Paradigm uniformity bias in the learning of Korean verbal inflections

Abstract
This study explores the role of a bias against alternations, favoring uniform paradigms (Hayes 2004; McCarthy 1998), in the acquisition of Korean verbal inflections. Paradigm uniformity bias has been proposed in a constraint-based phonological framework, but has rarely been supported by corpus-external evidence. This paper provides experimental evidence for paradigm uniformity bias from four- to seven-year-old Korean children learning their native language phonology. Experiment 1 demonstrates that children alter morphological structures in order to produce non-alternating verb forms. Experiment 2 shows that the tendency to adjust morphological structures is rooted in children's preference for uniform paradigms, not in their ignorance of alternations. The results suggest that paradigm uniformity bias plays a role in forming children's preferred production patterns, which favor non-alternating forms even after they have acquired adult-like knowledge of the patterns of alternations.
Keywords: alternations, paradigm uniformity, learning bias, Korean, language acquisition

1. Introduction

Phonological learning involves discovering phoneme inventories, phonotactic patterns, and alternations. Experimental and computational studies investigating how learners perform these learning tasks show discrepancies between the outcomes of learning and the statistical properties of the input. For example, learners apparently learn some phonological patterns in language data perfectly while being unable to learn others, and they may undergeneralize or overgeneralize the statistical properties of a certain part of the data. One interpretation of such discrepancies between learning outcomes and input is that learners bring learning biases to the tasks of phonological learning (Moreton 2008; Wilson 2006).

Within the traditional Optimality Theoretic framework for phonology (OT; Prince and Smolensky 1993, 2004), the proposal for a learning bias is based on the following assumption: human learners are equipped with a set of universal constraints, and the rankings of the constraints predict the learnability of phonological patterns. A strong view of this thesis is that patterns not predicted by the interactions of the ranked constraints are outright unlearnable (Becker, Ketrez, and Nevins 2011). However, other studies suggest instead an approach based on learning bias that some patterns may be harder to learn than others, or that learners are more likely to ignore certain patterns (Moreton 2008; Hayes et al. 2009).

Work on phonological learning has mainly focused on two types of learning biases. First, it has found that learners more readily acquire simple or general patterns than complex or specific ones (Pater and Moreton 2012). Simplicity or generality is defined in terms of the number of features that participate in phonological processes; when an alternation involves more featural changes, learners have more difficulty acquiring the pattern (Peperkamp et al. 2006; Skoruppa, Lambrechts, and Peperkamp 2011). Likewise, when a phonological pattern requires more features to define it, learners have a harder time acquiring the pattern (Cristià and Seidl 2008; Pycha et al. 2003; Saffran and Thiessen 2003). For instance, Saffran and Thiessen (2003) found that English-learning 9-month-olds learned a pattern distinguishing [p t k] from [b d g] better than a pattern distinguishing [p d k] from [b t g]. The former pattern is more general and simple in that the sets are distinguished by a single phonological feature. Second, investigators have suggested that patterns that have phonetic motivations are easier to learn than those that do not. This type of bias is "substantive bias" according to Wilson

(2006). For instance, Wilson (2006) found that participants trained in velar palatalization before [e] generalized the pattern to apply before [i] in a test session, while those trained in velar palatalization before [i] did not generalize to the [e] context. This asymmetry can be accounted for by the fact that velars are more similar to palato-alveolars when they occur before [i] than when they occur before [e]. While studies systematically looking for a simplicity bias have found evidence supporting it, studies testing a bias related to phonetic motivation have had mixed results: some report supporting evidence (Baer-Henney and Vijver 2012; Carpenter 2010; Wilson 2006; Skoruppa, Lambrechts, and Peperkamp 2011; Hayes et al. 2009) while some report no difference in learnability between phonetically better supported and less supported patterns (Pycha et al. 2003; Wilson 2003; Skoruppa and Peperkamp 2011). (See Pater and Moreton (2012) and Moreton and Pater (2012) for overviews of the simplicity bias and the substantive bias.)

