
A Simulation Study on Word Order Bias

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The word order bias

- A simple declarative sentence involving verb (V), subject (S) and object (O) has 6 logically possible word orders (Dryer 2008):
 - **SOV**: e.g., Japanese (Kuno 1973:10): *John ga tegami o yon-da*
John SUBJ letter OBJ read-PAST
S O V
'John read the letter'
 - **SVO**: e.g., English: *John read the letter*
 - **VSO**: e.g. Tagalog;
 - **VOS**: e.g. Malagasy;
 - **OVS**: e.g., Coos;
 - **OSV**: e.g., Mamvu
- **The word order bias**: among these word orders, only three (**SOV**, **SVO** and **VSO**) are the most frequent ones in the world's extant languages (Greenberg 1963).
- This bias, based on 30 languages, is confirmed by recent, larger samples: e.g., Tomlin (1986), based on 1,063 languages, and Dryer (2008), based on 1,228 languages:
 - **SOV**: 45.8%, 40.5%; **SVO**: 41.5%, 35.5%
 - **VSO**: 11.0%, 7.0%; **VOS**: 1.5%, 2.1%
 - **OVS**: 0.3%, 0.7%; **OSV**: 0.0%, 0.3%

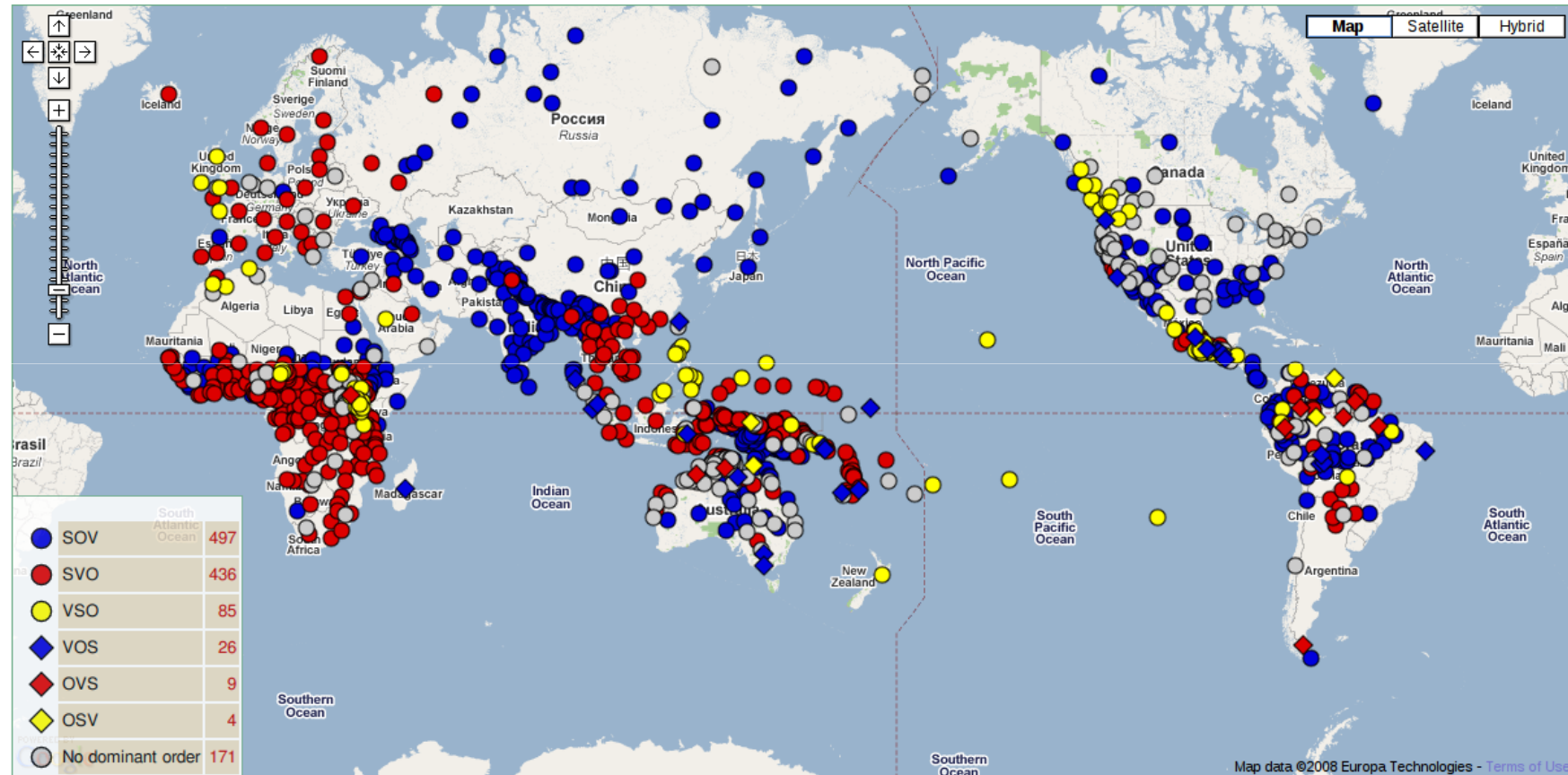
Greenberg, J. H. 1963. Some universals of grammar with particular reference to the order of meaningful elements. In: Greenberg, J. H. (Ed.), *Universals of language*. Cambridge, MA: MIT Press, pp. 73-113.

Dryer, M. S. 2008. Order of subject, object, and verb. In: Haspelmath, M., Dryer, M. S., Gil, D., Comrie, B. (Eds.), *The World Atlas of Language Structures Online*. Munich: Max Planck Digital Library, chapter 81. Available online at <http://wals.info/feature/81>. Accessed on July 14, 2008.

Tomlin, R. S. 1986. *Basic word order: Functional principles*. London: Croom Helm.

Linguistic background: the word order bias

- World Atlas of Language Structures (WALS, <http://wals.info>, Dryer 2008):



Dryer, M. S. 2008. Order of subject, object, and verb. In: Haspelmath, M., Dryer, M. S., Gil, D., Comrie, B. (Eds.), The World Atlas of Language Structures Online. Munich: Max Planck Digital Library, chapter 81. Available online at <http://wals.info/feature/81>. Accessed on July 14, 2008.



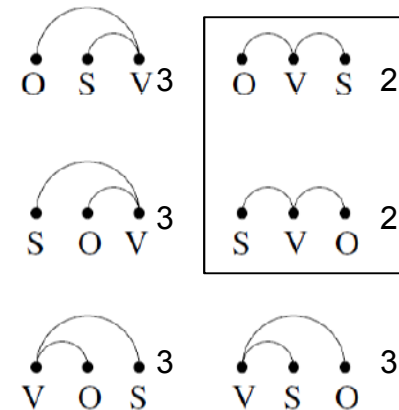
The available explanations on the word order bias

■ Innatism:

- Briscoe (2000): the acquisition of word order is affected by an innate universal grammar;

■ Cognitive constraints:

- Lupyán and Christiansen (2002): non-linguistic-constraint helps acquire word order;
- Ferrer-i-Cancho (2008): Memory versus predictability in syntactic dependency;
 - To maximize predictability: head first (VOS, VSO, V**); head final (**V, OSV, SOV);
 - To minimize memory: head middle (*V*, SVO, OVS);
 - Dependency links between heads (V) and modifications (S/O or others);
 - To minimize the Euclidean distance from head to modification;
 - SVO and OVS are the most biased word orders;



