

Derivational paradigms: Rules, patterns or neural networks?

Stela Manova, Dmitri Sitchinava & Maria Shvedova

University of Vienna / Russian Language Institute & Higher
School of Economics, Moscow / Kyiv National Linguistic
University

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Paradigms in morphology 1

- Paradigms play a **major role in inflectional morphology** and there is much research on the topic, even whole theories of morphology are built on the notion of paradigm, e.g. Paradigm Function Morphology (Stump 2001 and later work), Word and Paradigm Morphology (Blevins 2016 and previous work).
- In recent years, researchers have tried to **transfer the notion of paradigm from inflectional to derivational morphology** (van Marle 1984, Becker 1993, Bauer 1997, Booij 1997, Pounder 2000, a.o.).
- The idea is **to use the achievements of the research on inflectional morphology for explanation of derivational morphology** (Bauer 1997, Blevins 2001, Stump 2005, Štekauer 2014, Boyé and Schalchli 2016, Bonami and Strnadová 2018).

Paradigms in morphology 2

- The motivation for the paradigmatic approach rests on the believe that **the lexicon is structured in terms of sets of paradigmatic relations that link members of morphological families** (evidence from **psycholinguistics** in Schreuder and Baayen 1997, de Jong et al. 2000, del Prado Martín et al. 2005, a.o.; and from **computational linguistics** in Pirrelli and Federici 1994, Pirrelli and Yvon 1999, Cotterell et al. 2017, see also **Construction Morphology**, Booij 2010)
- Of particular interest are **peculiar paradigms**, such that involve e.g. **syncretism** or **missing forms (gaps**, cf. Baerman et al. 2010, Sims 2015, Stump 2018).
- In the literature on word-formation, missing forms have been seen as due to **blocking: “the nonoccurrence of one form due to the simple existence of another”** (Aronoff 1976: 43), for a comprehensive bibliography of research on blocking see Rainer (2014).

Paradigms in morphology 3

- In inflectional morphology, the term paradigm is used in two senses:
 1. A paradigm of a word (or lexeme, depending on the theoretical framework)

Bg. SG *knig-a* ‘book’, PL *knig-i*, SG DEF *knig-a-ta*, PL DEF *knig-i-te*
 2. Inflection class, i.e. all lexemes with the same inflection

BG. *knig-a* ‘book’, *knig-i*, *knig-a-ta*, *knig-i-te*
Bg. *sten-a* ‘wall’, *sten-i*, *sten-a-ta*, *sten-i-te*

(*Kniga* and *stena* belong to **the same inflection class** in Bulgarian)
- In this presentation, we analyze derivational paradigms similar to inflection classes; starting from animals, we focus on the following derivational families:
 - i. diminutives of animals
 - ii. young animals
 - iii. diminutives of young animals

Rules, patterns and neural networks

Rule: if there is A, apply a given rule to derive B

input A → given rule → output B

Pattern: the pattern $(X_N + Y_N)$ derives Z_N , where X_N stands for a set of elements of the type X, likewise for Y_N and Z_N

input (X_N, Y_N) → follow the pattern $(X_N + Y_N)$ → output Z_N

Neural networks are widely used in computer science and are inspired by the organization of the human brain, i.e.

