



Universiteit
Leiden

The Netherlands

Emergence of linguistic universals in neural agents via artificial language learning and communication

Lian, Y.

Citation

Lian, Y. (2025, December 12). *Emergence of linguistic universals in neural agents via artificial language learning and communication*. Retrieved from <https://hdl.handle.net/1887/4285152>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/4285152>

Note: To cite this publication please use the final published version (if applicable).

Emergence of Linguistic Universals in Neural Agents via Artificial Language Learning and Communication

Proefschrift

ter verkrijging van

de graad van doctor aan de Universiteit Leiden,

op gezag van rector magnificus prof.dr.ir. H. Bijl,

volgens besluit van het college voor promoties

te verdedigen op vrijdag 12 december 2025

klokke 11:30 uur

door

Yuchen Lian

geboren te Jiangsu, China

in 1997

Promotor:

Prof.dr. A. Plaat

Co-promotores:

Dr. T. Verhoef

Dr. A. Bisazza (University of Groningen, NL)

Promotiecomissie

Prof.dr. M. M. Bonsangue

Prof.dr. S. Verberne

Prof.dr. A. Alishahi (Tilburg University)

Prof.dr. L. Beinborn (University of Göttingen)

Dr. R. G. Alhama (University of Amsterdam)

Copyright © 2025 Yuchen Lian.

This PhD project was conducted at the Leiden Institute of Advanced Computer Science, Leiden University, The Netherlands.

This work is financially supported by the Chinese Scholarship Council (CSC No. 201906280463).

Contents

1 Introduction	1
1.1 Studying the Emergence of Language Universals	2
1.2 Neural Network-Based Emergent Communication	5
1.3 Neural-Agent Language Learning and Communication Frame- work (NeLLCom)	7
1.4 Word Order and Case Marking	9
1.5 Thesis Overview and Research Questions	12
2 Neural-Agent Iterated Language Learning: Three Missing Fac- tors	21
2.1 Introduction	22
2.2 Miniature Languages	24
2.2.1 Fixed-order vs. Free-order	25
2.2.2 Case Marking	25
2.3 Neural-Agents Iterated Learning	26
2.3.1 Agent architecture	26
2.3.2 Individual and iterated learning	26
2.3.3 Evaluation	27
2.3.4 Training details	28
2.4 Effect of Least-Effort Bias	28
2.5 Effect of Input Language Variability	31
2.5.1 Variability Among Utterances	32
2.5.2 Variability Within Utterances	34

2.6 Effect of Learning Bottleneck	35
---	----

2.7 Discussion and Conclusions	35
--	----

3 A New Framework for Neural-Agent Artificial Language Learning and Communication: NeLLCom 39

3.1 Introduction	40
----------------------------	----

3.2 Background	41
--------------------------	----

3.2.1 Word order <i>vs.</i> case marking trade-off	41
--	----

3.2.2 Agent-based simulations of language evolution	42
---	----

3.3 NeLLCom framework	43
---------------------------------	----

3.3.1 The Task	45
--------------------------	----

3.3.2 Agent Architectures	45
-------------------------------------	----

3.3.3 Supervised Language Learning	47
--	----

3.3.4 Optimizing Communication Success	47
--	----

3.3.5 Combining Supervision and Communication	48
---	----

3.3.6 Evaluation	49
----------------------------	----

3.4 Experimental Setup	50
----------------------------------	----

3.4.1 Miniature Languages	51
-------------------------------------	----

3.4.2 Meaning Space	52
-------------------------------	----

3.4.3 Datasets	52
--------------------------	----

3.4.4 Model training	53
--------------------------------	----

3.5 Supervised Learning Results	53
---	----

3.5.1 Accuracy	53
--------------------------	----

3.5.2 Production Preferences	55
--	----

3.6 Communication Learning Results	55
--	----

3.6.1 Communication Success	55
---------------------------------------	----

3.6.2 Production Preferences	56
--	----

3.7 Individual Learners' Trajectories	60
---	----

3.8 Discussion and Conclusion	63
---	----

4 Modeling Group Communication with the Extended Framework NeLLCom-X 65

4.1 Introduction	66
----------------------------	----

4.2	Related Work	69
4.3	NeLLCom-X	71
4.3.1	Original Framework	71
4.3.2	Full-fledged Agent	73
4.3.3	Interactive Communication	75
4.4	Experimental Setup	76
4.4.1	Artificial languages	76
4.4.2	Evaluation	77
4.4.3	Production preferences	77
4.5	Replicating the Trade-off with Full-fledged Agents	78
4.5.1	Training details for the replication	78
4.5.2	67% marking in initial languages	79
4.5.3	Initial marking proportion	82
4.6	Interactive Communication	84
4.6.1	Training Details for Interactive Communication	84
4.6.2	Speakers of Different Languages	86
4.6.3	Effect of Group Size	89
4.7	Discussion and conclusion	91
5	Simulating the Emergence of Differential Case Marking with	
	NeLLCom-X	95
5.1	Introduction	96
5.2	Differential Case Marking	98
5.3	NeLLCom Framework	100
5.4	Experimental Setup	102
5.4.1	Evaluation	105
5.4.2	Model Configuration and Training Details	105
5.5	Results	106
5.5.1	Dominant Order Language	106
5.5.2	Neutral Order Languages	108
5.6	Discussion and Conclusion	110
6	Conclusions	113

Contents

Bibliography	123
Summary	139
Samenvatting	141
Acknowledgements	143
List of publications	145
Curriculum Vitae	147