Modelling the acquisition of Polish verb inflection

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The study of morphologically complex languages, such as Finnish, Serbian, or Spanish, has shown that the acquisition of inflectional morphology is affected by a range of factors, such as frequency of exposure and phonological neighbourhood density (PND), i.e. inflectional class size (Aguado-Orea & Pine, 2015; Mirković et al., 2011; Räsänen et al., 2015). Connectionist models provide an exposure-based learning mechanism that is sensitive to low-level statistical properties of the input and, thus, implement the constructivist idea that linguistic knowledge develops gradually on the basis of exposure.

We present a neural network model that was trained on Polish present tense verb inflection together with preliminary data on an elicited production experiment in Polish.

The empirical study tested 51 Polish-speaking children between 35 and 60 months of age on the production of inflected present-tense verb forms in six person/number contexts. The empirical results show an increase in accuracy for higher form frequency ($\beta = 0.37$, SE $= 0.09$, $p < 0.0001$) and for higher PND ($\beta = 0.078$, SE $= 0.063$, $p = 0.037$), conforming with previous results on Serbian and Finnish.

In order to model the learning process, a three-layer neural network model was presented with a phoneme representation of the verb stem (e.g., rɨsuj for *rysować*, 'to draw') together with a code for one out of six target person/number contexts and was trained to produce the complete inflected verb form on the output layer (e.g., rɨsujɛʃ for 2sg). The network was trained on 2923 different inflected present-tense verb forms (1326 verbs) from a Polish child-directed speech corpus (Haman et al., 2011), presented probabilistically according to their individual frequency.

Performance was analysed over five trained networks within a range from an intermediate to a near-expert level between 100 000 and 3 000 000 corpus sweeps (epochs). The results are summarised in Table 1 and Figure 1. A cluster analysis of the network's internal representations revealed that the model relied on slightly different groupings of the input than the inflectional classes that Polish grammar dictionaries suggest. Inflectional PND was nevertheless a significant predictor of the network's performance alongside the corpus frequency of the inflected form. These results are in agreement with our empirical findings.

In addition, the modelling results show an interaction between form frequency and PND in the way that low-frequency forms benefited more from PND than high-frequency forms (see Figure 1A). We did not find this in our experimental results. However, there is some evidence for this kind of interaction from a previous verb inflection study in Finnish by Räsänen et al. (2015). Furthermore, we found that (a) the model made more errors for low-frequent person/number contexts (e.g., 3pl vs. 3sg, see Figure 1B), these errors often involved (b) producing the correct P/N context but from a different inflectional class (overgeneralisation) or (c) producing a higher-frequency form (e.g., 3sg instead of 3pl), and that (d) the effect of PND decreased over training. The network's error patterns and internal representations will be discussed in relation to empirical findings.

Taken together, the results of experiment and modelling support the feasibility of input-based acquisition of verb inflection and show some insight into the way information in the input might be used over the course of learning.

	Coef β	SE(β)	z value	Pr($>|z|$)
(Intercept)	5.24	0.10	52.67	< 0.001
log(Form freq.)	1.14	0.04	26.46	< 0.001
log(P/N freq.)	0.41	0.03	16.26	< 0.001
log(PND)	0.45	0.08	5.52	< 0.001
Epoch	3.23	0.08	40.88	< 0.001
log(Form freq.):log(PND)	0.13	0.03	5.18	< 0.001
log(Form freq.):Epoch	0.64	0.03	20.06	< 0.001
log(PND):Epoch	0.15	0.05	2.91	0.004

Table 1: Neural network performance: Results of a logistic mixed-effects regression with network output accuracy as dependent variable and network and verb as random intercept. Predictors were scaled and centred at zero.

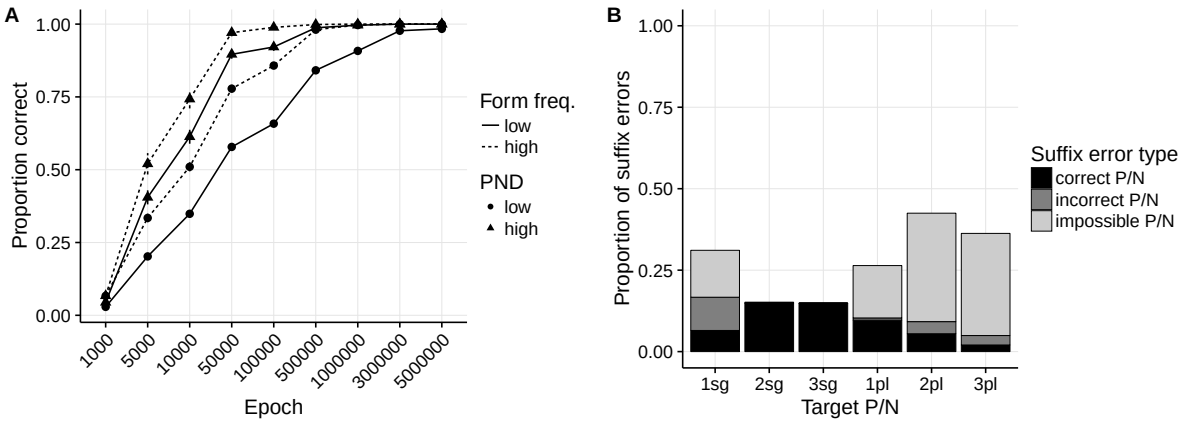

Figure 1: **A:** Network output accuracy over epochs by target form frequency and phonological neighbourhood density of hidden layer clusters. **B:** Proportion and type of suffix errors by target P/N produced by the network at 500 000 epochs. 'Correct P/N' indicates overgeneralisation.

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