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Simulating Over-regularized plurals in Williams Syndrome

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1. Introduction

Aim

This study compares two morphological theories regarding the formation of the English plural based on connectionist modeling of over-regularized plurals observed with individuals with Williams Syndrome (henceforth SW).

2. Development study of pluralization

- In Clahsen and Almazan (2001), they investigated 4 children diagnosed with WS.
- Mental ages of individuals with WS were measured based on the scores on the Wechsler Intelligence Scale for Children - IIIuk (Wechsler 1992).
- The data of control groups are taken from Gordon (1985) and Christian (1997), and crucially the controls are grouped based on their chronological age.
- Table 4 shows the result of the plural formation experiment.

Table 4
Percentages of correct plurals and overregularizations

Group	Correct regulars	Correct irregulars	Overregularizations
WS5	100%	28.5%	50%
WS7	100%	50%	35.7%
CTR5	100%	96%	4%
CTR7	100%	98.5%	1.4%

- WS children produced fewer correct forms of irregular plurals than control group.
- WS children tends to wrongly apply regular plural formation to singular nouns that require irregular plural forms.

- In Zukowski's (2005) experiments, participants include 12 children and adolescents with WS, 12 typically developing children and typically developing adult college students.
- Crucially, each WS participants is matched for a typically developing child based on their mental age measured by the Kaufman Brief Intelligence test.
- The result is summarized in table 5.

Table 5. Mean percentage of production of different noun forms in response to the plural prompt: Participants with Williams syndrome and child controls.

	Objects with irregular nouns (e.g., *mouse*)						Objects with regular nouns (e.g., *rat*)						Objects with nonsense nouns (e.g., *crote*)					
	WS			Control			WS			Control			WS			Control		
Response	*M*	No.	*SD*	*M*	No.	*SD*	*M*	No.	*SD*	*M*	No.	*SD*	*M*	No.	*SD*	*M*	No.	*SD*
Regular plural (e.g., *mouses, rats, crotes*)	25.4	15	33.1	45.3	26	33.9	**94.8**	91	11.3	**92.7**	89	19.6	**86.5**	82	18.0	**87.5**	82	27.0
Irregular plural (e.g., *mice*)	**29.2**	17	24.6	**40.8**	24	34.1												
Singular (e.g., *mouse, rat, crote*)	45.4	25	34.9	13.9	7	22.8	5.2	5	11.3	7.3	7	19.6	13.5	13	18.0	12.5	12	27.0

Note. Correct responses are shown in boldface.

- As can be seen in table 5, the largest difference between groups is observed in the rates of correct plural forms in the irregular noun condition.
- The result shows that rates of correct plural forms of WS participants in irregular nouns condition were much lower in comparison to control group (M = 29.2 vs. M = 40.8)
- However, participants with WS produced fewer over-regularizations than the control group (15 vs. 26).

- It is important to note that both previous studies are consistent in that the means of production of correct irregular plural forms in individuals with WS never exceeding chance level. **[Fact 1]**

- On the other hand, when we think about over-regularization, only Clahsen and Almazan's (2001) study shows the significant differences between WS participants and control groups.
- As pointed out by Zukowski (2005), the discrepancy between these two studies regarding over-regularization may come from the data of the control group.
- In Zukowski's experiments, control groups are matched to WS group in terms of their mental age, whereas Clahsen and Almazan (2001) compare participants with WS grouped based on their mental ages with controls grouped by chronological ages.

- Whatever the account, based on the data given in table 5, we can conclude that individuals with WS produce less over-regularization of irregular nouns. Rather, they tend to use a singular form even in environment where a plural form is required. **[Fact 2]**

3. Theoretical approaches to irregular plurals

3.1 Words and Rules approach

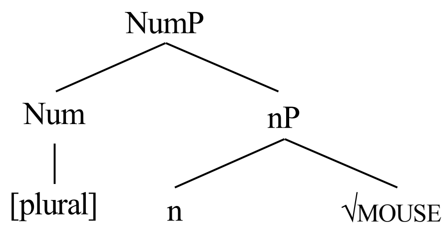
- Clahsen and Almazan (2001) assume that nouns contain their information about plural forms.
- Their assumption is given in (7), where information about plural forms is stored as a sub-node of lexical items.
- As shown in (7), they assume that nouns in general are listed as their singular forms in the lexicon.