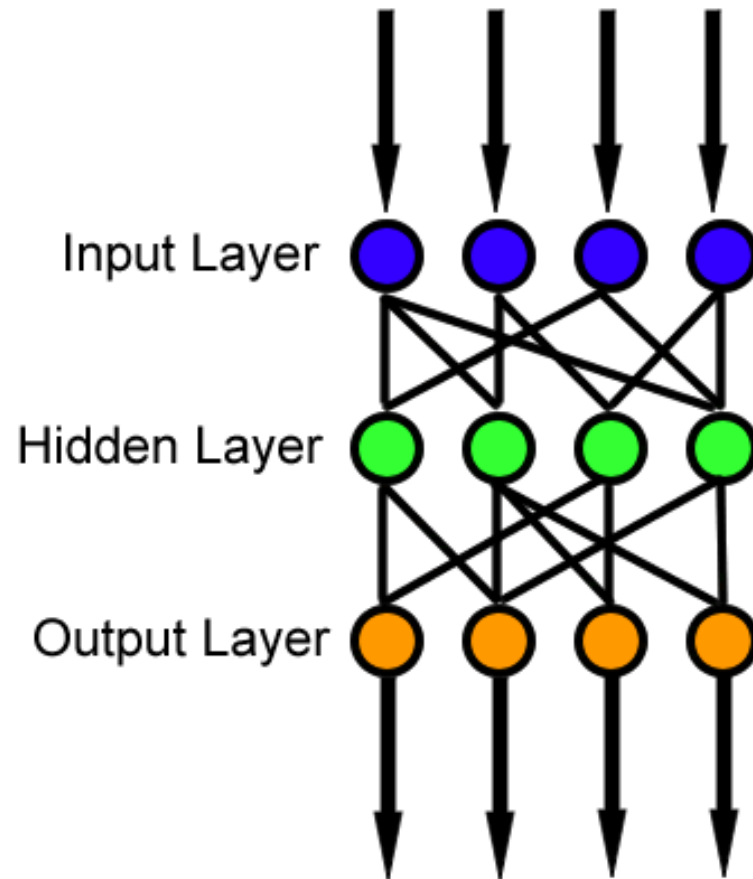
input → hidden layer(s) → output

The hidden layer(s) analyze(s) / weight(s) frequencies of occurrence of sequences of elements and discover(s) patterns which then use(s) as rules. There are different types of neural networks.

Feedforward neural network

information always goes one direction

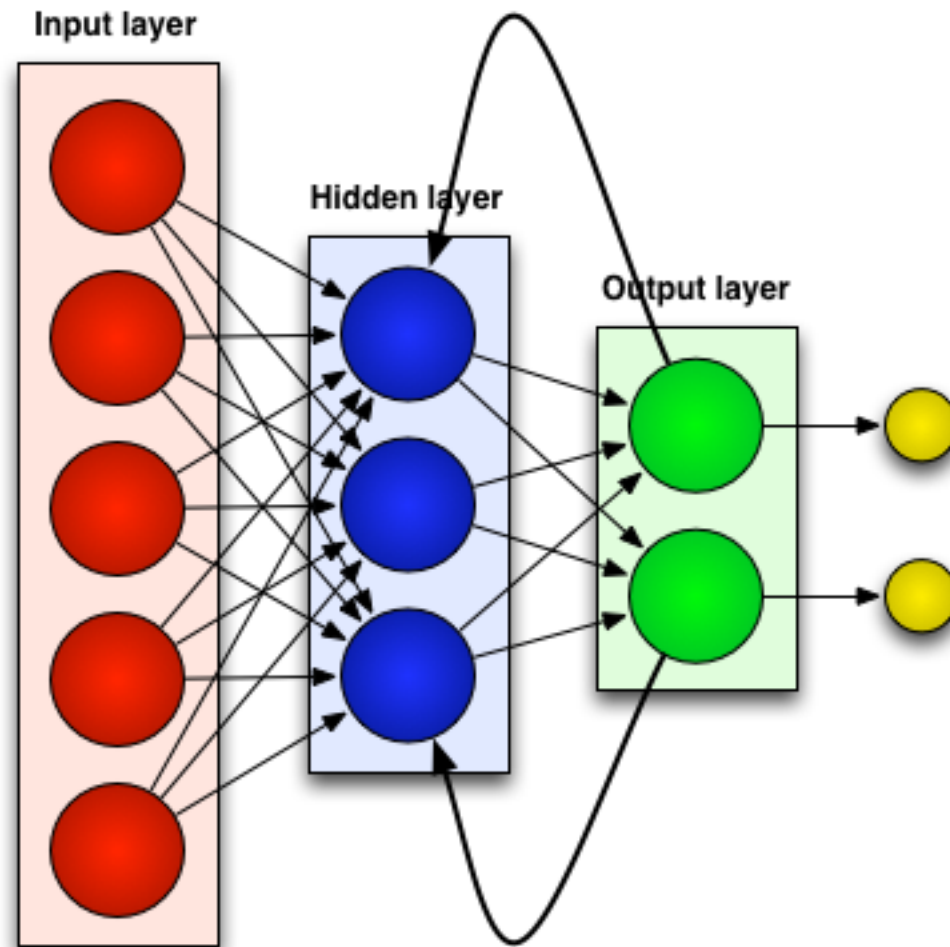
Source: https://en.wikipedia.org/wiki/Feedforward_neural_network#/media/File:Feed_forward_neural_net.gif



