The Multiple Inflection Generator: A generalised developmental model of inflectional morphology

Themis N. Karaminis & Michael S. C. Thomas

Birkbeck, University of London, UK

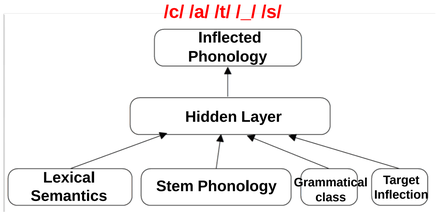
AIM: A model of word inflection that can capture developmental patterns in two different languages (English and Greek)

We present a connectionist model of a general system for producing inflected words. The Multiple Inflection Generator (MIG) assumes that the goal of the system is to output a phonological form appropriate to the grammatical context in which the word appears.

MIG combines elements of several previous models (e.g., multiple inflections for a grammatical class: Hoeffner & McClelland, 1993 ; lexical-semantic input: Joanisse & Seidenberg, 1999; multiple grammatical classes: Plunkett & Juola, 1999). We examined whether: (1) a connectionist architecture could simulate patterns of the acquisition of English morphology in typical and atypical development; (2) the same architecture could capture the acquisition of inflectional morphology in a morphologically rich language: Modern Greek. We sought to capture the order of acquisition of different inflections types and characteristic developmental error patterns.

The model

Architecture



Training Set

• An artificial language (CVC, CCV, VCC) with features of English
• Type frequency measurements obtained from the tagged Brown Corpus (Francis & Kucera, 1978) with Natural Language Toolkit (NLTK®).

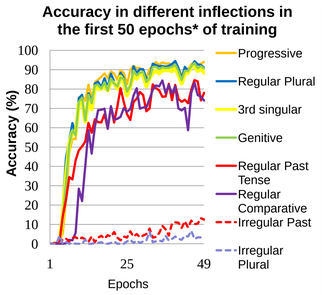
English Training Set

					NUMBER OF ITEMS IN THE TRAINING SET
NOUNS (800)		SINGULAR (600)			600
		PLURAL (150)	*REGULAR (770)	*/s/ (140)	140
				*/z/ (500)	500
				*/ez/ (130)	130
			*IRREGULAR		30
	GENITIVE (50)	*/s/ (150)			150
		*/z/ (500)			500
		*/ez/ (150)			150
VERBS (400)		BASE FORMS (130)			130
		3rd SINGULAR (70)	*/s/ (130)		130
			*/z/ (200)		200
			*/ez/ (70)		70
	PROGRESSIVE (80)				80
	PAST TENSE (120)	*REGULAR (330)	*/t/ (65)		65
			*/d/ (180)		180
			*/ed / (85)		85
		*IRREGULAR (70)	*IDENTITY		10
			*VOWEL_CHAN		50
			*ARBITRARY		10
ADJECTIVES (400)	BASE FORMS (320)				320
	COMPARATIVE (40)	*REGULAR (380)			380
		*IRREGULAR (20)			20
	SUPERLATIVE (40)	*REGULAR (380)			380
		*IRREGULAR (20)			20

Results

A. Order of Emergence of different inflections

The order with which the different inflections emerge presents notable similarities with the order described in Brown (1973) and de Villiers & de Villiers (1973).

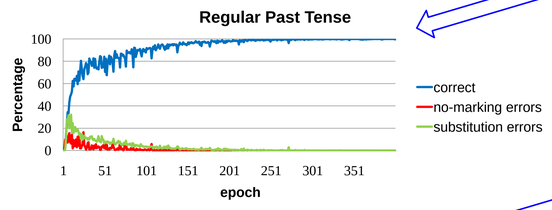


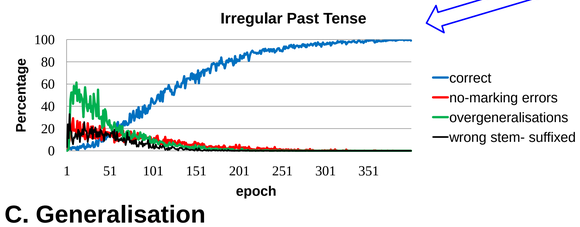
Inflection	Order with which different inflections reach accuracy levels of 90%		
	Brown (1973)	*de V & de V (1973)*	*MIG*
Progressive	1	1	1
(Regular) Plural	2	1	2
3rd Singular	6	5	3
Genitive	5	4	4
Regular Past	4	5	5
Regular Comparative	(n/a/)	(n/a)	6
Irregular past	3	3	7
Irregular Plural	(n/a/)	(n/a)	8

*1 epoch=1 presentation of the full training set

B. Error patterns

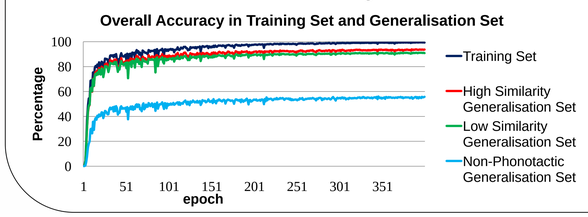
The model captures basic error patterns, such as no-marking errors (e.g. Rice, Wexler & Cleave, 1993), and overgeneralisations (e.g., Brown,1973).





