Quantifying Kids: Old Puzzles, New Findings

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Research questions

- What grammatical and pragmatic processes produce and constrain the interpretations of quantified expressions?
- Do children and adults process quantified expressions in the same ways?
- How do SLI children process quantified expressions?

Grammatical Specific Language Impairment (G-SLI)

(Fonteneau & van der Lely 2008; van der Lely 2005; van der Lely & Battel 2003)

- SLI is a heterogeneous disorder with variable linguistic characteristics.
- G-SLI have a primary grammar-specific language impairment in syntax, inflectional morphology and phonology, but intact non-linguistic cognitive abilities.
- Children with G-SLI exhibit inconsistent comprehension and use of various grammatical processes:
  - tense marking
  - pronominal reference
  - WH-questions
  - passivization

Computational Grammatical Complexity Model (CGC) (van der Lely & Marshall, in press)

Core Claim

G-SLI lack the computations to consistently form hierarchical, structurally complex forms or dependencies in one or more components of grammar that normally develop between 3 and 6;6 years of age.

Wh-Questions

Wh-feature movement

$[_{CP}\ \text{Who}_i\ [_{C'}\ \text{did}_j\ [_{IP}\ \text{Ralf}\ \ e_j\ \ \text{see}\ \ e_i\ ]]]$

WH-movement

CGC and Quantifying NPs

Quantifier Raising

$[_{IP}$ Every pirate$_1$ $[_{VP}$ 2 swords$_2$ $[_{VP}$ e$_1$ is waving e$_2$]

Quantifier Raising

\`For every x, x a pirate, x is waving 2 swords'

CGC Predictions

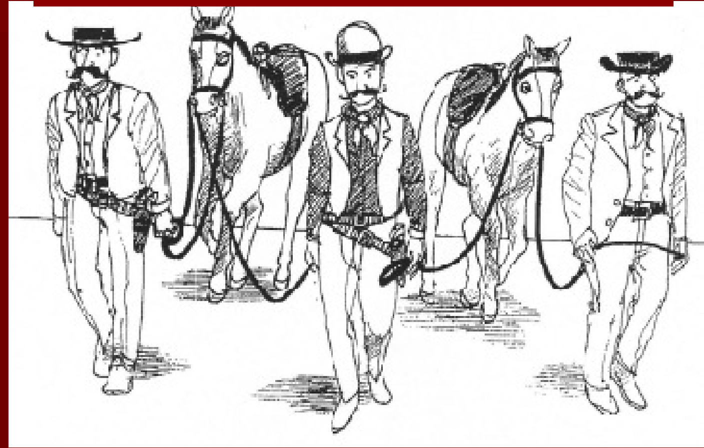
Distributive Context (DIST)

Every/2 : Every pirate is waving 2 swords

3/2 : 3 pirates are waving 2 swords

Prediction 1:
Children with G-SLI should not consistently accept *Every/2* and *3/2* sentences in DIST contexts.

Cumulative Context (CUM)

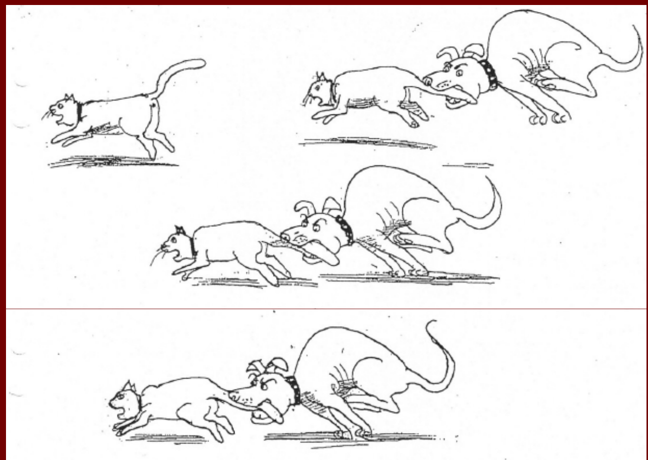


3/2 : 3 cowboys are pulling 2 horses

Prediction 2:
Children with G-SLI should consistently accept *3/2* sentences in CUM contexts.

Domain Selection Errors

(Geurts 2003; Drozd 2001; Brooks & Braine 1996; Philip 1995)



Every dog is biting a cat.

Adults: Yes

Exhaustive Pairing: No, not this one.

Adult discourse-semantic representation
(Kamp & Reyle 1990)

x dog(x)	< every>	y cat(y) x is biting y

Exhaustive Pairing
(Geurts' (2003) Type A response)

y cat(y)	< every>	x dog(x) x is biting y

Weak and relational quantification (Geurts 2003)

Weak Quantification

Fred photographed 2 llamas

`there are two individuals x such that x is a llama and Fred photographed x.'

< two>

x
llama(x)
Fred photographed x

Relational (Strong) Quantification

Fred photographed all llamas.

`For all individuals x, x is a llama, Fred photographed x.'

X
llama(x)

< all>

Fred photographed x

Weak Quantification Hypothesis (Geurts 2003)

Step 1. Weak processing strategy

< every>

x y
dog(x)
cat(y)
x is biting y

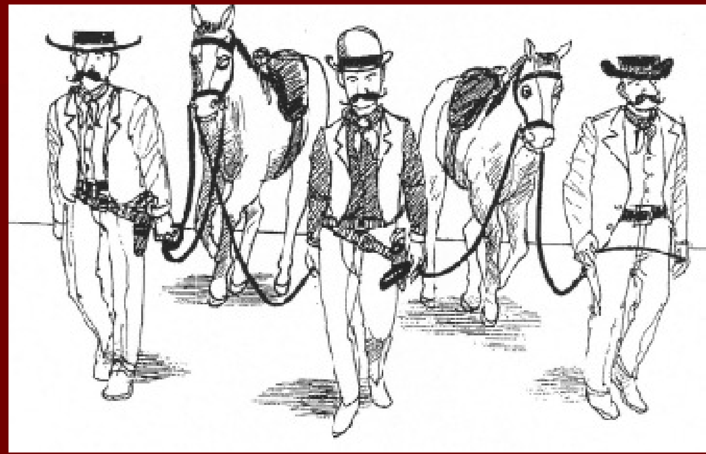
Step 2. Children know that *every* is relational.