Recurrent neural network

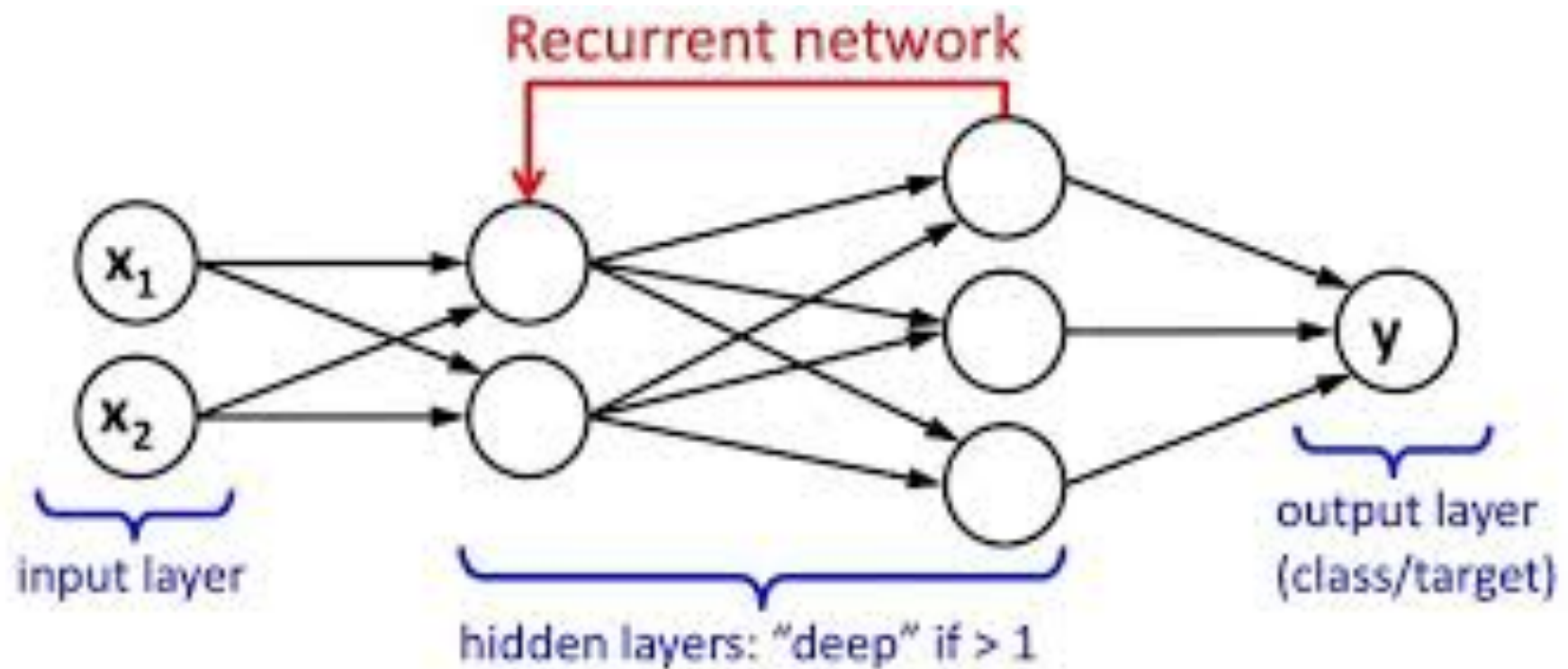
with a single hidden layer

<https://towardsdatascience.com/understanding-recurrent-neural-networks-the-preferred-neural-network-for-time-series-data-7d856c21b759>



