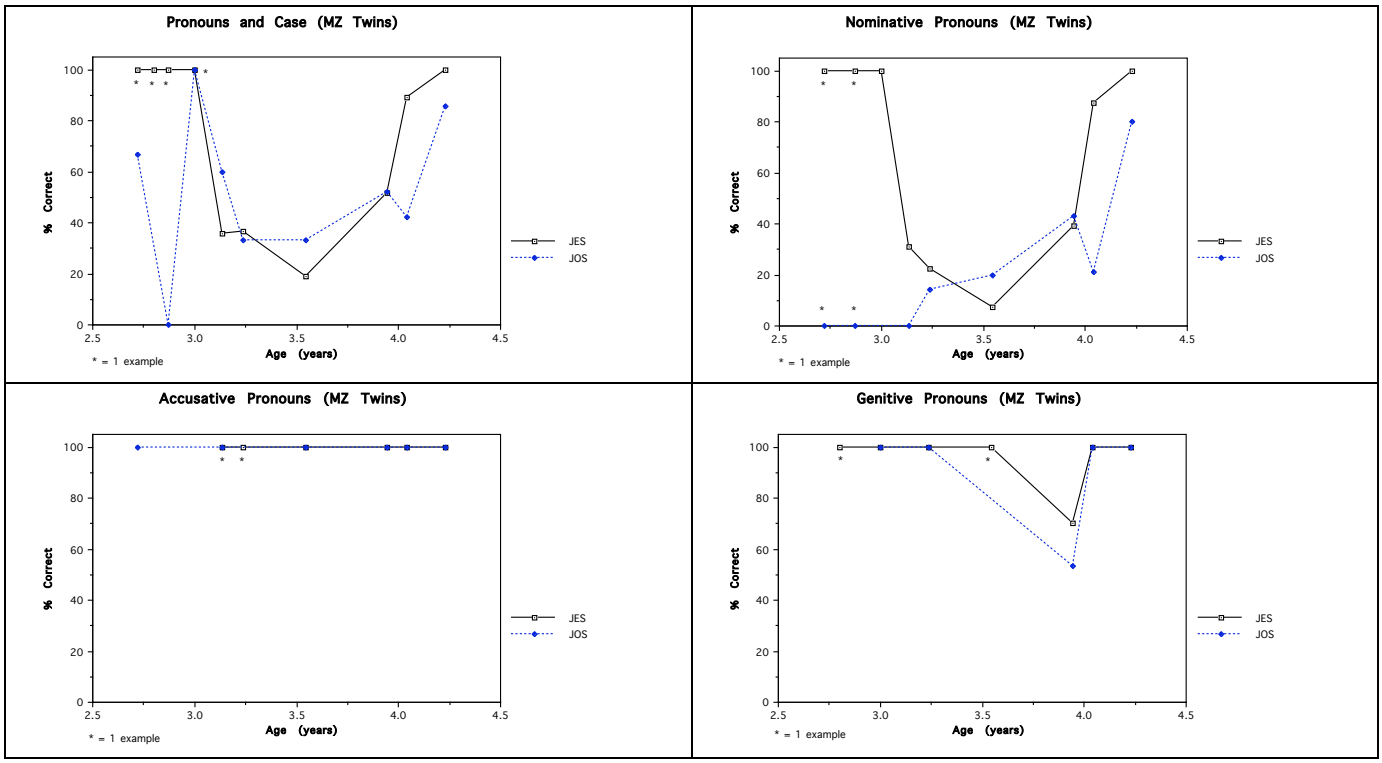

Overregularization (DZ Twins)
% Overregularized
100
80
60
40
20
0
4.0
4.2
4.4
4.6
4.8
5.0
5.2
Age (years)
MAL
RYL