. . .	< every>	x y dog(x) cat(y) x is biting y

Step 3. Exhaustive Pairing

y cat(y)	< every>	x dog(x) x is biting y

WQH Predictions



Every pirate is waving 2 swords

3 pirates are waving 2 swords

3 cowboys are pulling 2 horses

WQH Prediction 1:
Children should consistently match *Every/2* sentences with DIST contexts.

WQH Prediction 2:
Children should inconsistently match *3/2* sentences with DIST contexts.

WQH Prediction 3:
Children should consistently match *3/2* sentences with CUM contexts.

Experiment

Subjects

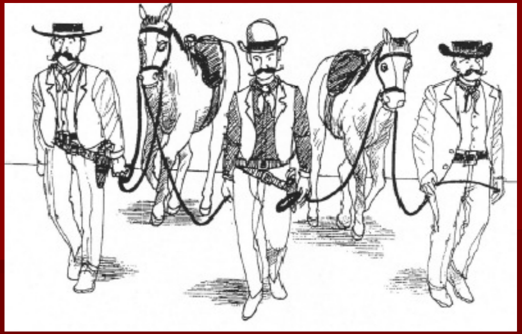
36 Typically developing language matched children (TD)

- 12 TD1 (4;6-6;1; Mean 5;7, matched on ITPA)
- 12 TD2 (6;1-7;3; Mean 6;7, matched on TROG)
- 12 TD3 (7;7-9;7; Mean 7;9, matched on BPVS)

14 Children with G-SLI (Mean Age: 13;3)

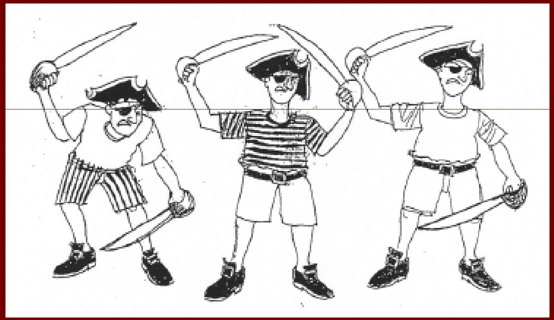
12 Adults

CUM Context



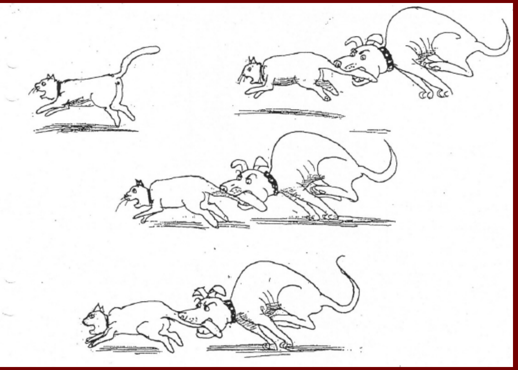
3/2	3 cowboys are pulling 2 horses.
Every/2	Every cowboy is pulling 2 horses.
3/Every	3 cowboys are pulling every horse.

DIST Context



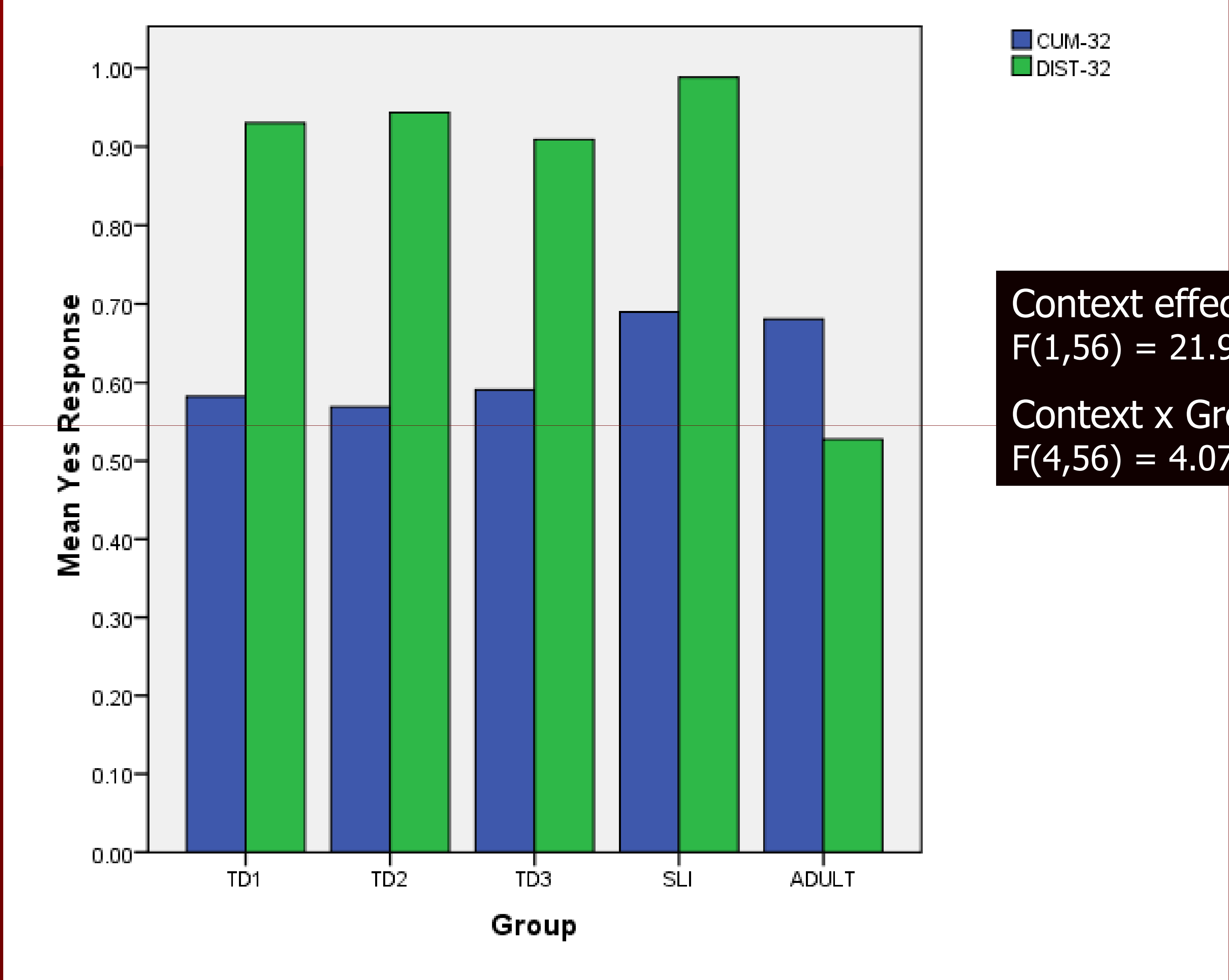
3/2	3 pirates are waving 2 swords.
Every/2	Every pirate is waving 2 swords.
3/Every	3 pirates are waving every sword.