(1) [maus] → [… ai …]$_{+plur}$

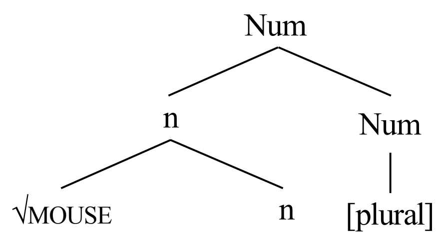
- They assume that rule-based formation of regular plural forms contains at least two steps; retrieval of lexical entry (i.e. singular form) and application of inflectional rules (i.e. pluralization).
- Therefore, under their proposal, over-regularization of plurals observed in individuals with WS is analyzed as a selective impairment in retrieving the relevant sub-node information from the lexicon.

- Their analysis can be restated within the framework of Distributed Morphology.
- Irregular plurals can be analyzed based on readjustment rules.
- Suppose that the English plural nouns have the structure like (3a).
- After the head incorporation, we obtain the structure like (3b).

(2) a.



b.



- Since we have the root √MOUSE in (3b), the [plural] feature on the Num head must be realized as the null allomorph.
- Furthermore, since the root √MOUSE is c-commanded by the [plural] feature, the root √MOUSE is changed into √MICE via a phonological readjustment rule.

- Since the readjustment rule is conditioned by the [plural] feature and a root, it can be treated on a par with the pluralization rule discussed in Clahsen and Almazan (2001).

- For both analyses, irregular plurals start with its singular form, and will be realized based on a specific condition on its plural form.

3.2 Siddiqi (2009)

- Siddiqi (2009) points out that the readjustment approach includes a strange interdependency.
- This is because the [plural] feature and a root mutually regulate their surface forms under the readjustment approach. This will cause a chicken-and-egg problem.
- Moreover, the readjustment analysis cannot capture the contrast between regular and irregular plurals in nominal compounding.

(3)	a.	rat-eater	[singular]
	b.	* rats-eater	[regular plural]
(4)	a.	mouse-eater	[singular]
	b.	mice-eater	[irregular plural]

- As shown in (3b), regular plural forms cannot appear in the non-head position of nominal compounds.
- In contrast, irregular plural forms such as "mice" can be used as a non-head element as in (4b).

- Under the readjustment analysis, there is no structural difference between regular and irregular plurals.
- Therefore, it is difficult to account for the contrast between (3b) and (4b) under this analysis.[1]

- Given this, Siddiqi (2009) proposes that a singular form and an irregular plural form compete each other with respect to the Vocabulary Insertion rule.
- Siddiqi (2009) also adopts the structure (5b). However, he assumes that the Vocabulary Insertion rule is applied to the feature bundle which is created by another morphological operation called as Fusion.
- As a result of Fusion, a root, a nominalizer and the Num head results in one node to which the Vocabulary Insertion rule applies.
- This Vocabulary Insertion rule obeys the economy principle defined below.

(5) *Minimize Exponence*
The most economical derivation will be the one that maximally realizes all the formal features of the derivation with the fewest morphemes. (Siddiqi 2009)

- Crucially, a singular form and an irregular plural form compete each other with respect to the Vocabulary Insertion rule under Siddiqi's (2009) analysis.
- For example, both "mouse" and "mice" can be counted as candidates of the target node, as shown in (6).

(6) a. Target Node: √MOUSE, [n], [plural] ← "mice" is inserted instead of "mouse".
b. Target Node: √MOUSE, [n] ← "mouse" is inserted instead of "mice".

- It is important to keep in mind that under Siddiqi's (2009) analysis, irregular plurals must be stored as a candidate for the Vocabulary Insertion rule.
- Singular forms and Irregular plural forms have the same status with respect to the Vocabulary Insertion rule.

[1] Notice that if we assume several levels within the model of lexical phonology and morphology, like Kiparsky (1982), Clahsen and Almazan's (2001) original analysis might capture the contrast between (3b) and (4b). However, this line of approach has been criticized for the level ordering, which is not supported in other models of grammar. See Siddiqi (2009) and references therein.

4. Connectionist modeling: Simulations of plural production in Williams Syndrome

- The overall design of our simulations can be divided into two paradigms.
- Each of the simulation paradigms is based upon one of the competing linguistic theories surrounding the pluralization of regular and irregular English nouns.
- With regards to atypical development, parametric manipulations to the number of hidden units will be introduced.
- This manipulation is intended to replicate deficiencies in working memory that have been shown in individuals with Williams Syndrome (Rhodes, Riby, Fraser, & Campbell, 2011).
- We hypothesize that models with fewer hidden units will show a pattern of performance similar to that of these individuals. In particular, we expect to see a number of incorrect forms of plurals of the irregular nouns.