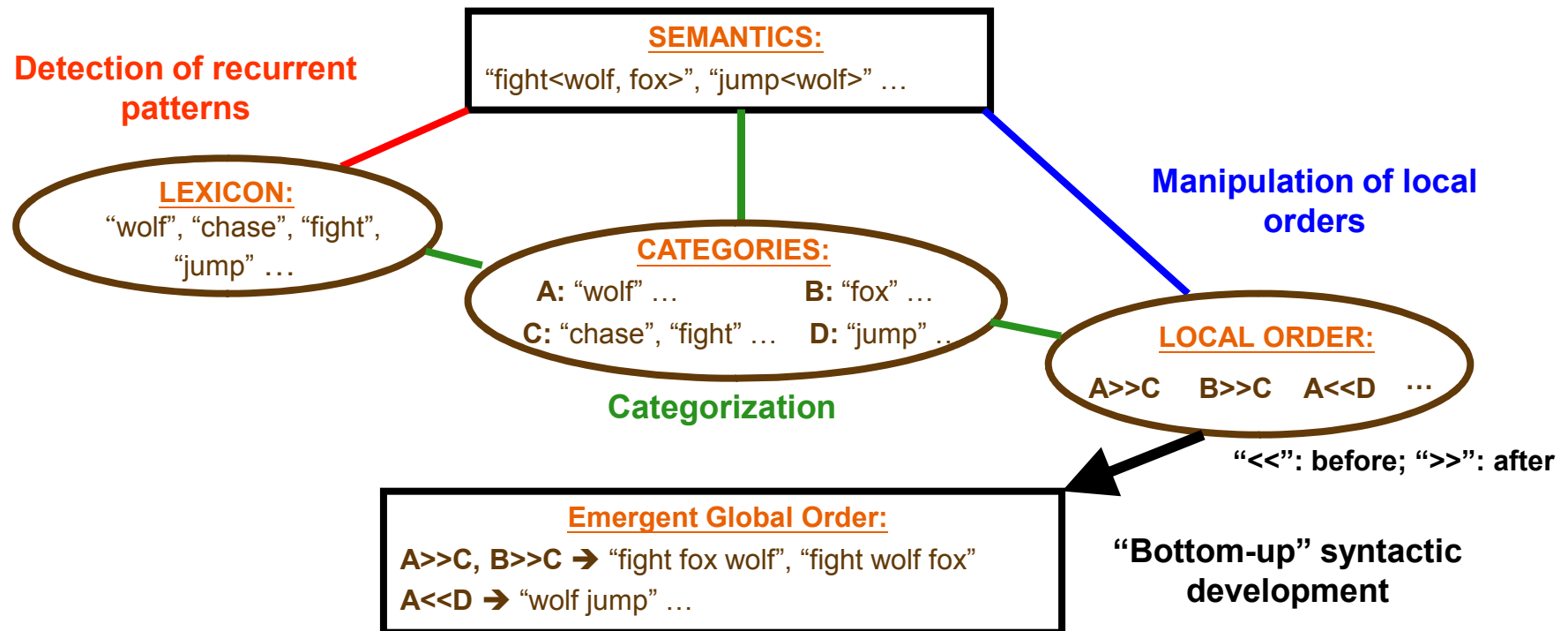
Briscoe, E. J. 2000. Grammatical acquisition: Inductive bias and coevolution of language and the language acquisition device. *Language* 76(2), 245-296.

Lupyán, G., Christiansen, M. H. 2002. Case, word order, and language learnability: Insights from connectionist modeling. In B. Bel & I. Marlien (Eds.), *Proceedings of 24th annual conference of the cognitive science society* (pp. 596-601). Mahwah, NJ: Lawrence Erlbaum.

Ferrer-i-Cancho, R. 2008. Some word order biases from limited brain resources: A mathematical approach. *Advances in Complex Systems* 11(3): 393-414.

The lexicon-syntax coevolution model (see Gong 2009)

- Semantics: two types of integrated meanings for individuals to exchange:
 - **Semantic roles:** Ag, Pr, Pat;
 - “Pr₁<Ag>”: e.g., “hop<deer>” (“a deer is hopping”);
 - “Pr₂<Ag, Pat>”: e.g., “chase<fox, wolf>” (“a fox is chasing a wolf”);





The representation of linguistic knowledge

- Language consists of a set of **M-U mappings**: e.g., “fight<wolf, fox>” \leftrightarrow /a b c/;
- The rule-based system to represent linguistic knowledge:
 - Lexical rules**: to map semantic items to utterance syllables;

Holistic rules:

(a) “chase<wolf, bear>” \leftrightarrow /a b/ (0.5)

(b) “hop<deer>” \leftrightarrow /c/ (0.4)

(c) “hop<deer>” \leftrightarrow /d e/ (0.6)

Compositional rules:

(d) “wolf” \leftrightarrow /f/ (0.6)

(e) “run<#>” \leftrightarrow /c/ (0.7)

(f) “chase<#, bear>” \leftrightarrow /e f * g/ (0.7)

Numbers within () are rule strengths; “#” is unspecified semantic item; “*” is unspecified utterance syllable(s);

- Syntactic rules**: to record local orders to regulate the syllables of two lexical rules.

| Category 1 (S) << Category 2 (V) (0.8)

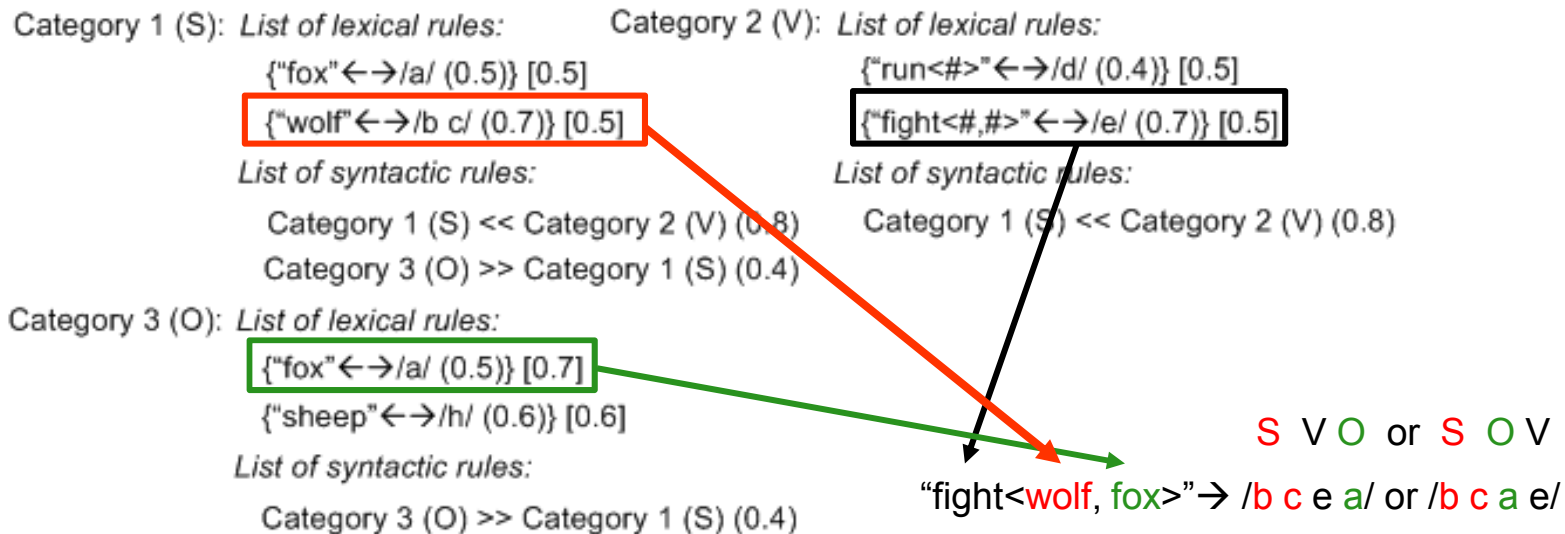
| Category 3 (O) >> Category 2 (V) (0.4)

Local orders: “<<” BEFORE; “>>” AFTER;



The representation of linguistic knowledge

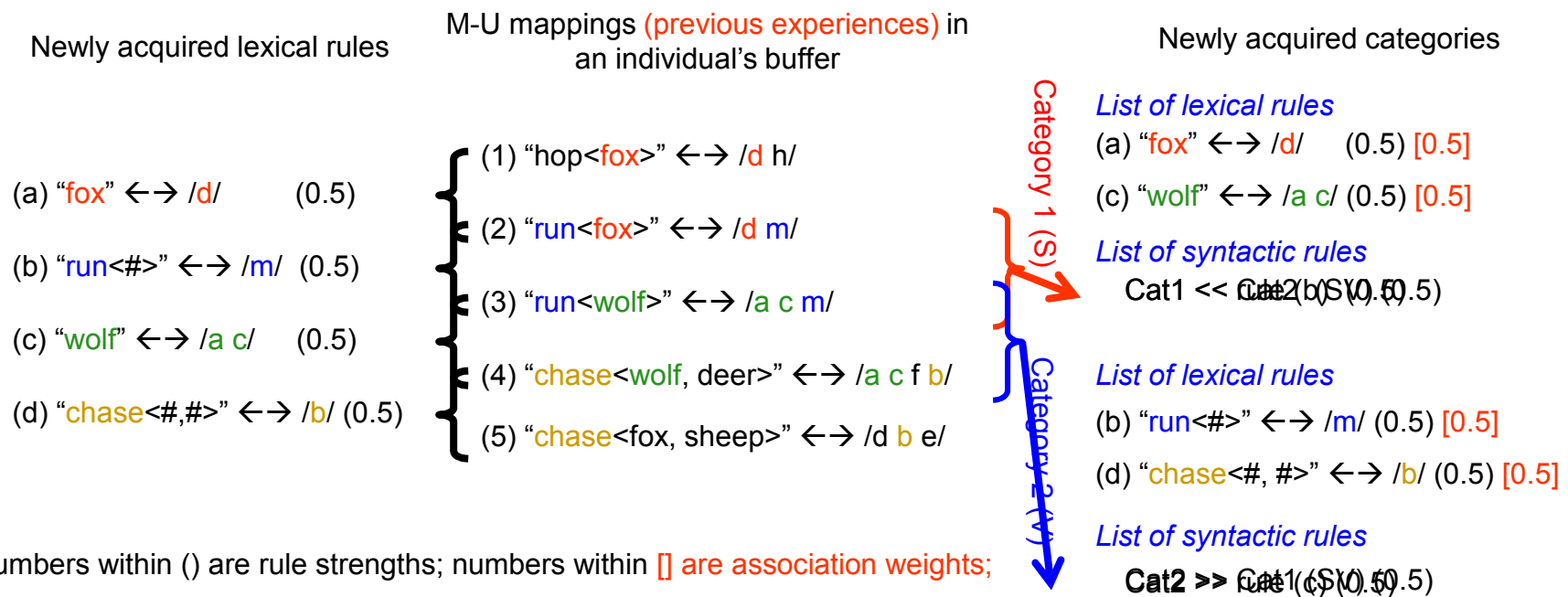
- Categories:
 - A syntactic role: e.g., **Subject (S)**, **Object (O)** or **Verb (V)**;
 - A **list of lexical rules** (having the same semantic role) and a **list of syntactic rules** (to regulate orders between these lexical rules and those from other categories);
 - **Association weights** of a lexical rule to a category indicates **the membership value** of this association.