Exhaustive Pairing Context



Every/a	Every dog is biting a cat.

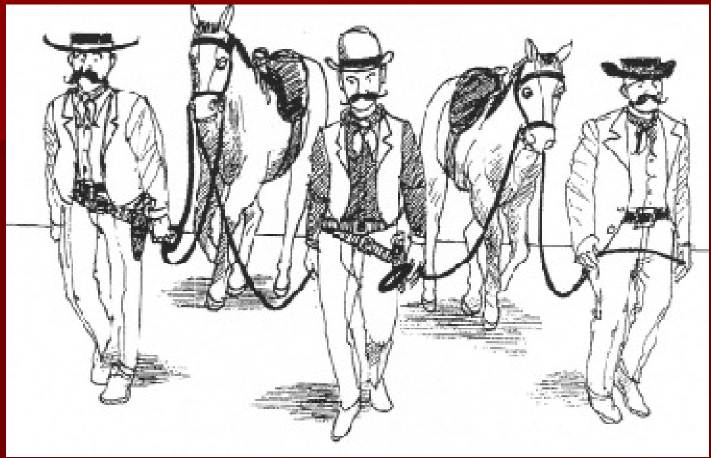
3/2 Sentences: CUM and DIST Contexts



Context effect
F(1,56) = 21.99, $p < .01$

Context x Group effect
F(4,56) = 4.07, $p < .05$

3/2 Sentences: Adult rejections



3 cowboys are pulling 2 horses.

Reference to subsets (91%)

No, 2 cowboys are (only) pulling 1,
No, (only) 1 is pulling 2.

3 pirates are waving 2 swords.

Cumulative Reference (35%)

No, 3 pirates are waving 6 swords.

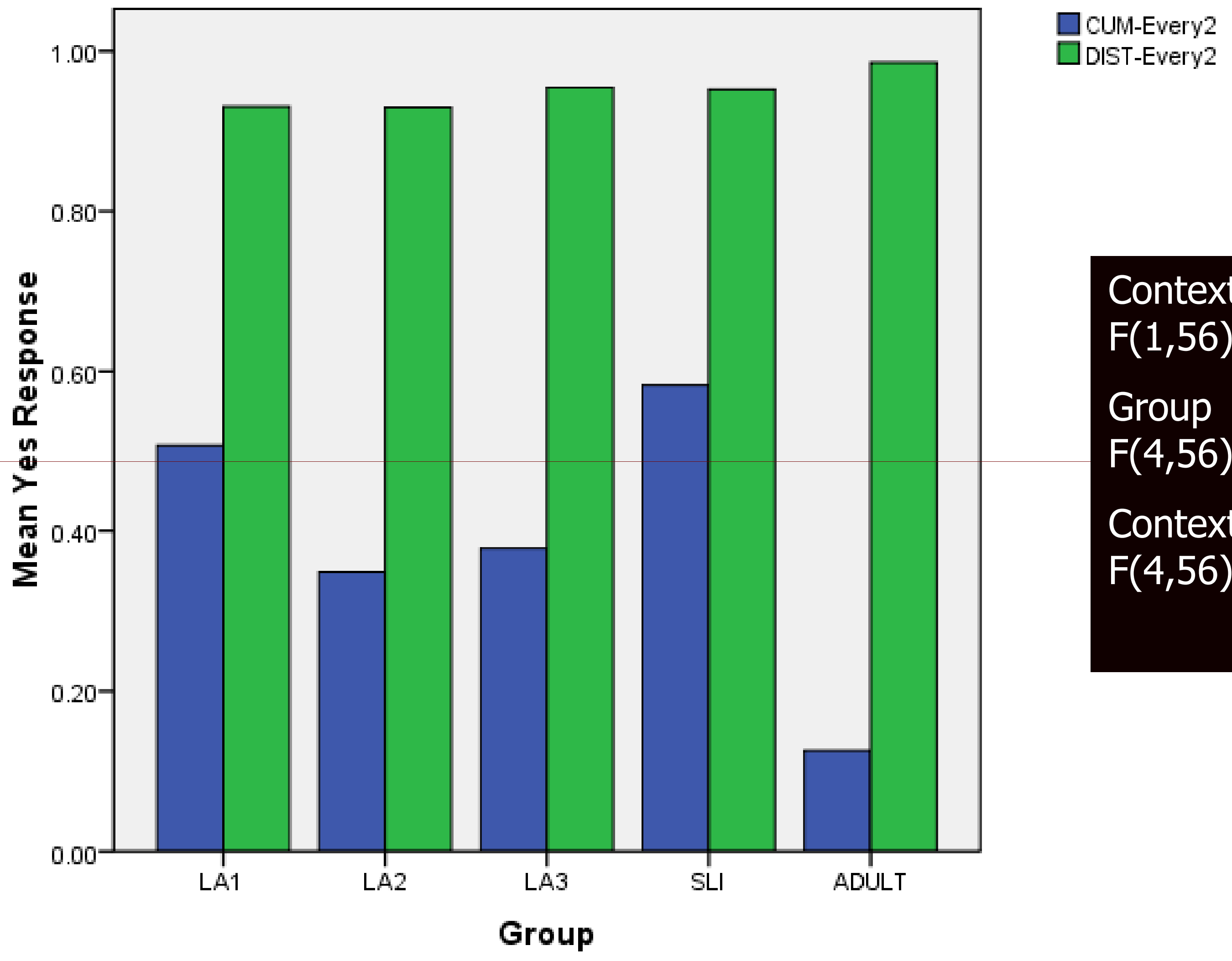
Add Quantifier (62%)

No, <u>every</u> pirate is waving 2 swords. No, 3 pirates are <u>each</u> waving 2 swords.