This paper focuses on another learning bias, which is underexplored in the current literature: paradigm uniformity bias. The idea of paradigm uniformity has a long tradition in historical phonology, and there is also a long tradition of theorizing diachronic changes toward uniform paradigms (Kiparsky 1974, 1978). Within OT, the idea has been formalized in terms of Output-to-Output Faithfulness constraints (Benua 1997, 2000; Burzio 1998; Kenstowicz 1997; Steriade 2000), which require phonological similarities between the surface forms of morphologically related words. Experiments in this study test natural phonological acquisition and the results show that non-alternating paradigms are expected by child learners. Based on this finding, I argue that Output-to-Output Faithfulness constraints are undominated in the initial state of learning (Hayes 2004; McCarthy 1998). The following section discusses paradigm uniformity bias in detail.

2. Background

2.1. Paradigm uniformity bias in OT

This study focuses on the learning stage when learners start to understand morphological constraints and paradigms. McCarthy (1998) and Hayes (2004) argue that learners prefer morphological paradigms without phonological alternations, or paradigm uniformity, at this stage. Within OT, this bias can be formalized in terms of Faithfulness constraints. Forms exhibiting alternations violate two types of faithfulness constraints: Input-Output Faithfulness (IO-Faith hereafter) constraints, which require that surface forms match their corresponding underlying forms, and Output-Output Faithfulness (OO-Faith hereafter) constraints, which demand identity among morphologically related surface forms. In principle, prioritizing either type of faithfulness constraint could bias a learner in favor of grammars that do not produce alternations. However, following work on the learnability of constraint-based grammars (Hayes 2004; Jesney and Tessier 2011; Prince and Tesar 2004; Tesar and Smolensky 2000), this paper assumes that it is not IO-Faith constraints that are prioritized to favor uniform paradigms, because this would incorrectly predict unattested contrasts and raise subset issues in learning. (See Tessier 2012 for details of learnability issues when IO-Faith constraints are prioritized.) Instead, OO-Faith constraints are assumed to be prioritized to favor paradigms with no alternations.

The high ranking of OO-Faith constraints is needed for the learning of phonological patterns in derivational paradigms as well as in inflectional paradigms. McCarthy (1998) lays out the logic of how the high ranking of OO-Faith constraints allows learning of some Morpheme

Structure constraints (Halle and Jones 1959; Stanley 1967) found in derivational morphology. For example, English in general lacks morpheme-internal consonant-[h] sequences (*[CONSONANT-H]), but such sequences can be derived through affixation, as in *knigh[th]ood* and *ma[nh]ood*, and through compounding, as in *alpe[nh]orn* and *jac[kh]ammer*. In order to learn that the realization of the consonant-[h] sequence is possible in derived forms, learners need to assume a faithfulness constraint that requires the segments in each morpheme to have output correspondence in a derived word (Max-OO), and to rank it higher than the relevant markedness constraints that otherwise ban such sequences (*[CONSONANT-H]). An example constraint ranking deriving the correct form of *ma[nh]ood* is provided in (1).

(1) Example 1: The grammar of OO-Faith >> Markedness

[mɛn]+[hʊd]	MAX-OO	*[CONSONANT-H]
☞ [mɛnhʊd]		*
[mɛhʊd]	*!	
[mɛnʊd]	*!	

Another argument for paradigm uniformity in learning derivational paradigms is made by Hayes (2004). General phonotactic patterns can be overridden in some allophones in order to maintain paradigm uniformity. The learning of such allophones is possible when faithfulness constraints regulating the relation between the base and the derived words are assumed to be undominated. For instance, in some English dialects, the diphthong [aɪ] is raised to [ʌɪ] before voiceless obstruents as in *write* [ɹʌɪt], but is [aɪ] otherwise as in *time* [tʰaɪm]. However, when a form is derived from a base whose corresponding vowel is [ʌɪ], the raised [ʌɪ] is retained in the derived form even before a voiced flap as in *writer* [ɹʌɪɾɹ̩], not [ɹaɪɾɹ̩]. In other words, *writer* is realized with a raised diphthong [ʌɪ] on the basis of the raised diphthong in the base form *write* [ɹʌɪt]. When children learn that *writer* is derived from *write*, they will assume that the diphthongs in the base *write* and the derived form *writer* are identical, and will thus pronounce *writer* as [ɹʌɪɾɹ̩]. In this case, faithfulness constraints regulating diphthong quality (e.g., IDENT[LOW]-OO: any correspondent of a base segment specified as low must be low in the derived forms) should *a priori* outrank a relevant markedness constraint banning [ʌɪ], as in (2). (See Chomsky and Halle 1968 for an alternative analysis.)