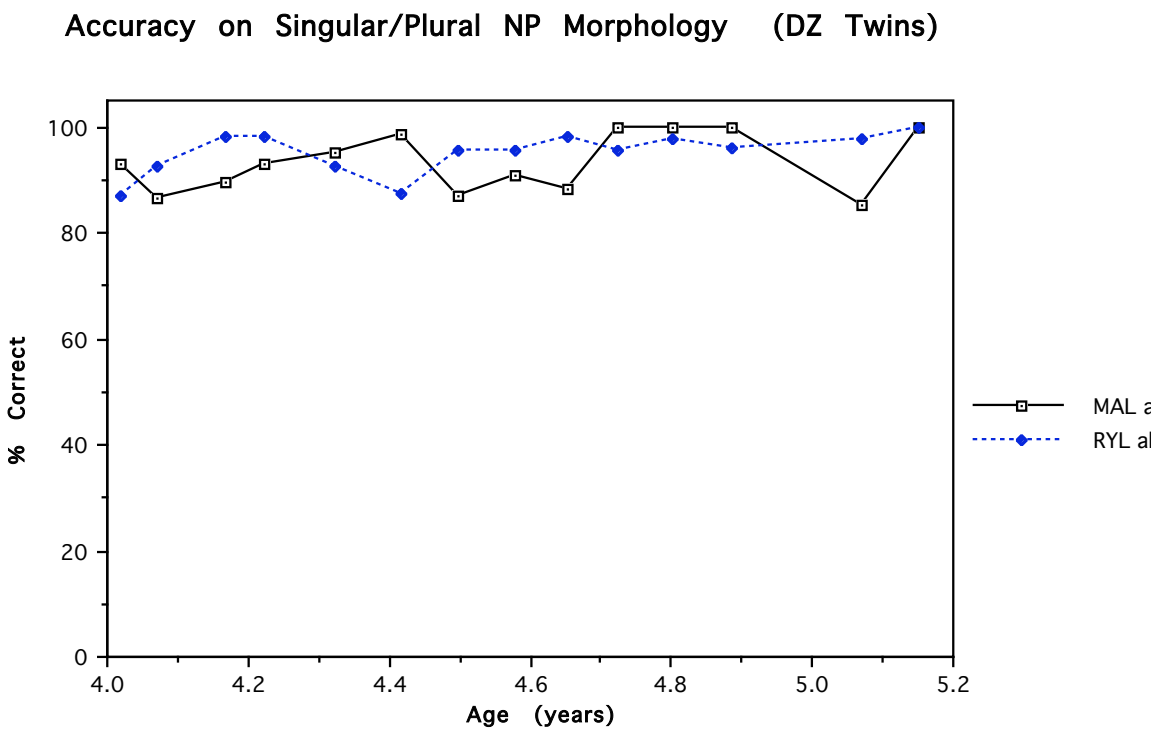

Overregularization (MZ Twins)
% Overregularized
100
80
60
40
20
0
2.5
3.0
3.5
4.0
4.5
Age (years)
*
JES
JOS