Numbers inside () are rule strengths; numbers inside [] are association weights (the membership value for a lexical rule to be associated into a category)

The acquisition mechanisms

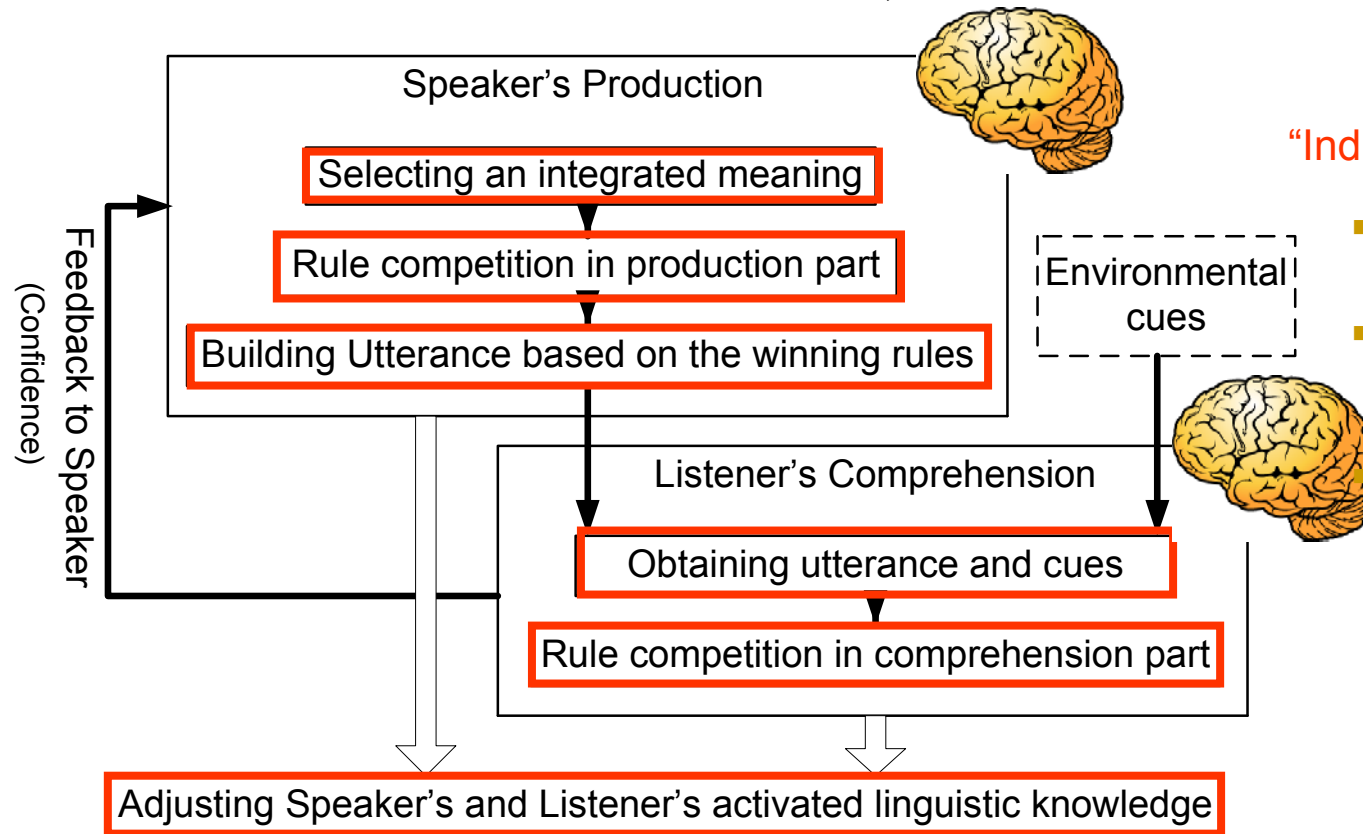
- **Random creation** of holistic expressions.
- Item-based learning from experiences:
 - **Detection of recurrent patterns** → lexical rules;
 - Association of lexical rules with the same semantic roles and their local orders with respect to other lexical rules → categories and syntactic rules;



Numbers within () are rule strengths; numbers within [] are association weights;

The communication scenario

- Nonlinguistic information (**environmental cues**) assists comprehension.
- **Reliability of Cue**: the probability with which the speaker's intended meaning is contained in a cue that is available to the listener;



"Indirect meaning transference"

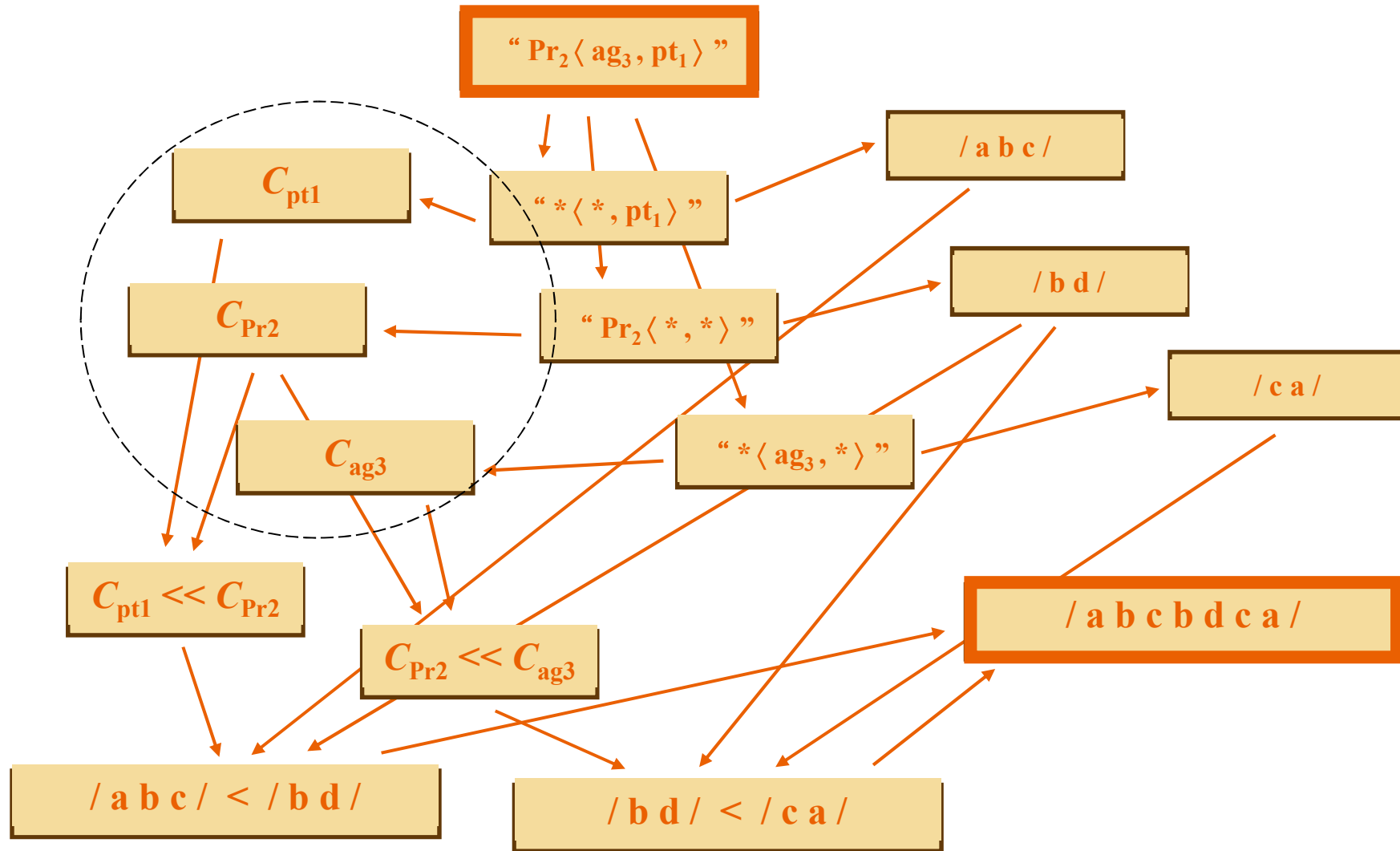
- Independent linguistic knowledge;
- No direct meaning check, but a confidence feedback;