3/2 Sentences:
Overall Rejections in CUM Contexts

	Response Category		
Group	Reference to Subsets	Cumulative Reference	Other
TD1	.78	.03	.19
TD2	.93	.03	.04
TD3	.93	.03	.04
SLI	.77	.03	.20
Adult	.91	.04	.05

Every/2 Sentences: CUM and DIST Contexts

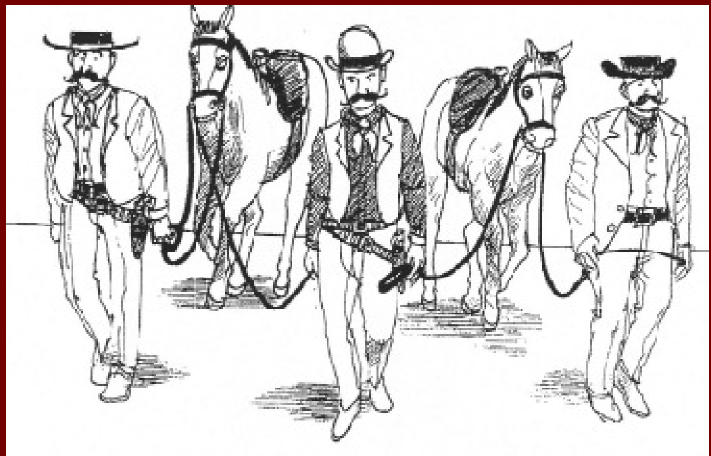


Context
F(1,56) = 172.73, $p < .01$

Group
F(4,56) = 2.87, $p < .05$

Context x Group
F(4,56) = 2.79, $p < .05$

Every/2 Sentences: Adult rejections in CUM contexts



Every cowboy is pulling 2 horses.

Reference to subsets (92%)

No, 2 cowboys are (only) pulling 1,
No, (only) 1 is pulling 2.

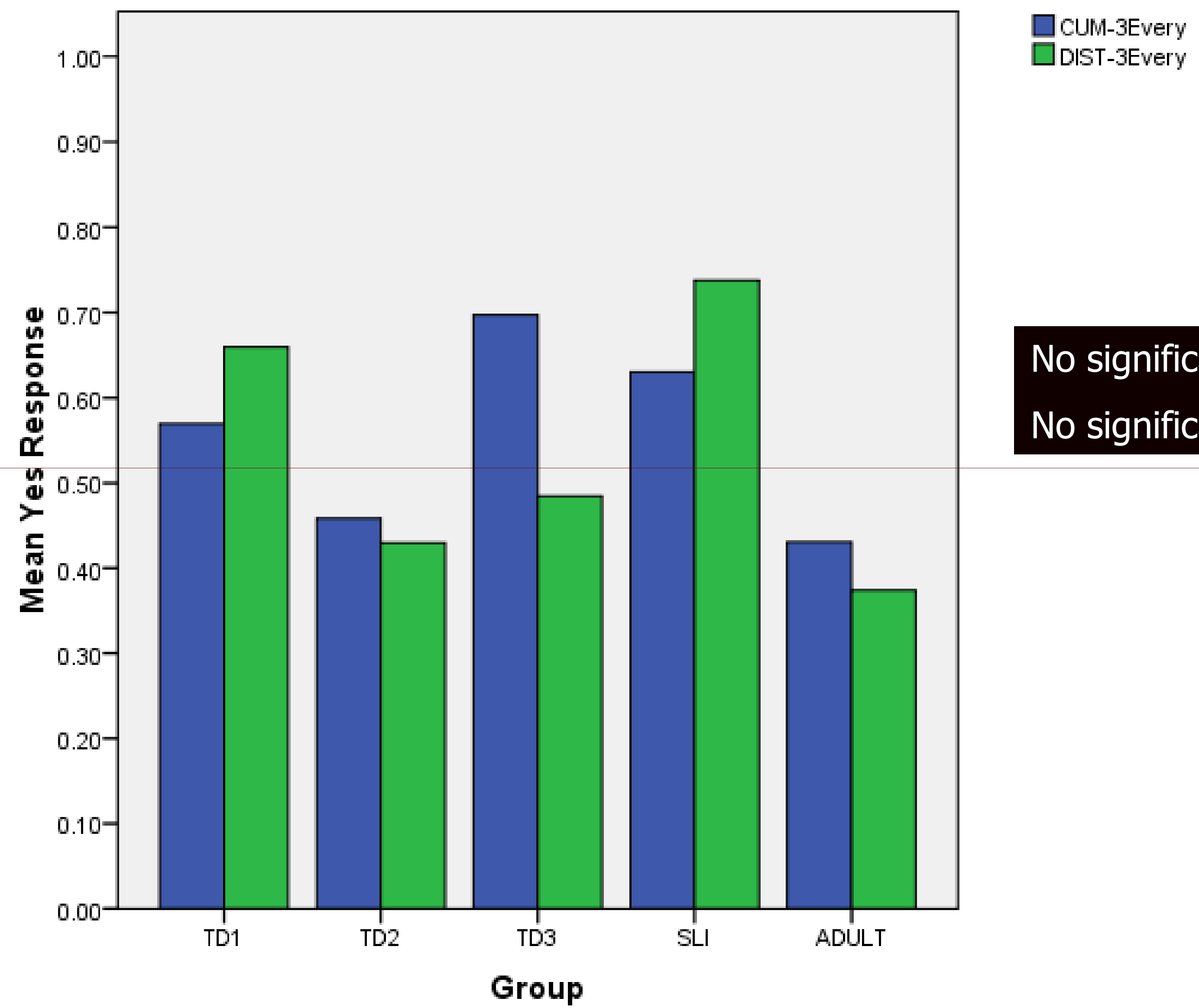
Cumulative reference (4%)