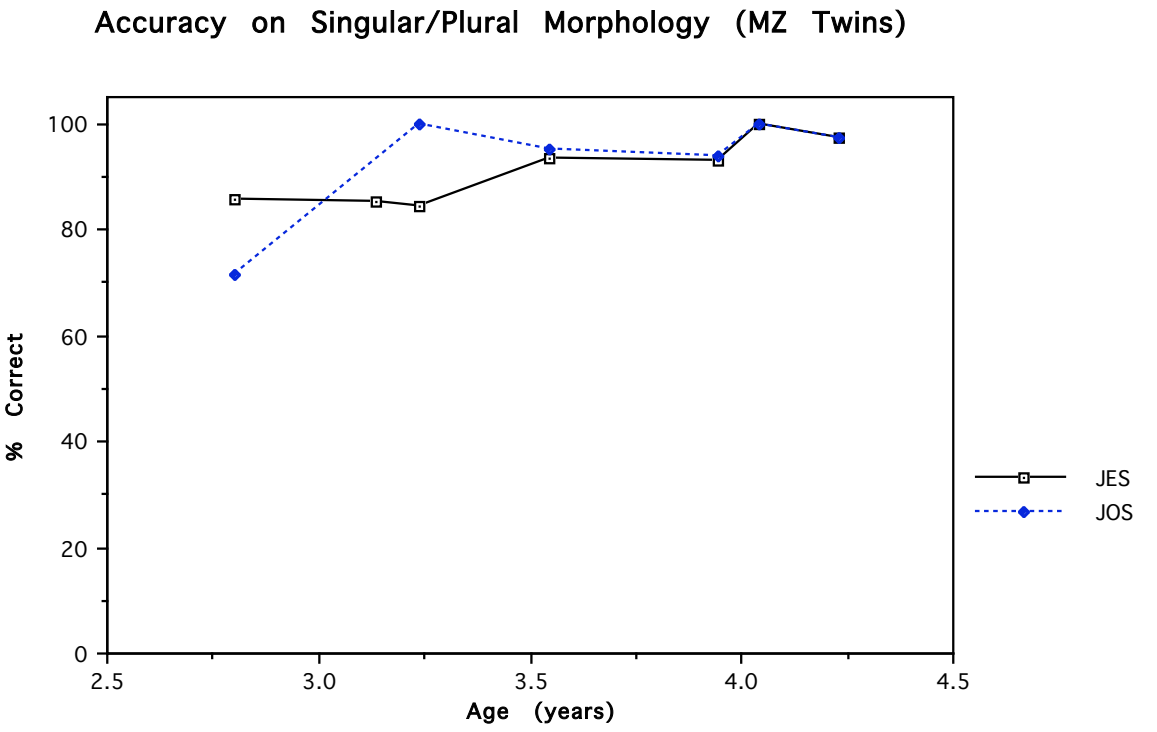
* = 1 example

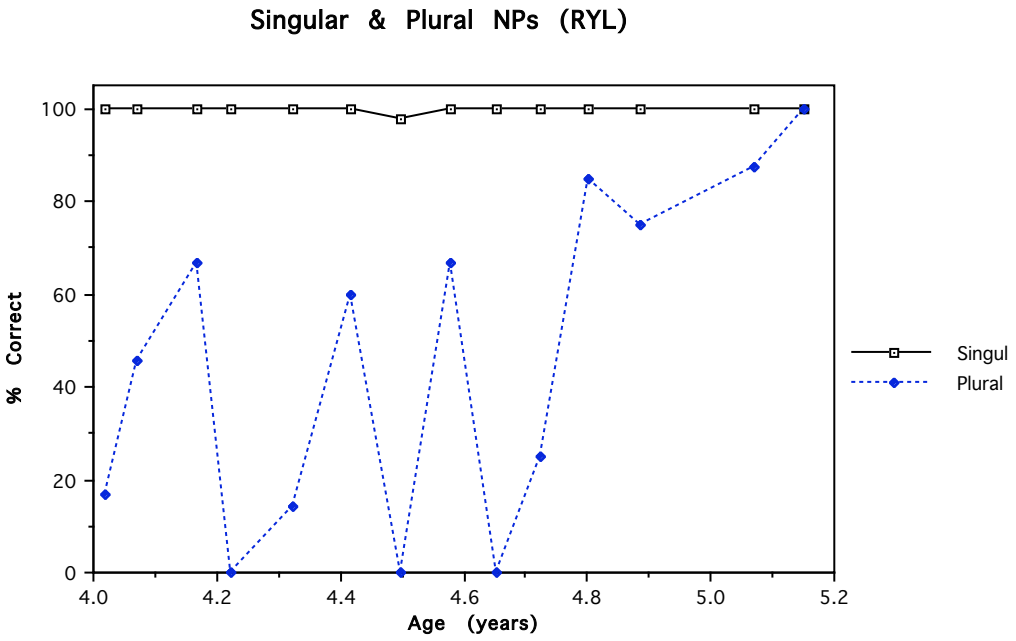
Pronominal Case

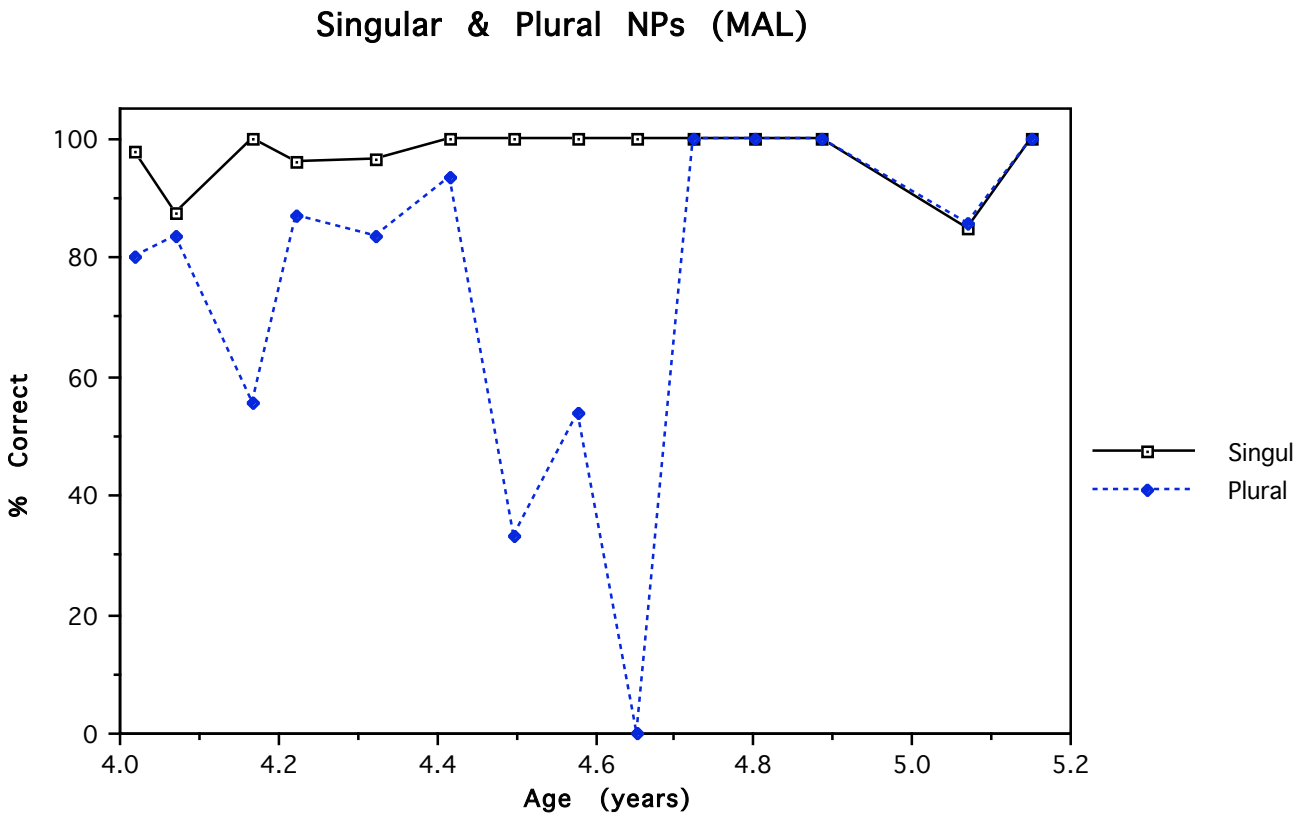