Deep recurrent neural network

more than one hidden layer



Returning to linguistics: Our goals

- to contribute to the research on ***the relation between derivation and inflection*** (young animals constituted an inflectional class in Proto-Slavic, **nt*-stems; young animals and diminutives in modern Slavic languages are considered derivational morphology (non-prototypical word-formation, Dressler 1989, a.o.)
- to provide strong evidence for the **existence of derivational paradigms**
- to contribute to the **better understanding of the nature and the organization of derivational paradigms**
- to research **how the human brain processes closely related paradigms that are between derivation and inflection**

Data

East Slavic

Russian (Dmitri Sitchinava)

Ukrainian (Maria Shvedova)

Belorussian (Uladzimir Koščanka)

West Slavic

Polish (Iwona Burkacka)

Czech (Renáta Gregová)

Slovak (Renáta Gregová)

South Slavic

Bulgarian (Stela Manova)

Macedonian (Ljupco Spasovski)

Serbian (Milena Mihajlović)

Method

- **50 nouns for animals from each language** as well as the respective nouns for young animals, diminutives of animals and diminutives of young animals
- The 50 nouns for animals were distributed into the following **semantic groups**:
 1. Domestic animals
 2. Wild animals
 3. Exotic animals
 4. Birds
 5. Insects
- To make the data comparable and easily analyzable, we ordered all examples in all languages paradigmatically (derivational paradigms)
- Psycholinguistics experiments

South Slavic: Exotic animals

! small animal (DIM) = young animal

English translation	Animal	Small animal = DIM	Young animal	DIM of young animal
elephant	Bg. slon M. slon S. slon	slon-če slon-če slon-če / slon-čić	slon-če slon-če slon-če / slon-čić	slonč-ence slonč-ence slon-če / slon-čić
lion	Bg. lăv M. lav S. lav	lăv-če lav-če lav-ić	lăv-če lav-če lav-ić	lăvč-ence lavč-ence lav-ić
tiger	Bg. tigăr M. tigar S. tigar	tigăr-če tigar-če tigr-ić	tigăr-če tigar-če / tigre tigr-ić	tigărč-ence tigar-če / tigr-ence tigr-ić

South Slavic: Summing up

- For the majority of the nouns denoting animals, South Slavic languages do not make a distinction between small (DIM) and young animals (**recall syncretism in inflectional morphology**), that is:
- **young animals = inflectional diminutives**
 - with the suffix **-e** (this is especially true for Bulgarian and Macedonian, e.g. *zajč-e* 'young rabbit & rabbit-DIM' in both languages)
- **young animals = diminutives proper, i.e. derivational diminutives**
 - with the suffix **-če** in Bulgarian, Macedonian and Serbian, e.g. *slon* 'elephant' → young animal / DIM *slon-če*
 - with the suffix **-(č)ić** in Serbian, thus two forms *slon-če* and *slon-čić*
- Diminutives from young animals are derived uniformly, by the suffix **-ence**, in most cases (the rule is without exceptions in Bulgarian)
The very productive diminutive suffix **-ence** is related to the thematic marker ***-nt**.

! No gaps in the paradigms which is maybe due to the extensive syncretism, i.e. forms replace each other and there is no space for gaps.