(2) Example 2: The grammar with OO-Faith >> Markedness

/ ɹʌɪt +ɹ̩/ base: [ɹʌɪt]	IDENT[LOW]-OO	*ʌɪ
ɹaɪɾɹ̩	*!	
☞ ɹʌɪɾɹ̩		*

According to paradigm uniformity bias hypothesis, learners initially (i.e., prior to receiving any data) assume a grammar as in (1) and (2) where OO-Faith constraints dominate markedness constraints. One prediction of this hypothesis is that even if alternations apply consistently in the target language, learners may initially produce non-alternating forms that are unlike what they have heard. In fact, this phenomenon has been observed both in L1 acquisition (Kazazis 1969) and artificial grammar experiments (Tessier 2012; White 2013; Wilson 2003, 2006). Kazazis (1969) reports one four-year-old child's production error during the course of learning inflectional paradigms of Modern Greek. The error consisted of generalizing one form of the verbal stem throughout a verb's paradigm; the child incorrectly

produced ['exete] 'you-pl. have' on the basis of ['exo] 'I have', while the correct second person plural form of 'have' is ['eçete]. Hayes (2004) points out that this data is notable because the sequence [xe] found in the child's production form ['exete] is not allowed in Modern Greek. Given that the child had no chance to hear the illegal [xe] sequence from adults, a markedness constraint banning [xe] should have been at the top of the constraint hierarchy. Yet the [xe] sequence was produced by the child. This outcome can be understood when we assume that the OO-Faith constraints regulating the [x]/[ç] distinction were *a priori* ranked even higher than the markedness constraint *[xe], which enforces a phonotactic restriction in Modern Greek. Bernhart and Stemberger (1998) also suggest that "some faithfulness constraints being ranked higher than in the target adult language " (p. 636). They specifically argue that the faithfulness constraints high in the child language are the ones regulating the match between morphologically related forms, supporting paradigm uniformity bias in child phonology.

Despite some evidence for paradigm uniformity bias, no research has provided systematic evidence from natural phonological acquisition. This study tests the predictions of paradigm uniformity bias hypothesis by focusing on the learning of inflectional paradigms. Specifically, the study investigates native-Korean-speaking children's learning of inflected verb forms. I will show that children produce a variety of verb forms that deviate from the correct adult forms and that a unified pattern across children's production can be best understood by assuming a ranking of constraints in the initial grammar that reflects paradigm uniformity bias, namely the undominated ranking of the OO-Faith constraints. Given the current lack of empirical evidence for paradigm uniformity bias, the main focus of this study is experimental investigation. Formal analysis and modeling of the trajectory of the OO-Faith constraints' demotion will be left for future study.

2.2. Korean verbal inflection

Korean verbal inflection is a good test case to explore the role of paradigm uniformity bias in phonological acquisition: the paradigms exhibit a variety of phonological alternations, including regular ones as well as irregular ones. If learners initially assume uniform paradigms, they will produce no alternating forms regardless of type of alternation. This article first presents some of the major patterns of alternations that children learning Korean verb paradigms need to acquire. Based on the leading hypothesis concerning the acquisition of alternations, namely paradigm uniformity bias hypothesis, I will then provide predictions for the expected production patterns of inflected verb forms in the initial stage of learning alternations.

2.2.1. Alternations in verb paradigms

A majority of the regular alternations found in the verb paradigms are governed by the phonotactic restrictions of Korean. Therefore, phonotactics relevant to the alternations of verbal stems will be introduced first[1].

Korean has a three-way laryngeal contrast between lenis, aspirated, and tense obstruents, as in (3) (Jun 2010).

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[1] This section includes the phonotactic patterns relevant to the current experiments. For an extensive list of alternations and the phonotactics of Korean, see Cho (2016).

(3) Laryngeal contrast among Korean obstruents

	Labial		Coronal		Velar
	Stop	Stop	Fricative	Affricate	Stop
Lenis	p	t	s	c	k
Aspirated	pʰ	tʰ		cʰ	kʰ
Tense	p'	t'	s'	c'	k'