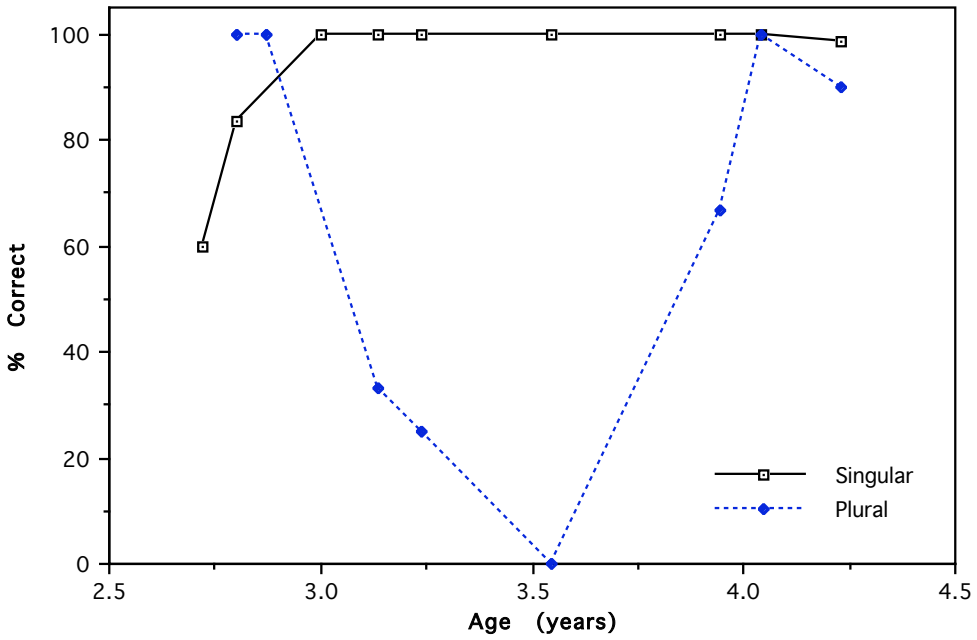

Accuracy on Singular/Plural NP Morphology (DZ Twins)
% Correct
100
80
60
40
20
0
4.0
4.2
4.4
4.6
4.8
5.0
5.2
Age (years)
MAL a
RYL al