Both linguistic and nonlinguistic information participate in comprehension → **the emergence of displacement**

If the feedback is positive, acquisition of linguistic knowledge in listener

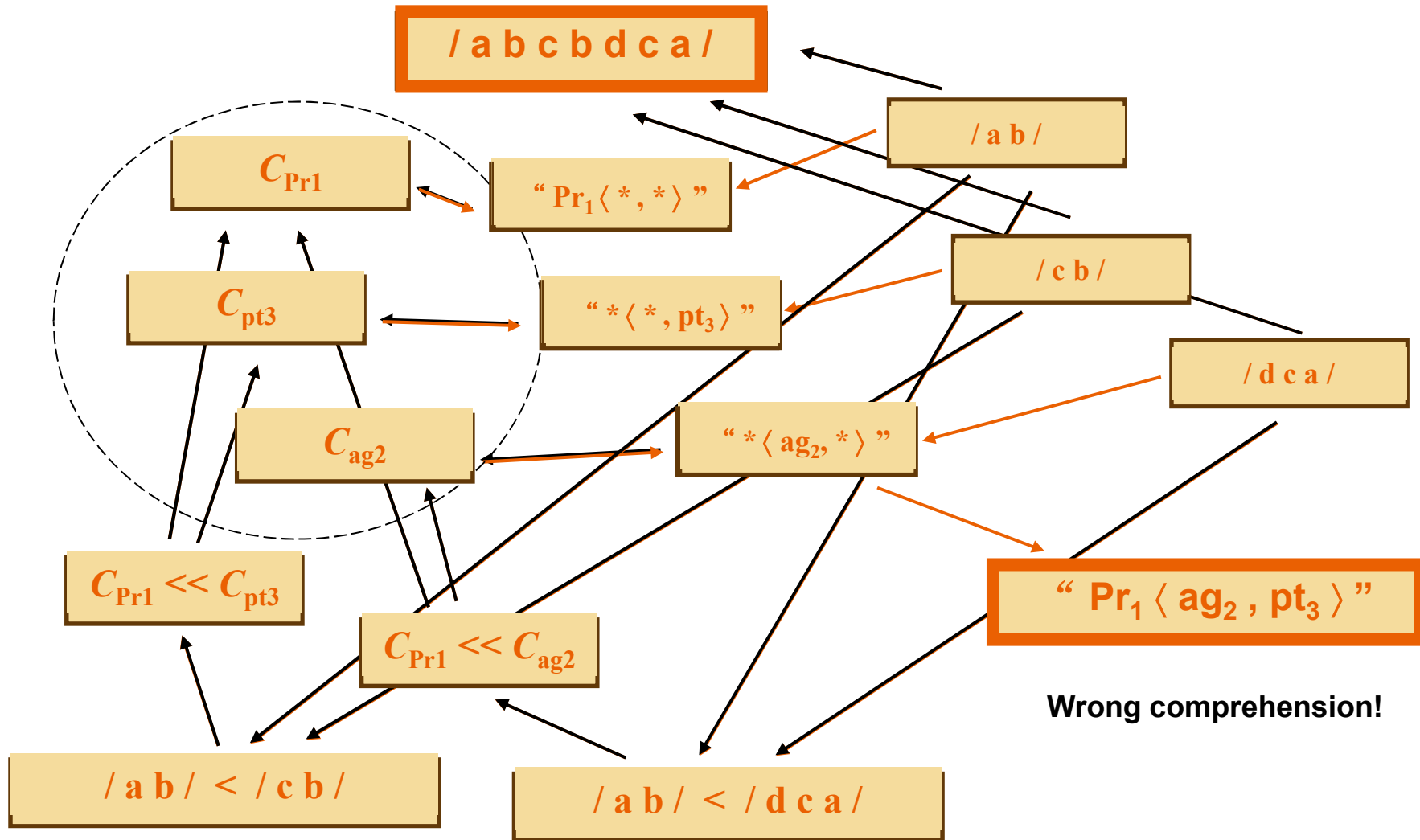


The interaction of linguistic rules in production





The interaction of linguistic rules in comprehension



The simulation setup

- The simulation setup:
 - **Semantic space:**
 - 4 “Ag”, 4 “Pr₁”, 4 “Pr₂”, 4 “Pat” (=“Ag”);
 - in total, 64 integrated meanings (16 intransitive and 48 transitive meanings);
 - **System setup:**
 - Population size: 10;
 - No. communications: 6000 (600 rounds), each having 20 utterance exchanges.
 - **Individual learning abilities:**
 - Individual buffer size: 40;
 - Rate for detection of recurrent patterns: 0.25;
 - Rate for detection of local orders: 0.25;
 - Adjustment in rule competition: 0.1;
 - Adjustment in rule forgetting: 0.01; forgetting occurs after each round of communications;
 - Reliability of Cue: 0.6;

- All individuals initially share a communal language:
 - Each semantic item is encoded in a lexical rule;
 - These lexical rules are associated with 3 categories having corresponding syntactic roles (S, V, or O);
 - 2 or 3 local orders among these categories;

Lexical items (8):
Lex0(A|Pt)(1.00): ' 0 '<->/20 /
Lex1(A|Pt)(1.00): ' 1 '<->/3 10 /
Lex2(A|Pt)(1.00): ' 2 '<->/11 /
Lex3(A|Pt)(1.00): ' 3 '<->/15 15 /
Lex4(Pr)(1.00): '4<#,#>'<->/10 /
Lex5(Pr)(1.00): '5<#,#>'<->/22 15 /
Lex6(Pr)(1.00): '6<#,#>'<->/22 0 /
Lex7(Pr)(1.00): '7<#,#>'<->/3 /

Local orders (SV + SO):



The initial local orders

- The initial local orders can form 1 or 2 global orders;
 - **Precise syntax:** 2 or 3 local orders → 1 global order (e.g., SV+VO → SVO);
 - **Imprecise syntax:** 2 local orders → 2 competing orders (e.g., SV+SO → SVO or SOV);
 - **Complete syntax:** 3 local orders → 1 global order (e.g., SV+VO+SO → SVO);
 - **X-dominant syntax:** 2 local orders involving the same syntactic role (e.g., SV+VO → SVO; SO+VO → SVO or VSO);

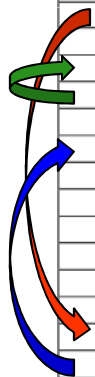
- 18+1 word order states

- State 1: **no dominant**;
- States 2-5: **S-dominant**;
- States 6-9: **V-dominant**;
- States 10-13: **O-dominant**;
- States 14-19: **complete**;

- Order change → state change:

- **Add of a local order;** e.g., SV+SO → SV+SO+VO (State 2 → State 14);
- **Delete of a local order;** e.g., SV+OV+SO → SV+OV (State 15 → State 7);
- **Mutation of a local order;** e.g., VS+OS → VS+SO (State 5 → State 4);

State	Dominant local orders	Dominant global orders	Syntax type
1	none	none	none
2	SV and SO	SVO or SOV	S-dominant syntax
3	SV and OS	OSV	
4	VS and SO	VSO	
5	VS and OS	VOS or OVS	
6	SV and VO	SVO	V-dominant syntax
7	SV and OV	SOV or OSV	
8	VS and VO	VSO or VOS	
9	VS and OV	OVS	O-dominant syntax
10	SO and VO	SVO or VSO	
11	SO and OV	SOV	
12	OS and VO	VOS	Complete syntax
13	OS and OV	OSV or OVS	
14	SV, VO and SO	SVO	
15	SV, OV and SO	SOV	
16	SV, OV and OS	OSV	
17	VS, VO and SO	VSO	
18	VS, VO and OS	VOS	
19	VS, OV and OS	OVS	





The initial local orders

- Score of each order state:
 - $UR_{LocOrd}(XY)$: the percentage of integrated meanings that can be accurately understood by all individuals using a particular local order (SV, VS, SO, OS, VO, OV):

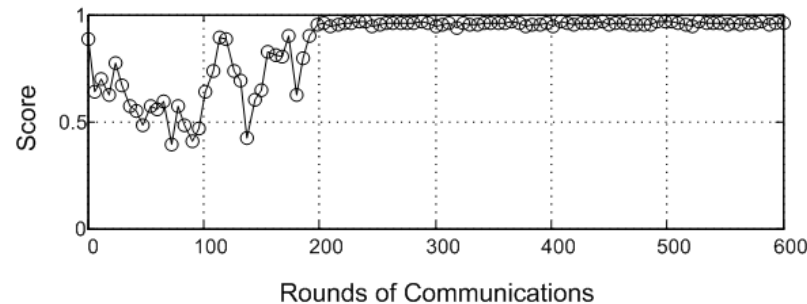
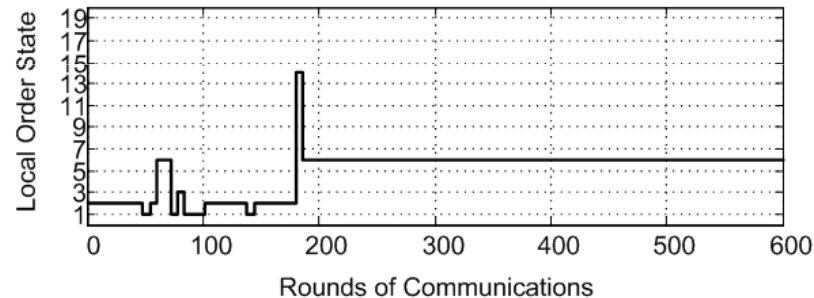
$$Score_i = \sqrt[3]{Value_{SV/VS} \times Value_{SO/OS} \times Value_{VO/OV}}$$

$$Value_{XY/YX} \begin{cases} UR_{LocOrd}(XY/YX) & \text{if } XY/YX \text{ is in order state } i; \\ 1 - \max(UR_{LocOrd}(XY), UR_{LocOrd}(YX)) & \text{otherwise;} \end{cases}$$