These obstruents undergo a range of phonological changes, four of which are relevant to the current study. First, obstruents / pʰ,p', tʰ , t' ,s, s', c, cʰ , c', kʰ, k'/ are neutralized to their homorganic lenis stop counterparts in coda position (i.e., coronal stops, affricates, and fricatives neutralize to [t], labial stops to [p], and velar stops to [k]), while the basic variants [pʰ,p', tʰ , t' ,s, s', c, cʰ , c', kʰ, k'] occur in other positions. Second, voiceless lenis stops /p, t, k/ are nasalized when a nasal /n, m, ŋ/ follows, surfacing as [m, n, ŋ] respectively, whereas the basic variants [p, t, k] occur when the following consonants are non-nasal. Third, lenis stops /p, t, k/ become their tense counterparts [p', t', k'] when preceded by a stop while they are realized as the basic variants [p, t, k] otherwise. Last, the voiceless lenis stops [p, t, k] are realized as [b, d, g] when flanked by sonorants. This is an allophonic pattern; i.e., the two stop series are in complementary distribution. The effects of allophonic intersonorant voicing are seen as in (4c and 4d). These four phonological processes are summarized in (4).

(4) Regular phonological processes of obstruents
   a. Coda neutralization
      a. /apʰ / [ap] 'front' vs. /apʰ-i/ [apʰi] 'front-Nom'
      b. /pat'/ [pat] 'field' vs. /pat'-hago / [pat'hago] 'field-with'
      c. /os/ [ot] 'clothes'vs. /os-i/ [osi] 'cloth-nom'
      d. /pic/ [pit] 'debt' vs. /pic-ɨl/ [picɨl] 'debt-Acc'
      e. /pak'/ [pak] 'outside' vs. /pak'-i/ [pak'i] 'outside-nom'
   b. Obs nasalization
      a. /ip-ta/ [ipt'a] 'wear-Decl' vs. /ip-nɨn/ [imnɨn] 'wear-Pres'
      b. /tat-ta/ [tatt'a] 'close-Decl' vs. /tat-nɨn/ [tannɨn] 'close-Pres'
      c. /mək-ta/ [məkt'a] 'eat-Decl' vs. /mək-nɨn / [məŋnɨn] 'eat-Pres'
   c. Post-obstruent tensification
      a. /kapʰ-a/ [kapʰa] 'pay back-Int' vs. /kapʰ-ta/ [kapt'a] 'pay back-Dec' vs. /ka-ta/ [kada] 'go-Dec'
      b. /tat-a/ [tada] 'close-Int' vs. /tat-ta/ [tatt'a] 'close-Dec' vs. /tʰa-ta/ [tʰa-da] 'ride-Dec'
      c. /k'ak'-a/ [k'ak'a] 'peal-Int' vs. /k'ak'-ta/ [kak't'a] 'peal-Dec' vs. /k'a-ta/ [k'a-da] 'peal-Dec'
   d. Intersonorant voicing
      a. /pam/ [pam] 'night' vs. /api/ [abi] 'father'
      b. /toŋ/ 'bronze' vs. /atam/ [adam] 'small'
      c. /koŋ/ [koŋ] 'ball' vs. /aki/ [agi] 'baby'

Phonotactic restrictions related to laterals are also relevant to the verbal alternations. In Korean, [ɾ] is an allophone of underlying /l/, occurring in the intervocalic environment; hence what is phonemically intervocalic /l/ surfaces phonetically as [ɾ] as in (5a).

(5) Regular phonological processes of laterals
   a. Intervocalic flapping /ili/ [iɾi] 'wolf' vs. /liɨl/ [liɨl] 'letter l'

The various phonological processes just outline in (4) and (5) give rise to regular alternations in the verb paradigms. To introduce patterns of stem-final alternations, I will first introduce verbal suffixes, which are the triggers of the alternations.

2.2.2. Korean verbal morphology

Korean verbs are conjugated (Martin 1992, Sohn 2001): every verb form in Korean is composed of a verbal stem and a sequence of inflectional suffixes. Korean verb roots are bound; thus a verbal stem followed by an inflectional suffix as in (6) is the shortest legal form. When tense is not specified, the verb is in present tense. For a declarative form, however, a present tense marker needs to be specified, as shown in (6); thus the shortest declarative form is a verbal stem, a tense marker, and a mood morpheme. Verbs can be very long in Korean due to the sequences of suffixes that mark grammatical contrasts, as in (6). There are over four hundred verbal suffixes (Lee and Ramsey 2000) and their orders are fixed (e.g., root-tense-mood). It is also possible to create longer verb forms with serial verb constructions or by adding auxiliary verbs or directional morphemes. To incorporate an additional morpheme, a complementizer is required after the first verbal stem as shown below.