East Slavic

! Each language derives young animals uniformly

English translation	Animal	DIM of animal	Young animal	DIM of young animal
elephant	R. slon	slon-ik	slon-ënok	slonënoč-ek
	Bl. slon	slon-ik / slon-ičak	slan-iania / slan-ianio	slanian-iatka
	U. slon	slon-yk	slon-en'a	slonen'-atko
lion	R. lev	*	l'v-ënok	l'vënoč-ek
	Bl. lieŭ	*	(i)l'viania / (i)l'vianio	(i)l'vianiatka
	U. lev	lev-yk	lev-en'a	leven'-atko
tiger	R. tigr	tigr-ik	tigr-ënok	tigrënoč-ek
	Bl. tyhr	tyhryk (rare)	tyhr-ania / tyhr.anio	tyhran-iatka
	U. tyhr	tyhr-yk	tyhr-en'a	tyhren'-atko

East Slavic: Russian

! derives young animals by *-onok / -ënok*

English translation	Animal	DIM of animal	Young animal	DIM of young animal
elephant	R. slon	slon-ik	slon-ënok	slonënoč-ek
lion	R. lev	*	l'v-ënok	l'vënoč-ek
tiger	R. tigr	tigr-ik	tigr-ënok	tigrënoč-ek

East Slavic: Belorussian

! derives young animals by *-iania* & *-ianio*

English translation	Animal	DIM of animal	Young animal	DIM of young animal
elephant	Bl. slon	slon-ik / slon-ičak	slan- iania / slan- ianio	slanian-iatka
lion	Bl. lieŭ	*	(i)Ív- iania / (i)Ív- ianio	(i)Ívianiatka
tiger	Bl. tyhr	tyhryk (rare)	tyhr- ania / tyhr- anio	tyhran-iatka

East Slavic: Ukrainian

! derives young animals by *-(en)'a*

English translation	Animal	DIM of animal	Young animal	DIM of young animal
elephant	U.slón	slón-yk	slón-en'a	slónen'-atko
lion	U. lev	lev-yk	lev-en'a	leven'-atko
tiger	U. tyhr	tyhr-yk	tyhr-en'a	tyhren'-atko

East Slavic

! diminutives of animals ≠ young animals

English translation	Animal	DIM of animal	Young animal	DIM of young animal
elephant	R. slon	slon-ik	slon-ěnok	sloněnoč-ek
	Bl. slon	slon-ik / slon-ičak	slan-iania / slan-ianio	slanian-iatka
	U. slon	slon-yk	slon-en'a	slonen'-atko
lion	R. lev	*	l'v-ěnok	l'věnoč-ek
	Bl. lieŭ	*	(i)l'viania / (i)l'vianio	(i)l'vianiatka
	U. lev	lev-yk	lev-en'a	leven'-atko
tiger	R. tigr	tigr-ik	tigr-ěnok	tigrěnoč-ek
	Bl. tyhr	tyhr-yk (rare)	tyhr-ania / tyhr.anio	tyhran-iatka
	U. tyhr	tyhr-yk	tyhr-en'a	tyhren'-atko

East Slavic: Summing up

- East Slavic languages keep young animals and small animals (i.e. diminutives) apart and both groups of nouns follow different derivational patterns.
- Only one suffix (**-onok / -ěnok**) for derivation of young animals in Russian; two suffixes, **-iania** and **-ianio**, in Belorussian; and **-(en)'a** in Ukrainian.
- ! The Russian suffix **-onok / -ěnok** can also derive diminutives, more precisely nouns with meanings similar to diminutives, that do not have anything to do with animals, e.g. *čertěnok* 'imp' from *čěrt* 'devil', *povarěnok*, colloq. style for 'a boy assisting a cook', derived from *povar* 'cook' (Švedova et al. 1980: 201). However, the pattern is not really productive.
- ! Some nouns in Ukrainian that do not denote young animals use the suffix **-en'a** for derivation of plural diminutive forms, e.g. *očen'ata* 'eye-dim-pl', *štanen'ata* 'trousers-dim-pl', *konen'ata* 'horse-dim-pl', *korolen'ata* 'king-dim-pl', *božen'ata* 'God-dim-pl', etc. (based on GRAC (General Regionally Annotated Corpus of Ukrainian), see also Rodnina 1970).

