Born To Be Gradient

Predicting Exceptions of Compound Tensing in Korean

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INTERACTION OF GRAMMATICAL BUILDING BLOCKS

Nutshell

How to deal with exceptionality ?

- **Compound Tensing (CT)** in Korean unexpectedly fails to apply to certain Noun-Noun compounds (Jun 2001; Zuraw 2011; Ito 2014; Kim 2016).
- Should this exceptionality be dealt with the grammar or through lexicalization ?

Gradient Symbolic Representation

- I argue for an account in terms of **Gradient Symbolic Representations** (**GSR** ; Smolensky and Goldrick, 2016, Rosen 2016).
- The intrinsic property of GSR captures **the nature of gradient inclination for CT**, which is impossible with other systems.

Learnability

- An **error-driven algorithm** also shows tat the scalar activities are learnable.

Data

Laryngeal contrasts

- Korean has a three-way distinction in terms of laryngeal contrast in obstruents

(1)

(a)	/pul/	→ [**p**ul]	'fire'
(b)	/p^{h}ul/	→ [**p^h**ul]	'grass'
(c)	/p'ul/	→ [**p'**ul]	'horn'

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Compound Tensing

- **Compound Tensing (CT)** :
  When a **compound** consist of two nouns, W_A and W_B, initial plain obstruents of W_Bs undergo junctural processes including **obstruent tensification**.

(2)

(a)	/hɛ/ + /pic/	→ [hɛ.**p'**it]	post Vowel
(b)	/kailɨl/ + /pi/	→ [ka.ɨl.**p'**i]	post Lateral
(c)	/pom/ + /pi/	→ [pom.**p'**i]	post Nasal
(d)	/pok/ + /pi/	→ [pok.**p'**i]	post obstruent

Exceptionality

- 23% noun-noun compounds exceptioanlly does not undergo CT in a random fashion
(Jun 2015; Zuraw 2011; Ito 2014; Kim 2016).

(3)

	Regular Pattern		Exception		
(a)	/hɛ/ + /pap/	→ [hɛ.**p’**ap]	(e)	/koŋ/ + /pap/	→ [koŋ.**p**ap]
(b)	/hɛ/ + /kuks’u/	→ [hɛ.**k’**uks’u]	(f)	/koŋ/ + /kuks’u/	→ [koŋ.**k**uk.s’u]
(c)	/pipim/ + /pap/	→ [pi.pim.**p’**ap]	(g)	/pipim/ + /kuks’u/	→ [pi.pim.**k**uk.s’u]
(d)	/koŋ/ + /karu/	→ [koŋ.**k’**a.ru]	(h)	/hɛ/ + /toci/	→ [hɛ.**t**o.ci]

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Gradient Pattern of Tensing

- The compound tensing exhibit continuum of **gradient preferences** depending on **both the conjuncts $\mathbf{W}^A$, $\mathbf{W}^B$** in the compound.

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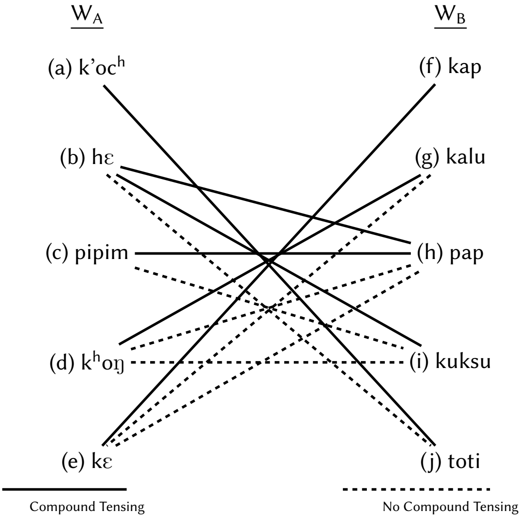
Gradient Pattern of Tensing

(6) Gradient patterns for compounding tensing



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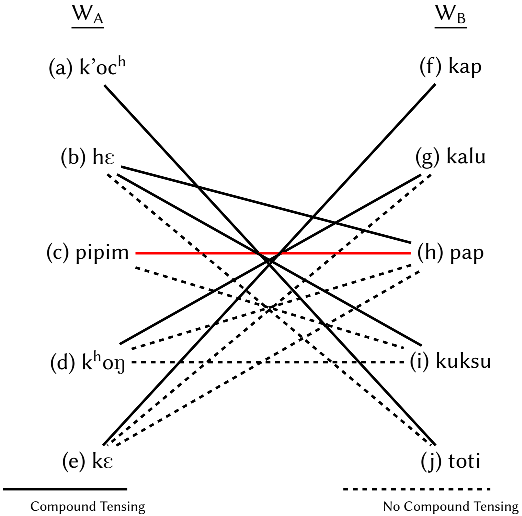