- Each model paradigm shares the same three primary components.
- The first component is the input, which is intended to represent the accumulation of experiences that one has had with the English plural.
- The second component consists of the hidden units, which is intended to represent working memory.
- The third component is the phonological output, which is intended to represent what is actually said aloud.

- We include a total of 30 nouns in their singular and plural forms as output from Buck-Gengler, Menn, and Healy (2004).

Table 1
Stimulus nouns (singular and plural forms) used in Experiments 1 and 2, by type

Irregular noun		Regular noun			
		Semantic match		Form match	
Singular	Plural	Singular	Plural	Singular	Plural
mouse	mice[a]	rat	rats[a]	nail	nails
tooth	teeth[a]	bead	beads[a]	tape	tapes
foot	feet[a]	hand	hands[a]	hat	hats
goose	geese[a]	duck	ducks[a]	bell	bells
man	men[a]	baby	babies[a]	letter	letters
louse	lice	fly	flies	knight	knights
child	children	doll	dolls	chain	chains
ox	oxen	horse	horses	ax	axes
woman	women	monkey	monkeys	watch	watches
fungus	fungi	fern	ferns	frog	frogs

[a] From Gordon (1985).

- In order to minimize the computational requirements of the simulations, we parameterize the output representations.
- These representations are broken down into three elements.
- The first element represents the root form of each noun. These will be sparsely coded, so will require a total of 30 nodes, one for each root word. For example, if the first root word is *rat* it would be coded as {1, 0, 0, ...} in the network. This allows for these to be represented as individual root words that do not overlap with the other root words in the network.
- The second element indicates whether and what type of change should be made to the root word in order to generate the plural form (Table 3). There are six irregular plural forms and one quasi-regular plural form that require modification to the body when spoken aloud. As such, we need seven additional nodes to represent these changes, one for each change. The change from *ou* to *i* in generating the plural mice from the singular mouse is coded as {1, 0, 0, 0, 0, 0, 0} in the network. As true regular plurals do not require a change in body before adding a final *-s*, they would be coded as all zeroes in this part of the network.
- The third element will consist of a single node, representing whether or not the plural -s should be added to the end of the word. In total, an output representation will consist of 38 nodes, of which only two should be activated, three in the case of quasi-regular plurals, in response to the input (Figure 6).

Singular	Plural	Change
mouse	mice	OU => I
tooth	teeth	OO => EE
woman	women	A => E
child	children	+REN
ox	oxen	+EN
fungus	fungi	US => I
watch	watches	+ES
rat	rats	+S

Table 3. Examples of English pluralization

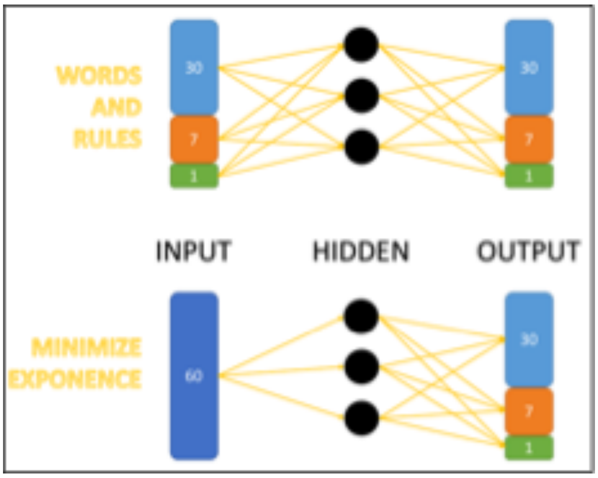


Figure 6. Proposed model paradig

5. TBA

References

Buck-Gengler, C. J., Menn, L., & Healy, A. F. (2004). What “mice trap” tells us about the mental lexicon. *Brain and language*, *90*(1), 453-464.

Clahsen, H., & Almazan, M. (2001). Compounding and inflection in language impairment: Evidence from Williams syndrome (and SLI). *Lingua, 111*, 729–757.

Kiparsky, P. (1983). Word-formation and the lexicon. In *Proceedings of the 1982 mid-America linguistics conference* (Vol. 3, p. 22). Lawrence: University of Kansas.

Siddiqi, D. (2009). *Syntax within the Word: Economy, Allomorphy, and Argument Selection in Distributed Morphology*. Amsterdam/Philadelphia: John Benjamins Publishing Company.