No, 3 cowboys are pulling 2 horses

Every/2 Sentences:
Overall Rejections in Cumulative Contexts

	Response Category			
Group	Reference to Subsets	Cumulative Reference	Add Quantifier	Other
TD1	.85	.02	.00	.13
TD2	1.00	.00	.00	.00
TD3	.83	.00	.00	.17
SLI	.77	.13	.03	.07
Adult	.92	.04	.00	.04

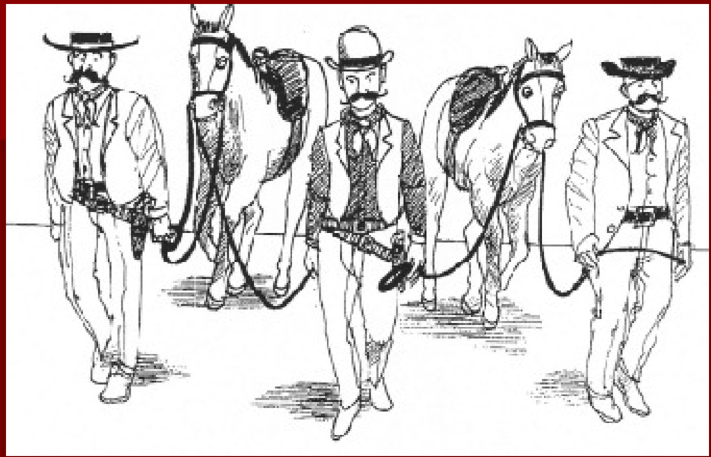
3/Every Sentences: Cumulative and Distributive Contexts



No significant main effects

No significant interactions

3/Every Sentences: Adult denials



3 cowboys are pulling every horse.

Reference to subsets (75%)

No, 2 cowboys are (only) pulling 1.

Replace quantifier (10%)

No, 3 cowboys are pulling 2 horses.

3 pirates are waving every sword.

Shift / replace quantifier (82%)

No, 3 pirates are each waving 2 swords.
No, Every pirate is waving 2 swords.

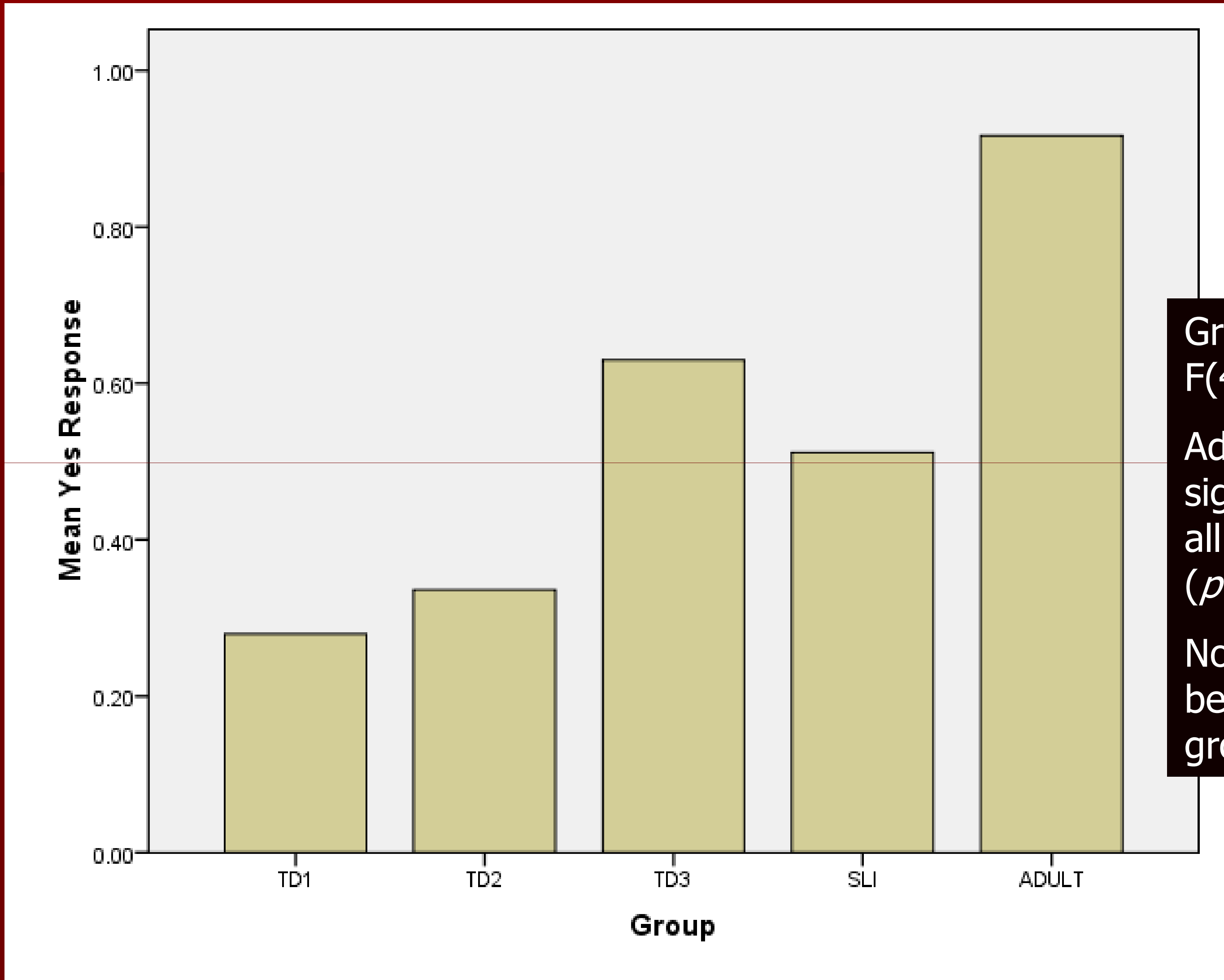
3/Every Sentences:
Overall Rejections in CUM Contexts