Score of State 2 (SV+SO)

$$Score_2 = \sqrt[3]{UR_{LocOrd}(SV) \times UR_{LocOrd}(SO) \times (1 - \max(UR_{LocOrd}(VO), UR_{LocOrd}(OV)))}$$

- Assumption to determine the word order states:
 - Language is assumed to stay in the state whose score is higher than 0.5, and is bigger than those of the other states; otherwise, it stays in State 1, i.e., no dominant orders;
- Evolution of local order states:
 - Start from State 2 (SV+SO);
 - Change to other states;
 - Stabilized in State 6 (SV+VO);





The evaluating indices

- Two types of simulations:
 - Simulation 1:** the semantic space contains only **48 transitive meanings**;
 - Simulation 2:** the semantic space contains both **16 intransitive and 48 transitive meanings**;
 - In each type of simulations,
 - 18 conditions:** each initializes one word order state (States 2-19);
 - 50 simulations** in each condition are conducted to build up the matrices;

Starting states\Ending states

	(1) none	(2) SV+SO	(3) SV+OS	(4) VS+SO	(5) VS+OS	(6) SV+VO	(7) SV+OV	(8) VS+VO	(9) VS+OV	(10) SO+VO	(11) SO+OV	(12) OS+VO	(13) OS+OV	(14) SV+SO+VO	(15) SV+SO+OV	(16) SV+OS+VO	(17) VS+SO+VO	(18) VS+OS+VO	(19) VS+OS+OV
(1) none	48.27	16.85	1.41	1.07	18.01	0.97	48.52	56.19	1.29	18.49	1.24	1.4	16.51	8.8	66.67	30	0	0	7.58
(2) SV+SO	8.52	47.71	0.23	0.15	0.18	0.97	10.06	0	0.01	14.9	0.82	0	0.48	18.66	33.33	0	0	0	0
(3) SV+OS	1	0.33	96.89	0	0.18	0.02	3.55	0	0	0	0	0	0.8	0	0	10	0	0	0
(4) VS+SO	1	0.25	0	97.41	0.36	0	0	0.95	0.01	1.26	0	0	0	0.35	0	0	50	0	0
(5) VS+OS	8.59	0	0.11	0.24	45.34	0	0	10.48	1.01	0.25	0	0.53	12.28	0	0	10	0	75	20.99
(6) SV+VO	3.57	11.68	0	0.05	0	96.57	0.59	0.95	0	10.79	0.15	0.23	0.24	35.92	0	0	0	0	0
(7) SV+OV	2.38	1.58	0.28	0	0.09	0.01	18.93	0	0.04	0	0.21	0	1.44	0.35	0	0	0	0	0
(8) VS+VO	1.71	0	0	0.15	0.54	0.04	0	15.24	0.01	0.59	0	0	0	0	0	0	0	25	0.29
(9) VS+OV	3.05	0	0.06	0	11.13	0	0.59	0	96.04	0.08	0	0.06	12.84	0	0	0	0	0	30.61
(10) SO+VO	8.96	13.68	0	0.83	0.18	1.1	0.59	13.33	0.01	45.69	0.05	0.23	0	23.94	0	0	50	0	0.29
(11) SO+OV	0.97	0.92	0	0	0.09	0	4.14	0	0.03	0.08	97.12	0	0.48	0	0	0	0	0	0
(12) OS+VO	1.15	0	0	0	0.45	0.01	0	1.9	0.01	0.25	0	97.26	0.08	0	0	0	0	0	0
(13) OS+OV	9.11	0.33	0.96	0	14.57	0	10.65	0	1.18	0	0.41	0.18	45.61	0	0	40	0	0	27.41
(14) SV+SO+VO	0.74	6.67	0	0.1	0	0.33	1.78	0.95	0	7.53	0	0	0	11.97	0	0	0	0	0
(15) SV+SO+OV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(16) SV+OS+VO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(17) VS+SO+VO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(18) VS+OS+VO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(19) VS+OS+OV	0.97	0	0.06	0	8.87	0	0.59	0	0.36	0.08	0	0.12	9.25	0	0	10	0	0	12.83

- Stability matrix:** the frequencies for word order states to remain unchanged (values at the leading diagonal);
- Transitivity matrix:** the frequencies for one word order state to change to another state (values except those in the leading diagonal);
- The biased word orders:** the states that have higher chances of remaining unchanged and other states have higher chances of changing to these states;



Simulation 1: transitive meanings only

- The stability matrix:
 - S-, V- and O-dominant, precise syntaxes are stable; their global orders are OSV, VSO, SVO, OVS, SOV and VOS, respectively;
 - V-dominant, imprecise syntaxes are unstable;
 - All complete syntaxes are unstable.

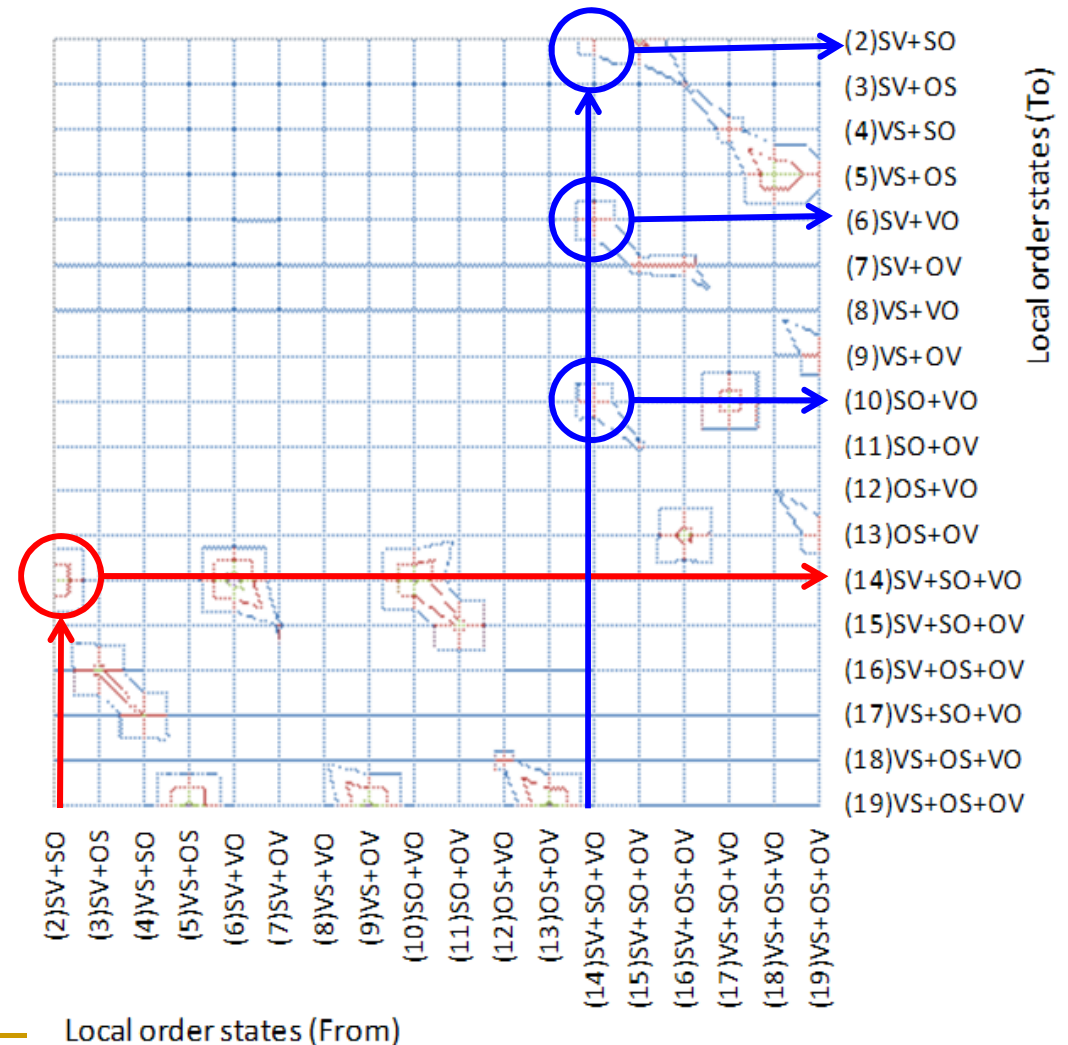
State	Local orders	Global orders	Stability (%)
2	SV + SO	SVO or SOV	47.63
3	SV + OS	OSV	96.7
4	VS + SO	VSO	97.36
5	VS + OS	VOS or OVS	45.3
6	SV + VO	SVO	96.54
7	SV + OV	SOV or OSV	18.29
8	VS + VO	VSO or VOS	14.75
9	VS + OV	OVS	96.03
10	SO + VO	SVO or VSO	45.08
11	SO + OV	SOV	96.82
12	OS + VO	VOS	97.17
13	OS + OV	OSV or OVS	45.56
14	SV + VO + SO	SVO	3.02
15	SV + OV + SO	SOV	0
16	SV + OV + OS	OSV	0
17	VS + VO + SO	VSO	0
18	VS + VO + OS	VOS	0
19	VS + OV + OS	OVS	3.82