R. & Bl: Gaps in the paradigms

! More gaps in diminutivization

- **No DIM in both languages**

lev 'lion' & *soroka* 'magpie'

- **No DIM in Belorussian**

alień 'deer' & *babior* 'beaver'

- **Rather potential than actual DIM forms**

R. *olen* 'deer' → ?*olen-čik*, *lastočka* 'swallow' → ?*lastočeč-ka*, *aist* 'stork' → ?*aist-ik*, *vorona* 'crow' → ???*voronoč-ka*

Bl. *krumkač* → ?*krumkačyk*

- **Problematic (but attested in older texts) forms for young animals**

R. *obez'jan-ěnok* (from *obez'jana* 'monkey'), *vš-onok* (from *voš* 'louse')

West Slavic: Czech & Slovak vs Polish

English translation	Animal	Small animal = DIM	Young animal	DIM of young animal
elephant	Cz. slon Sl. slon	slůn-ek slon-ík	slon-ě slon-íča	sloň-átko sloníč-atko
	Pl. słoń	słon-ik / słon-iczek	słon-ię / słon-ik	słon-iątko / słon-iczek (rare)
lion	Cz. lev Sl. lev	lv-ík lev-ík	lv-íče lev-íča	lv-íčata levíč-atko
	Pl. lew	*	lw-ię	lw-iątko
tiger	Cz. tygr Sl. tiger	tygř-ík tigr-ík	tygř-e tigr-íča	tygř-átko tigríč-atko
	Pl. tygrys	tygrys-ek	tygrys-ię / tygrys-ek	tygrys-iątko

West Slavic: Czech & Slovak

! different paradigms for small and young animals,
uniform patterns for young animals

English translation	Animal	Small animal = DIM	Young animal	DIM of young animal
elephant	Cz. slon Sl. slon	slůn-ek slon-ík	slon-ě slon-íča	sloň-átko sloníč-atko
lion	Cz. lev Sl. lev	lv-ík lev-ík	lv-íče lev-íča	lvíč-átko levíč-atko
tiger	Cz. tygr Sl. tiger	tygř-ík tigr-ík	tygř-e tigr-íča	tygř-átko tigríč-atko

West Slavic: Polish

! two paradigms for young animals: one like in South Slavic (i.e. young animal = DIM) and one with the suffix *-ię*, i.e. like in West Slavic; however, in contrast to South Slavic, DIM → young animal

English translation	Animal	Small animal = DIM	Young animal	DIM of young animal
elephant	Pl. słoń	słoń-ik / słoń-iczek	słoń-ię / słoń-ik	słoń-iątko / słoń-iczek (rare)
lion	Pl. lew	*	lw-ię	lw-iątko
tiger	Pl. tygrys	tygrys-ek	tygrys-ię / tygrys-ek	tygrys-iątko

Three psycholinguistic experiments

- Stimuli: 15 nouns for exotic animals from **Slovak**
- Participants: 60 students from P. J. Šafárik University (they were not paid for their participation)
- Method:
 - 20 participants were asked to write only the nouns for small animals, i.e. the diminutives
 - other 20 were asked to write only the nouns for young animals
 - still other 20 were asked to write both forms
- If participants did not know forms, they were asked to skip the example and leave the space blank.
- Participants wrote only one derivation per stimulus.