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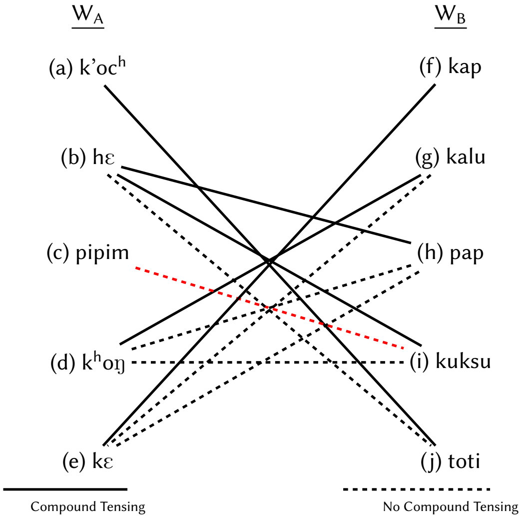


Gradient Pattern of Tensing

There is no way in standard rule-based (Chomsky and Halle, 1968) or Optimality theory frameworks (Prince and Smolensky, 1993) where features are binary or privative, to give a word a feature that will determine its precise degree of preference for CT .

Proposal

Gradient Symbolic Representation

- Symbols in a linguistic representation can have **different activities** :

  'Symbols are discrete but their degree of presence in a given linguistic representation is continuously gradient' (Smolensky and Goldrick, 2016, 2)

- (Continuous) Numerical strength from 0 to 1 can be associated to input

- Output elements are all fully active (1) as descrete forms

Gradient Symbolic Representation

- The underlying structure is grammatically computed inside **Harmonic Grammar** (Legendre et al. 1990)
- It can predict lexical exceptions :
  - Elements in the underlying representation of a morpheme can be **too weak** to undergo/trigger a certain process
  - Elements associated with different activity can be **strong enough** to undergo/trigger the same process

Claim

- I suggest that each edge of nouns in Korean may have **floating feature [cg]** (Zoll 1996) with **gradient activitity** in the underlying structures (Rosen 2016, 2018)

(7)

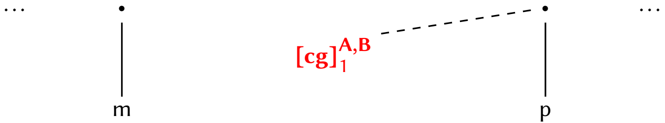
… • • …

m $[\mathrm{cg}]^{A}_{0.4}$ $[\mathrm{cg}]^{B}_{0.2}$ k

Claim

- CT occurs by the **coalescence** of two stem-specific, partially activated floating [cg] features and **docking** to the root node

(8)



Claim

- Only when the additive combination of these features $[cg]^{A,B}$exceeds some threshold Σ does tensing occur.

(9) A hierarchy of 5-level of activation values for compounding tensing

$[cg]_A$ / $[cg]_B$	0 ————————————-1				
0	✗	✗	✗	✗	✓
	✗	✗	✗	✓	✓
	✗	✗	✓	✓	✓
	✗	✓	✓	✓	✓
1	✓	✓	✓	✓	✓

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	✗	✗	✓	✓	✓
	✗	✓	✓	✓	✓
1	✓	✓	✓	✓	✓

Constraints

- MAX[cg] : Input must have output correspondents.
  It **rewards** underlying activity that makes it to the surface.

→ i.e., the more strength the feature bears, the more rewards it induces when it realizes

- IDENT[cg] : The specification for the feature [cg] of an input segment must be preserved in its output correspondent.

→ i.e., It **penalizes** the feature change

- UNIFORMITY[cg] : No feature [cg] in the output has multiple correspondents in the input.

→ i.e., 'No coalescence'

Optimization

- This analysis accounts for the gradient nature of CT.