Simulation 1: transitive meanings only

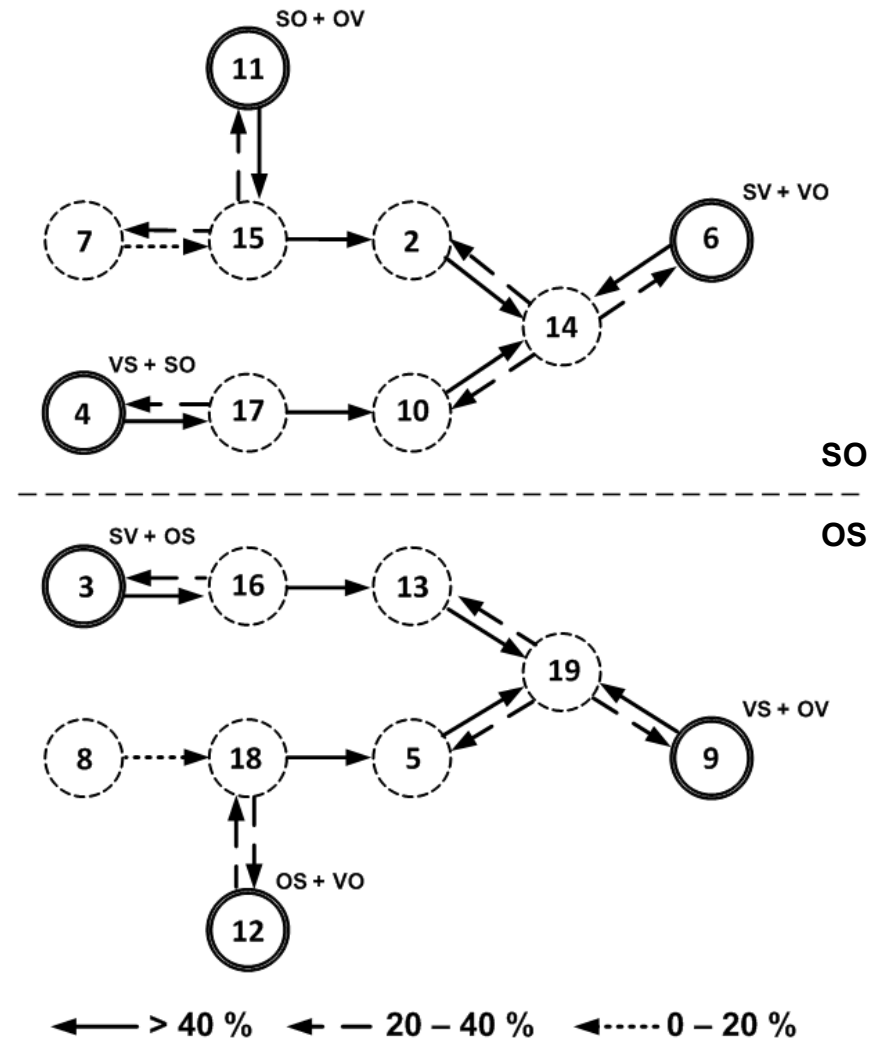
0-20 20-40 40-60 60-80

- The transitivity matrix:
- Imprecise syntaxes → complete syntaxes by developing a local order to clarify the unspecified order.
- e.g., State 2 (SV and SO) → State 14 (SV, VO and SO), by adding VO.
- Complete syntaxes tend to lose one of their local orders.
- e.g., State 14 (SV, VO and SO) → State 2 (SV and SO) by losing VO; → State 6 (SV and VO) by losing SO; → State 10 (SO and VO) by losing SV.



Simulation 1: transitive meanings only

- In the form of global orders:
- **Biased states (attractors):** OSV, VSO, SVO, OVS, SOV, VOS (States 3, 4, 6, 9, 11, 12);
- **Transient states:** all complete syntaxes (States 14-19);
- **Unbiased states:** V-dominant syntax without specifying the local order between S and O (States 7 and 8);
- **Two isolated parts** (the above states all having SO, the below states all having OS): to clarify Ag (S) and Pat (O);





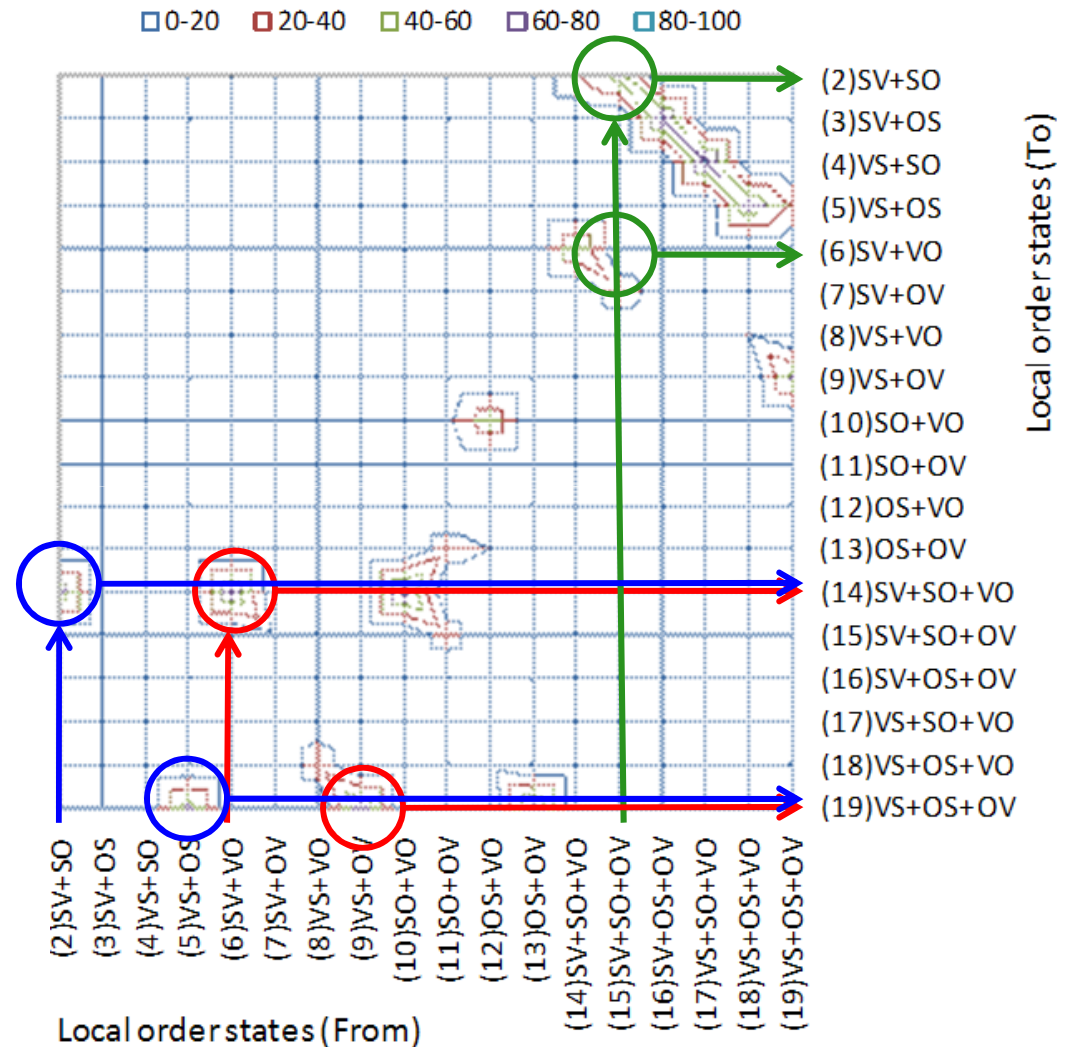
Simulation 2: both intransitive and transitive meanings

- The stability matrix:
- **S- and V-dominant precise syntaxes are very stable**; their global orders are OSV, VSO, SVO, and OVS, respectively.
- **Some S-dominant imprecise syntaxes are also stable**; their global orders are SVO/SOV and VSO/OVS, respectively.
- States 7 (SV and OV) and 8 (VS and VO) are slightly stable.
- O-dominant syntaxes are unstable;
- Complete syntaxes are unstable;