(6) Korean verb forms
a. Shortest forms

  cab-a[2]   cam-nɨn-da   cam-ci

  catch-Imp   catch-Pres-Dec   catch-Int

b. Longer forms
cab-at-t'a
catch-Pst-Dec
'caught (formal plain form)'

cab-at-sɨm-ni-da
catch-Pst -Hon-Ind -Dec
'caught (formal polite form)'

cab-a-məg-ət -t'a
catch-Comp-eat-Pst-Dec
'caught and ate'

cab-a-bo[3]-n[4]-da

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[2] Abbreviations: Comp = Complementizer, Conj = Conjunction, Dec = Declarative, Imp = Imperative, Int = Interrogative, Pres = Present, Pst = Past, Aux = Auxiliary, Pro = Progressive, Hon = Honorific, Ind = Indicative, Dir = Directional.

[3] In the literature, the treatment of the morphemes in this position is controversial: some researchers treat this as an auxiliary verb, some consider it as an aspectual marker, still others treat this as an additional main verb to construct serial verb constructions (see (Sohn 1999) for the details.). This paper assumes that this morpheme is am auxiliary verb.

[4] The present tense morpheme alternates between [nɨn] (for a stem ending in a consonant) and [n] (for a stem ending in a vowel); the child participants always chose the correct one of these

catch-Comp -Aux -Pres-Dec
catch-Comp –try-Pres-Dec
'try catching'

hɨll-ə-ga-n-da
flow-Comp-Dir-Pres-Dec
flow-Comp-away-Pres-Dec
'flow away from (a speaker)'

The inflectional suffix that is adjacent to the verbal stem may trigger alternations of stem-final segments. Additional inflectional suffixes are irrelevant to stem-final alternations. Patterns of stem-final alternations rely on whether the suffix-initial segment is a vowel, an obstruent, or a nasal. Examples of vowel-initial, obstruent-initial, the nasal-initial suffixes are given in (7).

(7) Vowel-initial and consonant-initial verbal inflectional suffixes in Korean

V-initial		Obs-initial		Nas-initial	
-a/ə[5]	Imperative Declarative Interrogative Complementizer	-ta	Declarative	-nɨna	Interrogative (formal)
		-ko	Conjunctive	-ni	Interrogative (informal)
		-ci	Interrogative	-nɨn	Progressive
		-ca	Imperative	-mjən	Conditional

Some of the alternations triggered by the suffixes in (7) represent regular, predictable phonological processes of Korean. Obstruents alternate to their homorganic lenis stop counterparts before a consonant-initial suffix due to coda neutralization. When a suffix-initial consonant is a nasal, the stem-final obstruents will further alternate to nasal, due to nasalization. When an obstruent-initial suffix follows an obstruent-final stem, it alternates to its tense counterpart due to post-obstruent tensification. When a vowel-initial suffix follows the stem-final voiceless lenis stop, the stem-final segments alternate to voiced ones due to allophonic intersonorant voicing. Alternations of stem-final obstruents are shown in (8).

(8) Alternations of stem-final obstruents

	Vowel-initial suffix /-a ~-ə/	Obs-initial suffix /-ta/	Nas-initial suffix /-nɨn/
/kapʰ/ 'repay'	kapʰ-a	kap-t'a	kam-nɨn
/matʰ/ 'undertake'	matʰ-a	mat-t'a	man-nɨn
/sək'/ 'mix'	sək'-ə	sək-t'a	səŋ-nɨn
/s'is/ 'wash'	s'is-ə	s'it-t'a	s'in-nɨn
/is'/	is'-ə	it-t'a	in-nɨn

two allomorphs.

[5] Vowel-initial suffixes show vowel harmony with the stem-final vowel, alternating between an [a]-initial form (for a stem with /a, o/) and an [ə]-initial form (for a stem with /i u e æ/). They have four different meanings as indicated in the table.