Stimuli used in the experiments

No	English translation	Slovak
1.	<i>elephant</i>	slon
2.	<i>lion</i>	lev
3.	<i>leopard</i>	leopard
4.	<i>giraffe</i>	žirafa
5.	<i>hippo</i>	hroch
6.	<i>crocodile</i>	krokodíl
7.	<i>tiger</i>	tiger
8.	<i>bison</i>	bizón
9.	<i>cheetah</i>	gepard
10.	<i>rhinoceros</i>	nosorožec
11.	<i>ostrich</i>	pštros
12.	<i>koala</i>	koala
13.	<i>panda</i>	panda
14.	<i>cockatoo</i>	kakadu
15.	<i>kenguru</i>	kengura

Slovak: uniform pattern for derivation of young animals by the suffix *-a* (! inflection), exotic animals are also derived uniformly but by the suffix *-iča* (! derivation)

English translation	Animal	DIM of animal	Young animal	DIM of young animal
sheep	<i>ovca</i>	<i>oveč-ka</i>	<i>jahň-a</i>	<i>jahn-iatko</i>
goat	<i>koza</i>	<i>koz-ička</i>	<i>kozl'-a</i>	<i>kozl-iatko</i>
cow	<i>krava</i>	<i>krav-ička</i>	<i>tel'-a</i>	<i>tel-iatko</i>
duck	<i>kačka</i>	<i>kač-ička</i>	<i>káč-a</i>	<i>kač-iatko</i>
rabbit	<i>králik</i>	<i>králič-ek</i>	<i>králič-a</i>	<i>králič-iatko</i>
horse	<i>kôň</i>	<i>kon-ík</i>	<i>žrieb-ä</i>	<i>žrieb-ätko</i>
donkey	<i>osol</i>	<i>osl-ík</i>	<i>osl'-a</i>	<i>osl-iatko</i>
goose	<i>hus</i>	<i>hús-ka</i>	<i>hús-a</i>	<i>hús-atko</i>
turkey	<i>morka</i>	<i>morč-ička</i>	<i>morč-a</i>	<i>morč-iatko</i>
cat	<i>mačka</i>	<i>mač-ička</i>	<i>mač-a</i>	<i>mač-iatko</i>
dog	<i>pes</i>	<i>ps-ík</i>	<i>šteň-a</i>	<i>šten-iatko</i>

Slovak: Exotic animals (examples from a previous slide)

! uniform pattern for young animals by the suffix *-iča*

English translation	Animal	Small animal = DIM	Young animal	DIM of young animal
elephant	slon	slon-ík	slon- iča	sloníč-atko
lion	lev	lev-ík	lev- iča	levíč-atko
tiger	tiger	tigr-ík	tigr- iča	tigríč-atko

Results of the experiments:

Derivational paradigms seem to depend on the task

(Alternative forms are inflection, i.e. derivational morphology is replaced by inflection!)

English	Slovak	Write DIM only	Write both forms/DIM	Write young animal only	Write both forms/young animal Alternatives!
elephant	slon	sloník 20x	sloník 20x	sloníča 20x	slon-íča 16x slôň-a 1x
leopard	leopard	leopardík 19x	leopardík 17x	leopardíča 18x	leopard-íča 11x leopard'-a 2x
hippo	hroch	hrošík 19x	hrošík 20x	hrošíča 18x	hroš-íča 10x hroš-a 3x
cheetah	gepard	gepardík 20x	gepardík 20x	gepardíča 18x	gepard-íča 8x gepard'-a 2x

Results: Slovak derivational paradigms for diminutives and young animals differ in terms of robustness

- Native speakers were more confident when only a single form had to be produced, i.e. a lesser number of paradigmatic gaps in the production of either young animals or diminutives
- When both forms had to be written, more alternative forms (i.e. with an existing but wrong suffix) were produced for young animals:
 - Young animals (more or less, uniform derivational pattern):
 - Task1: Write a single form – 3 instances of alternative forms (out of 15 stimuli)
 - **Task2: Write both forms – 6 instances of alternative forms** (out of 15 stimuli)
 - Diminutives (there is a relatively large set of suffixes for derivation of diminutives, thus alternative forms were expected):
 - Task1: Write one form - 4 instances of alternative forms (out of 15 stimuli)
 - Task2: Write both forms - 2 instances of alternative forms (out of 15 stimuli)
- Although there are alternative patterns for derivation of diminutives and one pattern for derivation of (exotic) young animals, the paradigm for young animals seems to be less robust than that for diminutives
- Transfer from DIM to young animals but not vice versa, e.g. for some speakers the diminutive *koal-ka* derived from *koala* also means 'young koala' (3x) (recall the Polish data)
- This transfer is opposite to what we observed in South and East Slavic where the forms developed from young animals (inflection diachronically) to diminutives (derivation).