State	Local orders	Global orders	Stability (%)
2	SV + SO	SVO or SOV	76.21
3	SV + OS	OSV	99.05
4	VS + SO	VSO	98.82
5	VS + OS	VOS or OVS	77.64
6	SV + VO	SVO	98.3
7	SV + OV	SOV or OSV	23.33
8	VS + VO	VSO or VOS	23.81
9	VS + OV	OVS	98.41
10	SO + VO	SVO or VSO	9.52
11	SO + OV	SOV	0
12	OS + VO	VOS	0
13	OS + OV	OSV or OVS	16.22
14	SV + VO + SO	SVO	0.77
15	SV + OV + SO	SOV	0
16	SV + OV + OS	OSV	0
17	VS + VO + SO	VSO	0
18	VS + VO + OS	VOS	0
19	VS + OV + OS	OVS	0.97

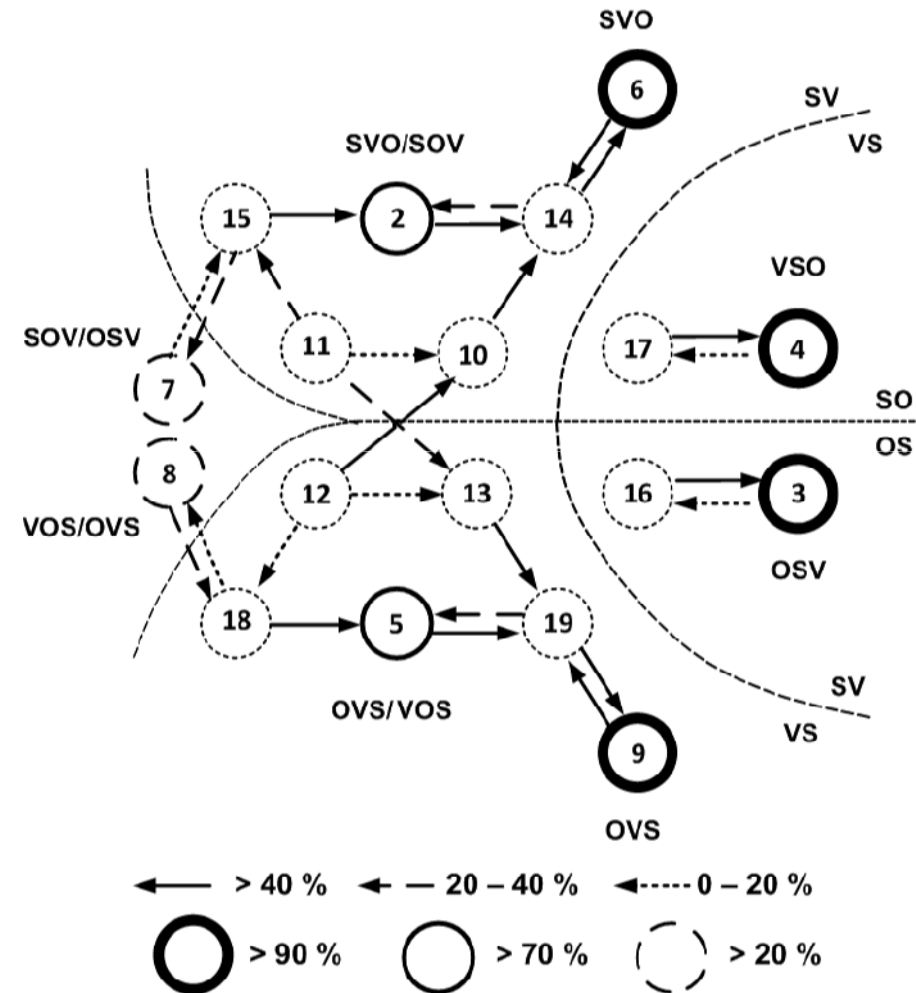
Simulation 2: both intransitive and transitive meanings

- The transitivity matrix:
- V-dominant, precise syntaxes may become complete syntaxes
e.g., State 6 → States 14; State 9 → State 19.
- S-dominant imprecise syntaxes tend to become complete syntaxes
e.g., States 2 → State 14; State 5 → State 19.
- Complete syntaxes tend to lose their VO/OV or SO/OS local order.
e.g., State 14 → State 2 by losing VO; → State 6 by losing SO, but rarely lose SV.



Simulation 2: both intransitive and transitive meanings

- In the form of global orders:
- **Biased states (attractors):** SVO/SOV and OVS/VOS (States 6 and 9, with variants States 2 and 5);
- VSO and OSV (States 3 and 4) remain **stable** if their local orders are **initialized**;
- States 7 (or 8) → States 2 and 6 (or States 5 and 9) via complete syntaxes, i.e., State 15 (or State 18);
- **Transition states:** complete syntaxes (States 14-19);
- **The isolated parts:** the order for intransitive meanings (SV/VS) and the order for transitive meanings (SO/OS);
- Unsymmetric change between SOV and SVO, as well as between VOS and OVS;



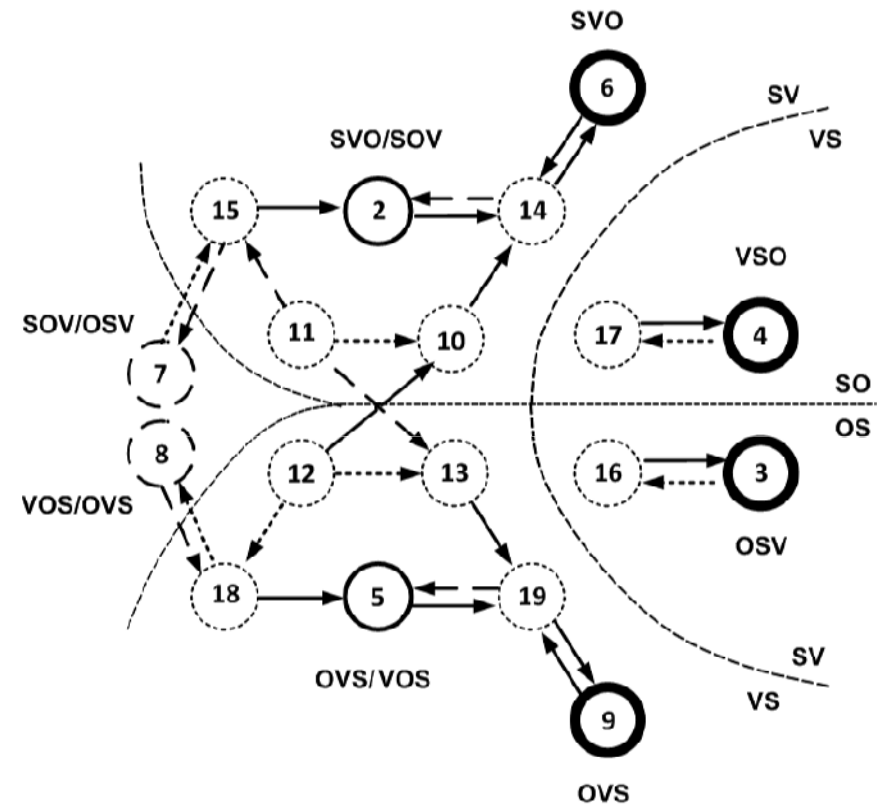


The explanation on the word order bias in this model

- The word order bias shown in the simulations:
 - With only transitive meanings (Simulation 1), there is no bias on global orders;
 - With both intransitive and transitive meanings (Simulation 2):
 - if SO is specified → SVO and SOV become the biased global orders;
 - if OS is specified → OVS and VOS become the biased global orders.
- Three factors to cause these results:
 - **The parsimony of syntax** → the lost of one local order in complete syntaxes;
 - Without affecting understandability, the average strength of 2 local orders tend to be greater than that of 3.
 - **The clarification requirement** → the states of SV+OV and VS+VO are unbiased due to not specifying the local order between S and O.
 - The importance to distinguish Ag and Pat in “Pr<Ag, Pat>” meanings;
 - **The semantic structure** → intransitive meanings require SV or VS → O-dominant syntaxes do not specify the order between S and V, so they are unbiased;
 - Ag in “Pr<Ag>” meanings and Ag in “Pr<Ag, Pat>” meanings are identical;

The explanation on the word order bias in this model

- There are 5 states that can explicitly or implicitly specify SO:
- For the sets that explicitly or implicitly specify OS, **State 9 (VS+OS: OVS)** and **State 5 (VS+OV: OVS/VOS)** are biased;



Local order states	biased or not	Reason & alternative changes
State 2 (SV+SO: SVO/SOV)	Biased	May change to State 6
State 6 (SV+VO: SVO)	Biased	May change to State 2
State 4 (VS+SO: VSO)	Biased as an initial state	Isolated
State 11 (SO+VO: SVO/VSO)	unbiased	Unspecify SV or VS
State 12 (SO+OV: SOV)	unbiased	Unspecified SV or VS