'exist'
| /mac/ | madʒ-a | mat-t'a | man-nɨn |

'correct'
| / c'ocʰ/ | c'och-a | c'ot-t'a | c'on-nɨn |

'chase'
| /cap/ | cab-a | cap-t'a | cam-nɨn |

'catch'

When a suffix triggers alternations to the stem-final obstruents, three types of stem allomorphs are realized, as shown in (8). The first type, which I will refer to as the "prevocalic allomorph," appears when the verbal stem is followed by a vowel (e.g., [kapʰ-a] 'repay-Imp'). The second type is a "pre-obstruent allomorph", which appears neutralized into homorganic lenis counterpart when the verbal stem is followed by an obstruent (e.g., [kap-t'a] 'repay-Dec'). The last type is a "pre-nasal allomorph", which appears nasalized when the verbal stem is followed by a nasal (e.g., [kam-nɨn] 'repay-Pres'). Crucially, pre-obstruent allomorphs and pre-nasal allomorphs are predictable from the prevocalic allomorph and the phonological environment, but not vice versa. This is because the final consonant of a prevocalic allomorph occurs in prevocalic position, which allows an aspirated and plain laryngeal contrast as well as fricative and affricate manners of articulation. For example, if the prevocalic allomorph ends in [pʰ], it is certain that the pre-obstruent allomorph will end in [p] and the pre-nasal allomorph will end in [m]. In contrast, if the pre-obstruent allomorph ends in [t] or the pre-nasal allomorph will end in [n], the prevocalic allomorph might end in [s], [s'], [t], [t'], [c], or [cʰ]. Each of these possibilities is illustrated in (8). This stem allomorphy is crucial to the experiments described later, where I will show that children tend to produce the prevocalic allomorph rather than the preconsonantal allomorphs.

Stem-final laterals show a regular alternation as well. A lateral alternates to a flap before a vowel-initial suffix, since this is the allophone of /l/ that appears in this position. When a lateral is followed by an obstruent, the basic allomorph [l] occurs. A stem-final lateral is, however, sometimes deleted before nasal-initial suffixes, which is not regular in Korean. The regular outcome for /ln/ is [ll] due to lateralization as in /ilnjən/ [illjən] 'one year', /səlnal/ [səllal] 'near year', /kalnal/ [kallal] 'edge of a knife', /mulnanli/ [mullalli] 'flood', and /culnəmki/ [culləmgi] 'jump rope'. Exceptionally however, the lateral is deleted before a nasal only within verb paradigms as in /sal-nɨn/ [sa-nɨn] 'live-Pres', /sal-ni/ [sa-ni] 'live-Imp', and /sal-na/ [sa-na] 'live-Int'. (See Kenstowicz and Sohn 2008 for an analysis of this exceptional alternation.) An example of a lateral-final verb's alternation is given in (9).

(9) Alternations of stem-final laterals

	prevocalic allomorph	pre-obstruent allomorph	pre-nasal allomorph
/sal-/ 'live'	saɾ-a	sal-da	sa-nɨn

There are some verbs that also undergo irregular alternations, as in (10). Stem-final /t/ as in /tɨt/ is expected to be [d] in prevocalic forms due to intersonorant voicing as in (10a-2), but in some lexically restricted environments, stem-final /t/ becomes [ɾ] in prevocalic forms as in (10a-1). The phonemic pattern of Korean tells us that stem-final /p/ will normally appear as its intervocalic allophone [b] before a vowel-initial suffix as in (10b-2), but in exceptional cases it alternates to [w] as in (10b-1). Stem-final /s/, though normally retained as in (10c-2),

is sometimes deleted in intervocalic position, as in (10c-1). And stem-final /ɾɨ/, while normally retained in cases in (10d-2), it appears instead as [ll] in prevocalic allomorphs for some verbs, as in (10d-1). For these cases, it is not possible to predict the correct forms of the preconsonantal allomorphs from the prevocalic allomorph.

(10)   Irregular alternations compared with regular alternations

	prevocalic allomorph	pre-obstruent allomorph	pre-nasal allomorph
a-1. /tɨt-/ 'listen'	tɨɾ-ə	tɨt-ta	tɨn-nɨn
a-2. /tat-/ 'close'	tad-a	tat-ta	tan-nɨn
b-1. /top-/ 'help'	tow-a	top-ta	tom-nɨn
b-2. /cap-/ 'catch'	cab-a	cap-ta	cam-nɨn
c-1. /is-/ 'connect'	i-ə	it-k'o	in-nɨn
c-2. /pis-/ 'brush'	pis-ə	pit-k'o	pin-nɨn
d-1. /hiɾɨ-/ 'flow'	hill-ə	hiɾɨ-go	hiɾɨ-nɨn
d-2. /iɾɨ-/ 'reach'	iɾɨ-ə → iɾ-ə[6]	iɾɨ-go	iɾɨ-nɨn

In sum, there are a variety of regular and irregular alternations in Korean verbal paradigms, as summarized in (11). When regular alternations apply, preconsonantal allomorphs are predictable on the basis of prevocalic allomorphs, but not vice versa. When irregular alternations apply, however, preconsonantal allomorphs are not predictable from prevocalic allomorphs.