Group	Response Category		
	Reference to Subsets	Replace Quantifier	Other
TD1	.78	.04	.18
TD2	.78	.07	.15
TD3	.90	.05	.05
SLI	.66	.13	.21
Adult	.75	.12	.13

3/Every Sentences:
Overall Rejections in DIST Contexts

	Response Category		
Group	Reference to Subsets	Shift / Replace Quantifier	Other
TD1	.15	.47	.38
TD2	.53	.30	.07
TD3	.15	.76	.09
SLI	.00	.62	.38
Adult	.02	.82	.13

Every/a sentences



Group effect
F(4,56) = 5.89, $p < .002$

Adults performed significantly better than all other groups ($p < .05$)

No significant differences between SLI and TD groups ($p > .05$)

Correlational Results

	CUM *Every/2*	CUM *3/2*	*CUM 3/Every*	DIST *3/Every*	*Every/a*
CUM *Every/2*	----				
CUM *3/2*	**.61	----			
CUM *3/Every*	**.50	**.52	----		
DIST *3/Every*	**.41	**.38	**.59	----	
CUM *Every/a*	-.08	-.01	.08	-.07	----

** = $p < .01$

Summary

TD children, G-SLI children, and adults performed similarly with

- 32 sentences in CUM contexts
- Every/2 sentences in DIST contexts
- 3/Every sentences in CUM and DIST contexts

TD and G-SLI children performed unlike adults with

- Every/2 sentences in CUM contexts
- 3/2 sentences in DIST contexts
- Exhaustive Pairing contexts

Predictions: Computational Grammatical Complexity Hypothesis

G-SLI children assign structurally complex semantic representations inconsistently to quantified sentences. ?

G-SLI children consistently assign structurally simpler semantic representations to quantified sentences. ☒

Predictions: Weak Quantification Hypothesis

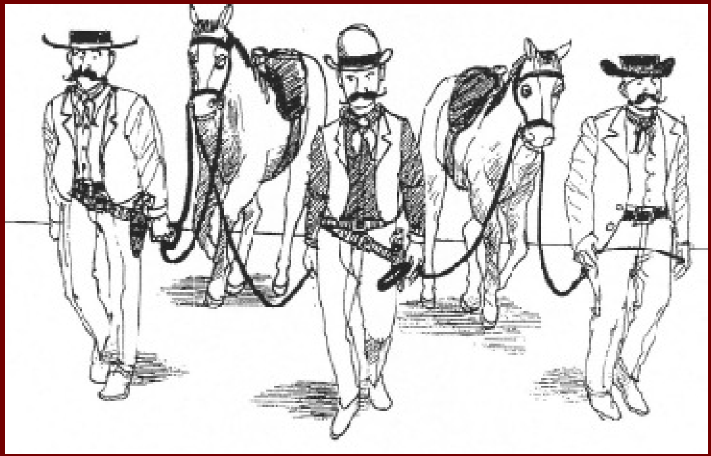
Children implement weak processing strategies. ☑

Children find weak quantification easier than relational quantification. ☒

Children always assign universal quantifiers relational interpretations. ☒

Thanks for your attention.

Appendix: Cumulative quantification (Beck & Sauerland 2000, Krifka 1986)



3 cowboys are pulling 2 horses.

[**R](X)(Y) =1 iff

$\forall x \in X, \exists y \in Y\ R(x)(y)$ and

$\forall y \in Y\ \exists x \in X\ R(x)(y)$

Steps 1 & 2. Plural NPs

X Y
cowboy(X)
|X| = 3
horse(Y)
|Y|=2
X are pulling Y

Step 3. ** operator insertion

X Y
cowboy(X)
|X| = 3
horse(Y)
|Y|=2
X are **pulling Y

Extending the Weak Quantification Hypothesis

Weak processing strategy

< every>

x y
dog(x)
cat(y)
x is biting y

Exhaustive Pairing

y
cat(y)

< every>

x
dog(x)
x is biting y

Weak processing strategy

< every>

x
cowboy(x)
x is pulling 2 horses

Every/2 CUM error

< every>

x Y
x ∈ X
cowboy(X)
horse(Y)
|Y| = 2
X is **pulling Y

Cumulative quantification (using Kamp & Reyle 1990)

x *N*

Fred(x)

$N = \sum$x:

y

senator(y)
x knows y

many(*N*)

Fred knows many senators

X *N*

$N = \sum$x:

x Y

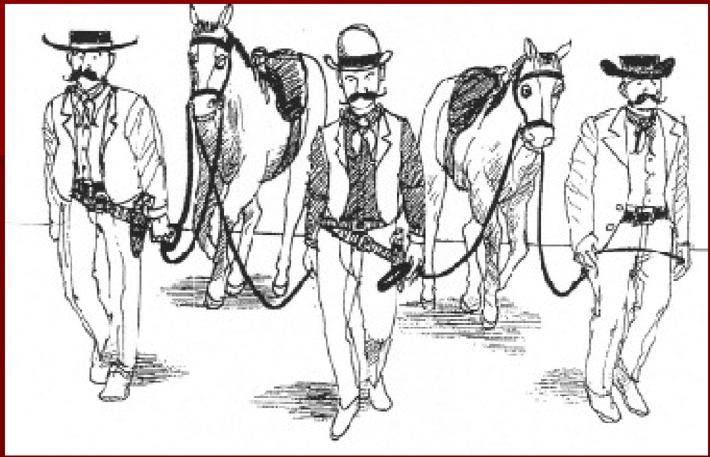
cowboy(x)
horse(Y)
x $\in$ X
|Y| = 2
x is **pulling Y

every(*N*)

Every cowboy is pulling 2 horses.