Slovak derivational paradigms for diminutives and young animals

- The two **patterns**, the one for derivation of diminutives and the one for young animals, are both **suffixational**, thus no mistakes wrt pattern.
- Statistically, the correct suffix for derivation of young animals is **-a (! inflection)**, i.e. **-a** is the default suffix.
- The **rule for exotic animals**, however, is **more specific** and **overwrites the default by attaching the suffix -iča (! derivation)**. Thus, mistakes wrt rule. (The suffix **-iča** was felt as unproductive by our informant.)
- The different tasks (produce a single form vs. produce two forms) seem to activate the brain differently, which thus led to different outputs, namely for the more difficult task (produce two forms) more subjects “relied on statistics” and preferred the highest weighted option, the default suffix **-a**, to the suffix **-iča**, which is the correct suffix but much less frequent in the system of related paradigms. Recall also that **-iča** cannot be used as a diminutive suffix in Slovak.

Conclusions

- All modern Slavic languages link young animals (historically an inflection class) and diminutives (derivational morphology) but the different languages took completely different paths in the development of those paradigms.
- In South Slavic and Polish, young animal = small animal. However, in South Slavic young animal (inflection) → small animal, i.e. DIM (derivation), while in Polish small animal (derivation) → young animal (inflection).
- In Russian and Ukrainian young and small animals have different derivational paradigms but the suffixes for young animals can be used for derivation of diminutives from nouns which do not mean animals. The process is not really productive in Russian.
- In Czech and Slovak, young animals and small animals differ and one cannot use the suffixes for derivation of young animals as diminutivizers.
- Three psycholinguistic experiments with native speakers of Slovak showed that the paradigm for derivation of young animals in Slovak is less robust than that for derivation of diminutives, which is thus entirely in contrast to what was observed in South and East Slavic languages.
- (More) gaps in the paradigm of diminutives, recall e.g. **lion*-DIM in some of the languages, which can be explained by the fact that diminutives are closer to derivational morphology (derivation is, unlike inflection, not obligatory).

Derivational paradigms: Rules, patterns or neural networks?

Closely related derivational paradigms that link inflection and derivation diachronically, if processed simultaneously, seem to be computed in a manner that reminds a neural network.

Thank you!

stela.manova@univie.ac.at

mitrius@gmail.com

masha.shvedova@gmail.com

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The paradigm of the nt-stem noun **отрочѧ** 'child' **-ѧТ-** < **-ent-**, in the nominative simplifies to **-ѧ**

(Old Church Slavonic Online: https://lrc.la.utexas.edu/eieol/ocsol/50#grammar_1000)

	Singular	Dual	Plural
N	отроч-ѧ	*отроч-ѧТ-ѣ	*отроч-ѧТ-а
A	отроч-ѧ	*отроч-ѧТ-ѣ	*отроч-ѧТ-а
G	отроч-ѧТ-ѣ	*отроч-ѧТ-оу	отроч-ѧТ-ѣ
L	отроч-ѧТ-ѣ	*отроч-ѧТ-оу	отроч-ѧТ-ѣхъ
D	*отроч-ѧТ-и	*отроч-ѧТ-ѣма	*отроч-ѧТ-ѣмъ
I	*отроч-ѧТ-ѣмъ	*отроч-ѧТ-ѣма	*отроч-ѧТ-ѣи
V	отроч-ѧ	*отроч-ѧТ-ѣ	*отроч-ѧТ-а