(11)   Three types of alternations

Regular	Coda neutralization Nasalization Obstruent voicing Flapping
Irregular	[l] deletion before nasal ɾ ~ t w~ p s deletion ll ~ ɾɨ

2.2.3. Predictions of paradigm uniformity bias hypothesis

For learners who have not yet mastered the patterns of alternations, it is predicted that the alternating verb forms presented in the previous section are likely to become the targets of reanalysis if the OO-Faith constraints are ranked too high in these learners' grammar. For example, if learners conform to paradigm uniformity on the basis of one specific allomorph, the paradigm with surface forms [tɨɾ-ə, tɨt-t'a, tɨn-nɨn] in (10) will be [tɨɾ-ə, *tɨɾ-ta, *tɨɾ-nɨn], [*tɨt-ə, tɨt-t'a, *tɨt-nɨn], or [*tɨn-ə, *tɨn-t'a, tɨn-nɨn], so that the verbal stems do not alternate.

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[6] Due to vowel coalescence, /ɨ-ə/ becomes [ə] in Korean.

Specifics of the reanalysis may differ depending on how OO-Faith constraints are evaluated. While it is mostly agreed that a paradigm uniformity bias will constrain derived forms to match their bases in the derivational paradigms (Benua 1997), there are conflicting proposals regarding inflectional paradigms. Some researchers have assumed that the bias will lead to mutual correspondence among surface forms without reference to a base form (McCarthy 2004), while others have argued that inflectional paradigms may also have privileged bases that the remaining forms must be faithful to (Benua 1997; Kenstowicz 1997; Albright 2002; Albright 2008). Even proposals assuming a base form in inflectional paradigms differ in how they suggest the base is determined (e.g., Albright 2002; Benua 1997). This article presents the predicted reanalysis in Korean verb paradigms according to the assumption behind Albright's (2002) "single-base hypothesis." The experimental results of the current study will show that Korean verbal inflections are one of the cases that give strong empirical support to the single-base hypothesis.

According to Albright (2002), learners attempt to select one surface form in the inflectional paradigm as the base. For example, in the Korean example of the paradigm for the verb /tɨt-/ 'listen', a learner will select one of the surface forms such as [tɨɾ-ə], [tɨt-t'a], or [tɨn-nɨn]. The selection of the base is guided by two main factors. First, the base form maximally preserves phonological contrasts among all surface forms. Second, the base form permits the most accurate generation of as many inflected forms of as many lexical items as possible. Crucially, the same paradigm cell must serve as the base within a language for all lexical items. For instance, if the learner selects the prevocalic form [tɨɾ-ə] as the base for the 'listen' paradigm, all other verbal inflectional paradigms should select the prevocalic form as the base. Once the base is selected, the learner projects the remaining surface forms using stochastic morphological rules.

Albright and Kang (2009) tested the single-base hypothesis (Albright 2002, 2008) with a computational learning simulation of Korean verbs showing that prevocalic forms are most informative and other members of the paradigms are best predicted from the prevocalic forms. Based on this evidence, they argue that adult learners will take the prevocalic forms as the base in Korean verbal paradigms. Do (2013) replicated the simulation in Albright and Kang (2009) to see if the prevocalic forms are predicted to be the base form in child Korean as well. Because no Korean corpus including a reliable size of child directed speech is available, the simulation was based on a set of hypothetical child directed speech: the simulation used three databases composed of the verbal roots with the highest 100, 300, and 500 token frequencies along with the ten verbal suffixes with the highest token frequencies from the Sejong Corpus (Kang and Kim 2004), with an assumption that children are more likely to hear high frequency verbs in frequently used inflected forms. Do's simulation predicts the prevocalic forms as the base forms, regardless of the size of the database. Based on this finding, it is argued that children acquiring Korean will take the prevocalic forms as base forms as well. Following Albright and Kang (2009) and Do (2013), this study also assumes that the prevocalic forms are the base forms of Korean verbal paradigms.

Thus far, I have made two assumptions. First, the constraints regulating paradigm uniformity, namely OO-Faith constraints, are highly ranked in young learners' phonological grammars due to an initial bias for paradigm uniformity. Second, the base form of Korean verbal paradigms is the prevocalic form. These two assumptions lead to the hypothesis in (12) regarding the initial stage of learning alternations.