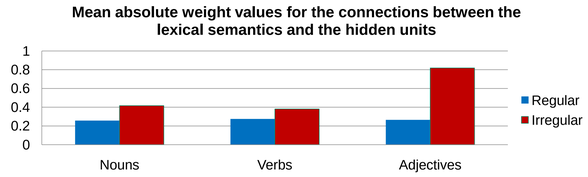
C. Generalisation

MIG is able to generalise inflectional regularities to novel items in high rates. Generalisation depends on the degree of similarity (e.g. the extent of rhyming, accordance with phonotactics) between novel items and items of the training set .



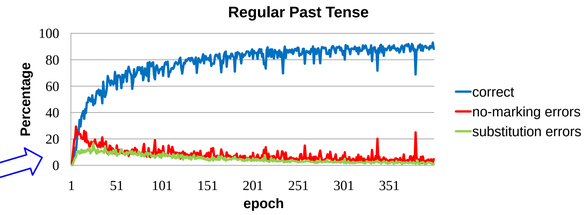
D. Two Routes and a Blocking Mechanism

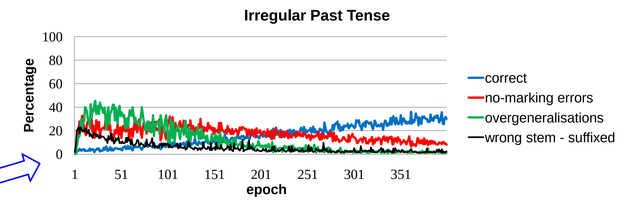
Pinker's (1984) dual-route architecture is an emergent product of learning in the network. Lexical Semantics blocks the output of the phonological route for the irregulars, implementing inhibition of the rule.



E. Atypical development

Considering a version of the model with fewer hidden units and weaker phonological representations produced a profile symptomatic of SLI (e.g., Rice, 2000; Leonard, 1998).

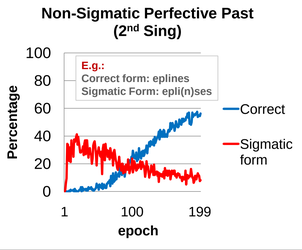


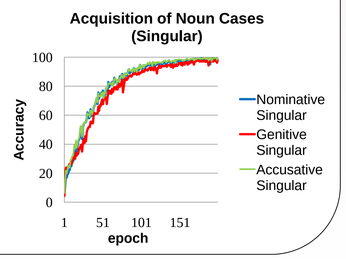


F. Acquisition of morphology in Modern Greek (in progress)

We trained the same architecture with a more complex training set, corresponding to the rich morphological paradigm of Modern Greek. The model captured features of the acquisition of morphology in modern Greek, such as:

- the overapplication of the 'sigmatic rule' in the formation of the past tenses of other (non-sigmatic) conjugational categories (Stavrakaki & Clahsen, 2009).
- the order of acquisition of the noun cases (late acquisition of the genitive case, cf. Stephany, 1997)





Discussion

Across development, the model flexibly integrates multiple cues from lexical-semantics, the phonological lexicon, grammatical word class information, and grammatical context information to output the appropriate inflected form.

• MIG simulated the order of acquisition of inflection types
• It demonstrated high rates of productive generalisation
• It reproduced characteristic errors in acquisition
• It is applicable to developmental deficits
• It presented the appearance of a "dual-route" architecture as an emergent property
• MIG showed cross-linguistic flexibility

Acknowledgements

This work was supported by UK MRC Grant G0300188. The studies of the first author are funded by the Greek State Scholarship Foundation (IKY).