Every/2 CUM error

Cumulative quantification
(Beck & Sauerland 2000, Krifka 1986)



3 cowboys are pulling 2 horses.

$[**R](X)(Y) = 1$ if and only if $\forall x \in X\ \exists y \in Y\ R(x)(y)$ and $\forall y \in Y\ \exists x \in X\ R(x)(y)$

Applies to a binary predicate to make the relation true if every X and every Y appears in some pair in the predicate's relation

Step 1. Plural NPs

X
cowboy(X)
|X| = 3
X are pulling 2 horses

Step 2. Plural NPs

X Y
cowboy(X)
|X| = 3
horse(Y)
|Y|=2
X are pulling Y

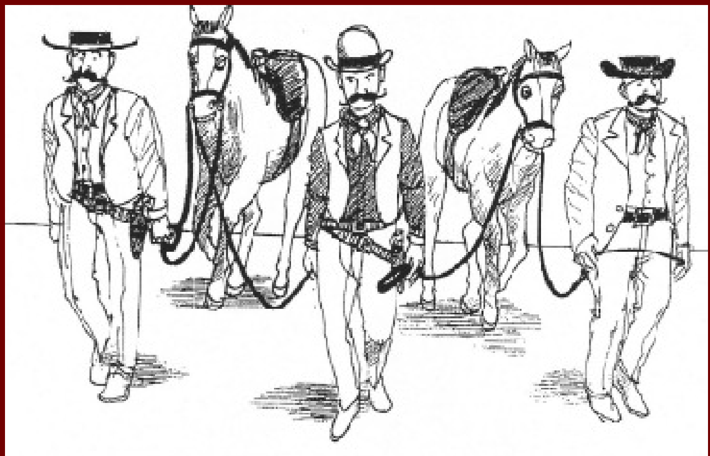
Step 3. ** operator insertion

X Y
cowboy(X)
|X| = 3
horse(Y)
|Y|=2
X are **pulling Y

Cumulative quantification
(Beck & Sauerland 2000, Krifka 1986)

< every>

x Y
cowboy(x)
horse(Y)
x is *pulling y



Every cowboy is pulling 2 horses.

Adult: No

Child: Yes

X *N*

$N = \sum x$:

x

cowboy(x)

every(*N*)
horse(Y)
|Y|=2
X are **pulling Y

Theoretical Points

The RDDR

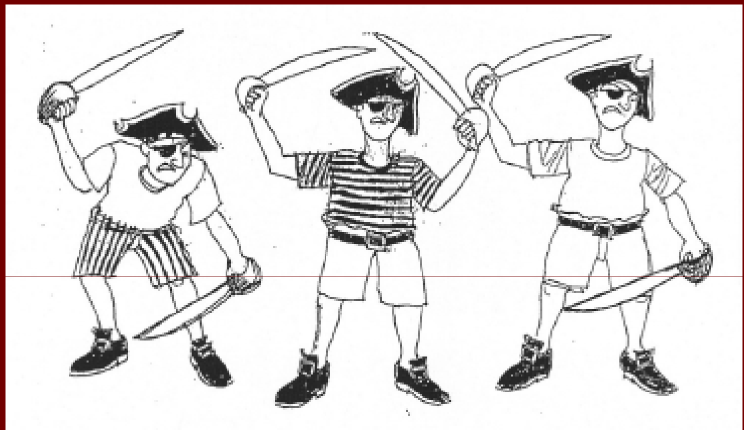
SLI children, like the younger children, assign scopal interpretations to sentences with quantifying and plural NPs. This provides counterevidence to the RDDR.

Weak Quantification

TD and SLI children often accept sentences with quantifying NPs as descriptions of cumulative contexts. However, there is no correlation between the rates of scope errors and exhaustive pairing errors.

This raises the possibility that children do process sentences with quantifying NPs using a weak quantification strategy but do not always follow through with a relational interpretation.

Processing Plural NPs:
Subject Wide Scope Readings (Kamp & Reyle 1993)



3 pirates are waving 2 swords.

Step 1. Plural NPs

X pirate(X) |X| = 3 X are waving 2 swords

Step 2. Optional distribution

X
pirate(X)
|X| = 3

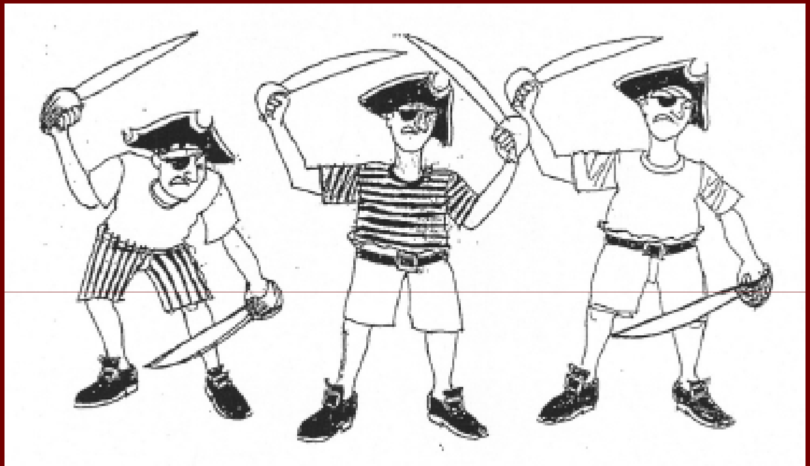
x $x \in X$	< every x>	x is waving 2 swords

Step 3. Plural NPs

X
pirate(X)
|X| = 3

x $x \in X$	< every x>	Y sword(Y), |Y| = 2 x is waving Y

Processing Quantifying Subject NPs (Kamp & Reyle 1993)



Every pirate are waving 2 swords.