- The Harmony of the representation τ is :

(10) $$H(r) = 1 \cdot \mathbb{C}_{\text{Max[cg]}}(r) - 0.6 \cdot \mathbb{C}_{\text{Ident[cg]}}(r) - 0.1 \cdot \mathbb{C}_{\text{Uniformity[cg]}}(r)$$

- The candidate with maximal harmony in its candidate set is the optimal output

Optimization : Compound Tensing

W_A : /pipim/ - τ : 0.4, W_B : /pap/ - τ : 0.4

(11) *T_1. pipim + pap → [pi.pim.**p'**ap]*

… • m $[cg]^{x}_{0.4}$ $[cg]^{y}_{0.4}$ • p …	MAX ([c.g]) $w = 100$	IDENT ([c.g]) $w = -60$	UNIFORMITY ([c.g]) $w = -10$	H
O_1 : … • m • p …				0
☞ O_2 : … • m $[cg]^{x,y}_{1}$ • p …	(0.4+0.4)	1	1	10

- The sum of additive feature [cg] from two conjuncts are **strong enougth** to undergo CT

Optimization : No Compound Tensing

W_A : /pipim/ - τ : 0.4, W_B : /kuksu/ - τ : 0.2

(12) *T_2. pipim + kuksu → [pi.pim.**k**uk.s'u]*

… m $[cg]^x_{0.4}$ $[cg]^y_{0.2}$ k …	MAX ([c.g]) $w = 100$	IDENT ([c.g]) $w = -60$	UNIFORMITY ([c.g]) $w = -10$	H
☞ O_1 : … m k …				0
O_2 : … m $[cg]^{x,y}_1$ k …	(0.4+0.2)	1	1	−10

- The total sum of the feature [cg] of 'pipim' and 'kuksu' is **too weak** to undergo tensification.

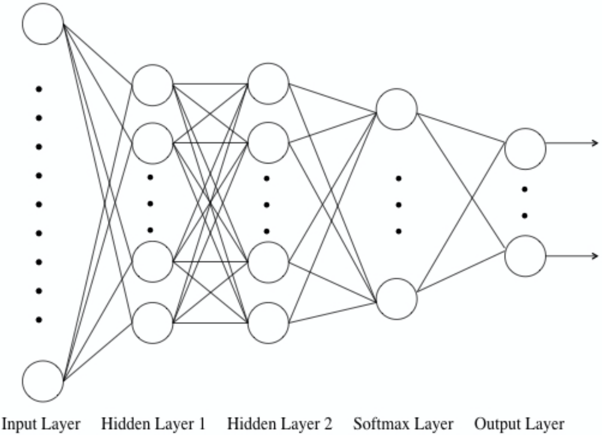
Why Gradience?

Not only do words that occur as **the second conjunct** of a compound exhibit gradient preferences for [cg], but **the first conjunct** in the compound also arguably exhibits the same kind of **gradient preference for triggering tensing** in the word that follows it.

Learnability

The error-driven learning algorithm

(13) An Architecture of Convolutional Neural Network



The error-driven learning algorithm

Step 1 : Initialization

1. A learning algorithm was trained through Convolutional Neural Network (Mikolov et al. 2013)
   - It consists of 2 hidden and 1 softmax layers
2. Activation levels for [cg] of the W^A s and W^Bs were initialized at 0.5
3. Constraints MAX and IDENT were initialized with unit values
4. UNIFORMITY and LINEARITY have fixed values
5. The threshold levels for the sum values of [cg] for compounds were set at 0.7

The error-driven learning algorithm

Step 2 : Iteration

1. The compounds [W^A+ W^B] are **evaluated** on each iteration to check whether each gross effect of CT is correctly derived;
   - will get a **reward** +10 if the correct pattern is derived,
   - will get a **penalty** -5 if the wrong pattern is derived

2. When two coalescing activations [cg] require **adjusting**,
   - It randomly refills the both values of [cg] by either decrementing or incrementing them (a stepsize of 0.05)
   - MAX and IDENT adjust their weights slightly adjusted through a simulated-annealing process (De Vicente et al. 2003) [1]

Step 3 : Convergence

- After 16533 iterations (i.e., when the algorithm can predict all the training set data of CT corretly) the training of this learning was converged.

1. with a decaying temperature T and random Gaussian noise N with m = 0 and $s.d.$= 0.05

Results

Results	
Average of iterations	32
Final Value of MAX	1.121
Final Value of IDENT	0.69
The number of activation levels for W^A	5
The number of activation levels for W^B	5

Conclusion

Conclusion

1. This **GSR analysis** can predict all the patterns of exceptional non-undergoer of Compound Tensing successfully without any redundancy rules
2. The intrinsic property of GSR enables the elements to bear a scalar strength and to **capture the lexical exception of alternation** in the same context
3. Although the distinction is not visible on the surface, there are reasons to believe that obstruents in Korean has diverse patterns of different underlying structures with a **gradiently active feature [cg]**
4. The learning algorithm also supports that this scaler grammar is **learnable**

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