References

Brown, R. (1973). *A first language: The early stages.* London: George Allen & Unwin Ltd.
de Villiers, J.G., & de Villiers, P.A. (1973). A cross-sectional study of the acquisition of grammatical morphemes in child speech. *Journal of Psycholinguistic Research* , 2(3), pp. 167-278.
Francis, W.N., & Kucera, H. (1979). *Manual of Information to Accompany a Standard Sample of Present-day Edited American English , for Use with Digital Computers.* Original ed. 1964, revised 1971, revised and augmented 1979. Department of Linguistics, Brown University, Providence, R.I.
Hoeffner, J. H., & McClelland, J. L. (1993). Can a perceptual processing deficit explain the impairment of inflectional morphology in developmental dysphasia? A computational investigation. In E. V. Clark (Ed.), *Proceedings of the 25th Child Language Research Forum*. Palo Alto, CA: Stanford University Press.
Joanisse, M.F., & Seidenberg, M.S. (1999). Impairments in verb morphology following brain injury: A connectionist model. *Proceedings of the National Academy of Science USA, 96,* pp. 7592-7597.
Leonard, L.B. (1998). *Children with specific language impairment.* Cambridge, MA: MIT Press.
Natural Language Toolkit, NLTK .....
Plunkett, K., & Juola, P. (1999). A connectionist model of English past tense and plural morphology. *Cognitive Science, 23,* pp. 463-490
Pinker (1984). Language learnability and language development. Cambridge, MA: Harvard university press
Rice, M.L. (2000). Grammatical symptoms of specific language impairment. In: D.V.M. Bishop & L.B. Leonard (Eds.), *Speech and Language Impairments in Children: Causes, characteristics, intervention and outcome* (pp.17-34). Hove, England: Psychology Press.
Rice, M, Wexler, K. & Cleave, P. (1995). Specific Language Impairment as a period of extended optional infinitive. *Journal of Speech and Hearing Research, 38,* pp. 850-863.
Stavrakaki, S. & Clahsen, H. (2009). The perfective past tense in Greek child language. *Journal of Child Language,* 36, pp.113-142.
Stephany, U. (1997). The Acquisition of Greek. In: Slobin, D. I. (ed.). *The cross-linguistic study of language acquisition 4* (pp.183-333).Hillsdale, NJ: Erlbaum.

E-mail addresses of the authors:
tkaram01@students.bbk.ac.uk, m.thomas@psychology.bbk.ac.uk

This poster can be downloaded from:
http://www.psyc.bbk.ac.uk/research/DNL/personalpages/themis.html

Modern Greek Training Set

NOUNS (800)	MASCULINE (100) (Five Conjugational categories)	nominative SINGULAR	ADJECTIVES (400) (Four Conjugational categories)	BASE (300)	MASCULINE	nominative SINGULAR
		genitive SINGULAR				genitive SINGULAR
		accusative SINGULAR				accusative SINGULAR
		nominative PLURAL				nominative PLURAL
		genitive PLURAL				genitive PLURAL
		accusative PLURAL				accusative PLURAL
	FEMININE (300) (Four Conjugational categories)	nominative SINGULAR			FEMININE	nominative SINGULAR
		genitive SINGULAR				genitive SINGULAR
		accusative SINGULAR				accusative SINGULAR
		nominative PLURAL				nominative PLURAL
		genitive PLURAL				genitive PLURAL
		accusative PLURAL				accusative PLURAL
	NEUTER (500) (Five Conjugational categories)	nominative SINGULAR			NEUTER	nominative SINGULAR
		genitive SINGULAR				genitive SINGULAR
		accusative SINGULAR				accusative SINGULAR
		nominative PLURAL				nominative PLURAL
		genitive PLURAL				genitive PLURAL
		accusative PLURAL				accusative PLURAL
VERBS (400)	PRESENT (200) (Two Conjugational categories)	1st Person SINGULAR		COMPARATIVE (100)	MASCULINE	nominative SINGULAR
		2nd Person SINGULAR				genitive SINGULAR
		3rd Person SINGULAR				accusative SINGULAR
		1st Person PLURAL				nominative PLURAL
		2nd Person PLURAL				genitive PLURAL
		3rd Person PLURAL				accusative PLURAL
	PAST IMPERFECTIVE (40) (Two Conjugational categories)	1st Person SINGULAR			FEMININE	nominative SINGULAR
		2nd Person SINGULAR				genitive SINGULAR
		3rd Person SINGULAR				accusative SINGULAR
		1st Person PLURAL				nominative PLURAL
		2nd Person PLURAL				genitive PLURAL
		3rd Person PLURAL				accusative PLURAL
	PAST PERFECTIVE (60) (Six Conjugational categories)	1st Person SINGULAR			NEUTER	nominative SINGULAR
		2nd Person SINGULAR				genitive SINGULAR
		3rd Person SINGULAR				accusative SINGULAR
		1st Person PLURAL				nominative PLURAL
		2nd Person PLURAL				genitive PLURAL
		3rd Person PLURAL				accusative PLURAL