Step 1. Quantified NPs

x pirate(x)	< every x>	x is waving 2 swords

Step 2. Plural NPs

x pirate(x)	< every x>	Y sword(Y), $\|Y\| = 2$, x is waving Y

Processing quantifying object NPs

3 girls are carrying every box.
(3 > every)

Step 1. Plural NPs

X
girl*(X)
|X| = 3
X are carrying every box

Step 2. Quantified NPs

X
girl(X)
|X| = 3
y
box(y)
< every y>
X are
carrying y

3 girls are carrying every box.
(every > 3)

Step 1. Quantified NPs

y
box(y)
< every y>
3 girls are
carrying y

Step 2. Plural NPs

y
box(y)
< every y>
X
girl(X)
|X| = 3
X are carrying y

- Evidence indicates that this subgroup has a primary grammar-specific language impairment that encompasses syntax, inflectional morphology and phonology, with secondary deficits in other components of language such as vocabulary (Fonteneau & van der Lely, 2008; van der Lely, Rosen, & McClelland, 1998)
- The CGC model claims that the language deficits found in children with G-SLI lie in hierarchical structural knowledge that is core to the computational grammatical system. Our work reveals that many school-aged children with G-SLI lack the computations to consistently form hierarchical, structurally complex forms in one or more components of grammar that normally develop between 3 and 6;6 years of age. The CGC model emphasises the notion that impairments in syntax, morphology and phonology are functionally autonomous, but cumulative in their effects (Marshall & van der Lely, 2007a; van der Lely & Marshall, in press; van der Lely, 2005)

- For children with SLI, their phonological deficit manifests as a difficulty with forms that are complex at the syllable and foot levels of the prosodic hierarchy (Gallon, Harris, & van der Lely, 2007). In a non-word repetition task, both children with G-SLI and children falling into a broader definition of SLI were found to simplify consonant clusters in all word positions, while unfooted syllables are deleted or cause syllabic simplifications and segmental changes elsewhere in the word (Gallon et al., 2007; Marshall, 2004; Marshall, Ebbels, Harris, & van der Lely, 2002).
- The CGC model predicts that children with a phonological deficit will have difficulty decoding words with complex phonological structure.
- Consistent with this model, children with G-SLI show frequency effects for regular past tense forms, do not show a regularity advantage in producing such forms and produce inflected plural forms inside compounds (e.g. **rats-eater*) (van der Lely & Christian, 2000; van der Lely & Ullman, 2001).

Table 2
Distribution of ages in participant groups

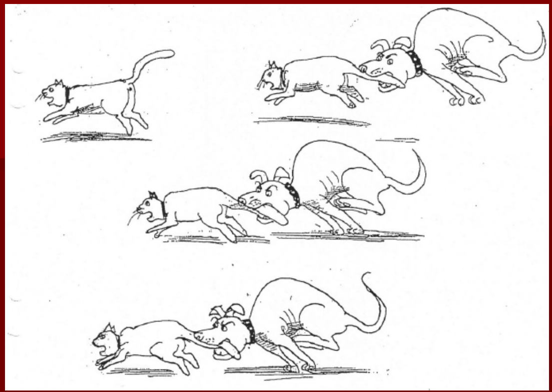
	G-SLI	LA1	LA2	LA3	CA
N	16	12	12	11	12
Age, mean (S.D.)	13.3 (2.0)	6.0 (0.5)	7.0 (0.3)	8.0 (0.5)	14.4 (1.5)

Table 3
Details of G-SLI and language-matched groups' scores on standardised language tests

			G-SLI	LA1	LA2	LA3
ITPA						
	Raw	Mean (S.D.)	**22.35 (3.74)**	**23.58 (5.12)**	26.67 (2.90)	28.27 (3.32)
		Range	**15–28**	**14–29**	21–30	22–32
	%	Mean (S.D.)	n/a[a]	47.83 (8.32)	45.50 (4.58)	42.09 (4.93)
		Range		31–55	38–53	33–47
TROG						
	Raw	Mean (S.D.)	**14.94 (1.95)**	14.08 (1.73)	**15.67 (2.57)**	16.36 (2.20)
		Range	**12–18**	11–17	**12–19**	12–19
	SS	Mean (S.D.)	72.13 (9.84)	104.58 (7.88)	109.00 (18.33)	104.91 (12.80)
		Range	55–98	91–117	90–139	86–133
BPVS						
	Raw	Mean (S.D.)	**82.56 (17.50)**	62.00 (14.45)	71.83 (8.60)	**79.00 (11.49)**
		Range	**59–114**	42–88	56–86	**56–96**
	SS	Mean (S.D.)	76.88 (12.94)	108.42 (16.87)	109.50 (7.80)	105.20 (9.66)
		Range	57–87	93–139	97–121	88–122

Group matches, on the basis of raw scores, are shown in bold. %: percentile; SS: standard score.
[a]Please note that the ITPA is not standardised for this age group.

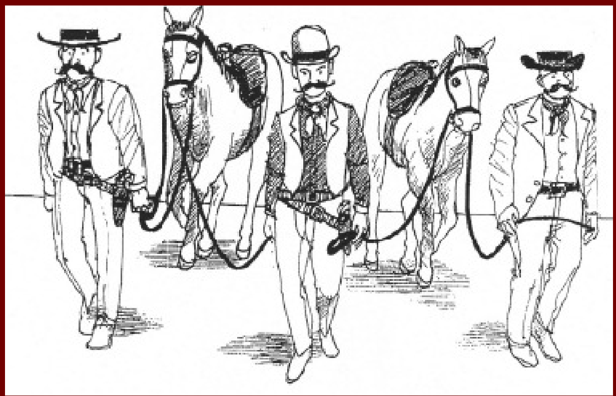
Extending the Weak Quantification Hypothesis



Every dog is biting a cat.
Exhaustive Pairing: No, not this one.

< every>

x y
dog(x)
cat(y)
x is biting y



Every cowboy is pulling 2 horses.
Adult: No.   Child: Yes

< every>

x Y
$x \in X$
cowboy(X)
horse(Y)
$\|Y\| = 2$
X is **pulling Y

Summary

Predictions 1 and 2 of the CGC only partially supported.

G-SLI children represent and process the structural dependencies required for quantifier scope / relational quantification.

- G-SLI participants correctly accept *3/2* and *Every/2* sentences in DIST contexts at adult levels.
- G-SLI participants, like adults, do not accept *3/2* sentences in CUM contexts.