Accuracy on Singular/Plural Morphology (MZ Twins)
% Correct
100
80
60
40
20
0
2.5
3.0
3.5
4.0
4.5
Age (years)
JES
JOS

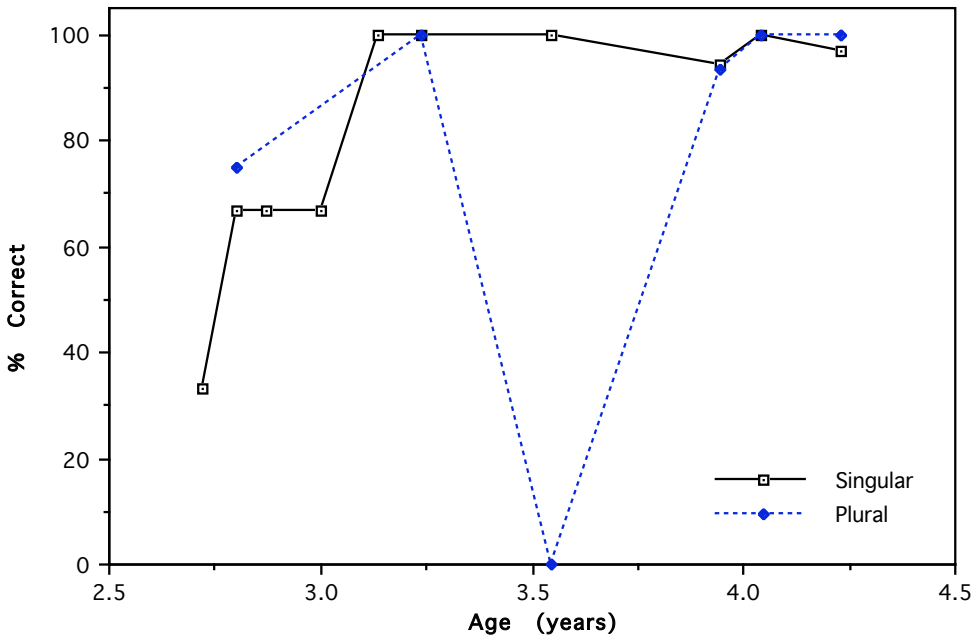

Singular & Plural NPs (RYL)
% Correct
100
80
60
40
20
0
4.0
4.2
4.4
4.6
4.8
5.0
5.2
Age (years)
Singul
Plural


Singular & Plural NPs (MAL)
% Correct
100
80
60
40
20
0
4.0
4.2
4.4
4.6
4.8
5.0
5.2
Age (years)
Singul
Plural

Singular & Plural NPs (MZ Twin: JES)



Singular & Plural NPs (MZ Twin: JOS)



Phonetic Inventory Concordance

Age	Position	MZ*	DZ*
4;0	Syllable initial	66.6% (16/24)	75.0% (15/20)
	Syllable final	47.1% (8/17)	73.3% (11/15)
	Word initial	84.2% (16/19)	64.7% (11/17)
	Word medial	52.6% (10/19)	50.0% (8/16)
	Word final	50.0% (8/16)	68.8% (11/16)
4;1	Syllable initial	76.2 % (16/21)	61.1% (11/18)
	Syllable final	60.0% (9/15)	68.8% (11/16)
	Word initial	77.7% (14/18)	64.3% (9/14)
	Word medial	62.5% (10/16)	30.8% (4/13)
	Word final	60.0% (9/15)	58.8% (10/17)
4;3	Syllable initial	72.7% (16/220	69.6% (16/230
	Syllable final	77.8% (14/18)	73.3% (11/15)
	Word initial	70.6% (12/17)	77.7% (14/18)
	Word medial	58.8% (10/17)	36.8% (7/19)
	Word final	82.4% (14/17)	73.3% (11/15)

* = $\frac{\text{\# of Phonemes Used by Both Twins in Twin Pair}}{\text{Total \# of Phonemes Used by Twin Pair}}$