The similarities with the word order bias in human languages

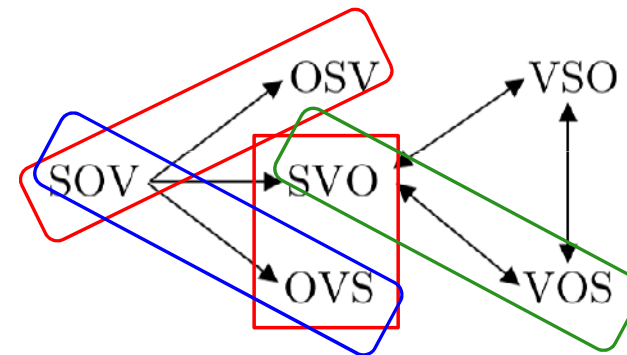
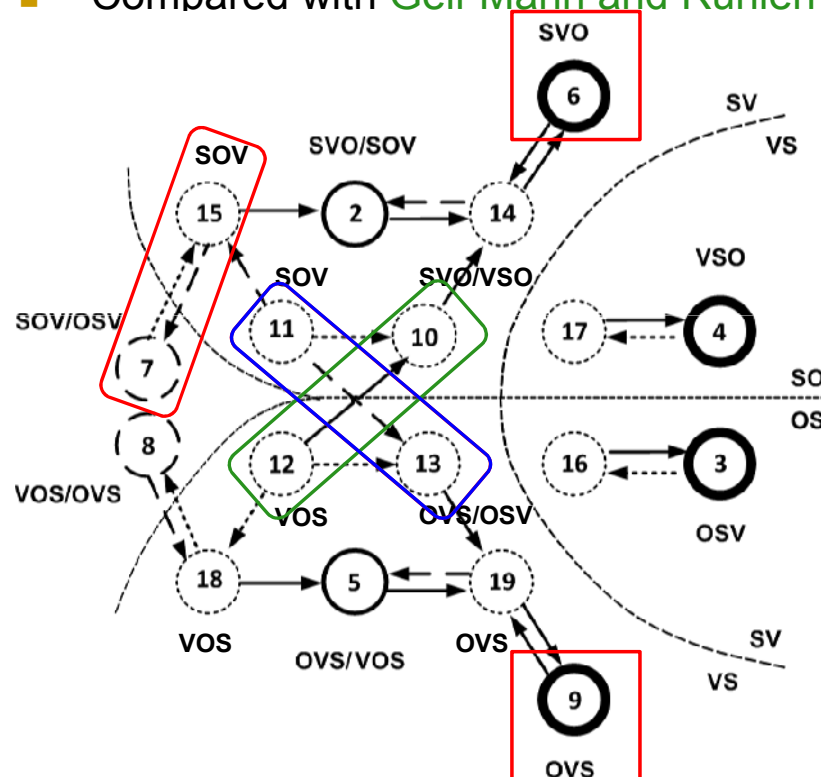
- The prevalence and coexistence of SOV and SVO in the extant languages:
 - Many SVO languages tend to display alternative SOV order;
 - **Sinitic languages:** SVO is dominant, but SOV also exists in *bǎ*-construction;
 - e.g., /我把 张三 打了/
I *bǎ* John hit
“I hit John”
 - **French:** SVO is prevalent, but SOV also exists in sentences having pronouns as patient;
 - e.g. /Je t(e)’amie/
I you love
“I love you”
 - The change of SOV to SVO are common in languages:
 - Medieval Chinese (SOV) → Modern Mandarin (SVO) (Li and Thompson, 1983);
 - e.g., /大王 来 何 操/ (《史记·鸿门宴》)
My lord come what take
“My Lord come and take what?”

Li, C. N., Thompson, S. A. 1981. Mandarin Chinese: A Functional Reference Grammar. Berkeley: University of California Press.



The similarities with the word order bias in human languages

- Intransitive predicates introduce the word order bias (Dryer 1997);
- The biased word orders (SVO/SOV, VOS/OVS) all have VO-binding (Tomlin 1986);
- Compared with Gell-Mann and Ruhlen (2005) and Ferrer-I-Cancho (2008):



From Gell-Mann and Ruhlen (2005)

Dryer, M. S. 1997. On the six-way word order typology. *Studies in Language* 21(1), 69-103.

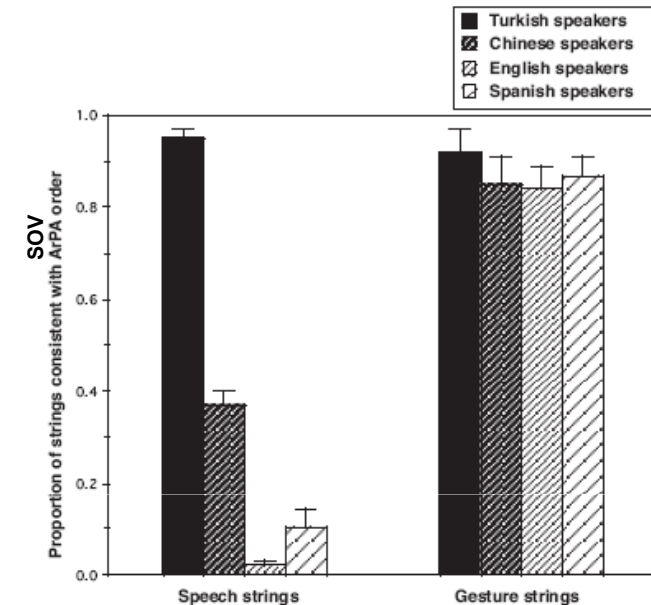
Tomlin, R. S. 1986. *Basic word order: Functional principles*. London: Croom Helm.

Gell-Mann, M., Ruhlen, M. 2005. *The origin and evolution of word order*. Unpublished manuscript.

Ferrer-i-Cancho, R. 2008. Some word order biases from limited brain resources: A mathematical approach. *Advances in Complex Systems* 11(3): 393-414.

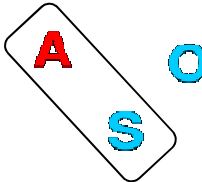
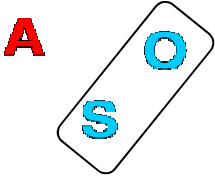
Some factors that cause the preference for SO over OS

- The dominant SOV order in nonverbal description of natural events (Goldin-Meadow et al. 2008):
 - Human subjects are asked to use **gesture** to describe an event;
 - The **order** of the gestures that correspond to actors participating in the event were:
 - **Independent** of subject's spoken **language**;
 - Consistently biased toward **SOV**;



Goldin-Meadow, S., So, W-C., Özyürek, A., Mylander, C., 2005. The natural order of events: How speakers of different languages represent events nonverbally. PNAS 105(27), 9163-9168.

Insights on the word order bias in ergative languages

- **Nominative-accusative languages:** the argument (S) of intransitive meaning and the agent (A) of transitive meaning are associated with the same category, e.g., English, Chinese;
 - **Ergative-absolutive languages (Song 2001):** the argument (S) of intransitive meaning and the patient (O) of transitive meaning are associated with the same category, e.g., most Mayan languages.
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- Factors that affect the word order bias in ergative languages:
 - **The clarification requirement** to distinguish A and O;
 - Since S is associated with O, the word order in intransitive sentences corresponds to OV/VO;
 - Since S and A are **semantically similar with respect to V**, there should be **similar local order** between A and V in transitive sentences and that between S(O) and V in intransitive ones;

Song, J. J. 2001. Linguistic typology: Morphology and syntax. Harlow: Longman.

Key references

- Final words: **computational simulation of linguistic phenomena:**
 - Manipulate parameters and set up comparative conditions;
 - Match the empirical data and provide insights on relevant phenomena;
 - **Limitations of the current simulation study;**
 - “Scaled-up” problem;
 - Indirect evidence for simulated behaviors: pattern extraction and sequential learning from cognitive experiments and animal studies (Monchi et al., 2001; Hauser et al., 2001); coevolution of lexicon and syntax from language acquisition, aphasia studies (Bates and Goodman, 1997);

Gong, T., Minett, J. W., Wang, W. S-Y. 2009. A simulation study on word order bias. *Interaction Studies*, 10(1): 51-76.

Gong, T. 2009. *Computational simulation in evolutionary linguistics: A study on language emergence* (Frontiers in Linguistics, Monograph IV). Taipei: Institute of Linguistics, Academia Sinica.

Your comments are welcome!
Thank you!

Monchi et al. 2001. Wisconsin card sorting revisited. *The Journal of Neuroscience*, 21(19): 7733-7741.

Bates, E. and Goodman, J. C. 1997. On the inseparability of grammar and the lexicon: Evidence from acquisition, aphasia and real-time processing. *Language and Cognitive Processes*, 12(5-6): 507-584.

Hauser, M. D., Newport, E. L., and Aslin, R. N. 2001. Segmentation of the speech stream in a non-human primate: statistical learning in cotton-top tamarins. *Cognition*, 78: B53-B64.