(12)   Hypothesis

Children learning Korean verbal paradigms will tend to produce inflected verb forms so that they are faithful to the prevocalic forms, the base of the paradigms, in the early stages of learning patterns of alternations when the OO-Faith constraints are given priority *a priori*.

When paradigm acquisition is not complete, or when learners have not yet mastered the correct surface forms, this hypothesis predicts that the reanalysis of surface forms will show incorrect uses of base forms for other, morphologically related forms. Recall that the alternations of obstruent-final stems are governed by the phonotactic principles of Korean, as shown in (8). Even if a learner creates forms incorrectly using prevocalic stem allomorphs, the application of regular phonological processes will predict the correct surface forms of obstruent-final verbal stems. For example, if a learner incorrectly uses the prevocalic stem allomorph where preconsonantal allomorphs are needed, such as *[kapʰ-t'a] and *[kapʰ-nɨn], the application of coda neutralization and nasalization will correct the forms to [kap-t'a] and [kam-nɨn].

The hypothesis in (12), however, predicts the production of incorrect forms in cases of irregular alternations as in (13)[7]. The forms in (13) show the use of prevocalic stem allomorphs where preconsonantal allomorphs are required. The absence of a Korean phonotactic constraint banning the sequences found in the incorrect forms allows the erroneous forms with the prevocalic allomorphs to be produced.

(13)   Predictions of the hypothesis

Irregulars	UR	Imperative	Declarative	Progressive
	/sal-/ 'live'	saɾ-a	saɾ-da	sa-nɨn vs. *saɾ-nɨn
	/tɨt-/ 'listen'	tɨɾ-ə	tɨt-t'a vs.*tɨɾ-da	tɨn-nɨn vs. *tɨɾ-nɨn
	/top-/ 'help'	tow-a	top-t'a vs.*tow-da	tom-nɨn vs.*tow-nɨn
	/is-/ 'connect'	i-ə	it-t'a vs. *i-da	it-nɨn vs.*i-nɨn
	/hiɾɨ-/ 'flow'	hill-ə	hiɾɨ-da vs. *hill-ɨ-da	hiɾɨ-nɨn vs. *hill-ɨ-nɨn

An alternative way to produce forms with prevocalic allomorphs is to employ morphologically longer forms, as in (14). As introduced in (6), longer forms may use prevocalic allomorphs, the stem allomorphs found in the base forms. The longer forms in (14) either include an auxiliary verb such as *-bo-* 'try –ing', an additional verbal stem such as *-cu-* 'give' to create a serial verb construction, or a directional morpheme such as –*o*- 'toward' or –*ga*- 'away'. Crucially, in all of the longer forms, the complementizer *-a/ə*- is needed, which requires the use of the prevocalic stem allomorphs.

(14)   Additional predictions of the hypothesis

	UR	Imperative	Declarative	Progressive
Irregulars	/sal-/	saɾ-a	saɾ-a-bo-da	saɾ-a-bo-nɨn

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[7] Assuming that learners who are beginning to figure out patterns of alternations have already learned at least some parts of the phonotactics of the target language (Hayes 2004), the predicted forms in (13) show the correct applications of Korean phonotactic constraints such as ɨ-insertion to avoid a CCC (*C/C_C) (Albright and Kang 2009).

	'live'		live-Comp-Aux-Dec live-Comp-try-Dec 'try living'	live-Comp-Aux-Pro live-Comp-try-Pro
	/tɨt-/ 'listen'	tɨɾ-ə	tɨɾ-ə-bo-da listen-Comp-Aux-Dec listen-Comp-try-Dec 'try listening'	tɨɾ-ə-bo-nɨn listen-Comp-Aux-Dec listen-Comp-Aux-Dec
	/top-/ 'help'	tow-a	tow-a-cu-da help-Comp-Stem -Dec help-Comp-give -Dec 'provide help'	tow-a-cu-nɨn help-Comp-Stem-Dec help-Comp-give-Dec
	/is-/ 'connect'	i-ə	i-ə-o-da connect-Comp-Dir-Dec connect-Comp-toward-Dec 'connect toward (a speaker)'	i-ə-o-nɨn connect-Comp-Dir-Dec connect-Comp-toward-Dec
	/hɨɾi-/ 'flow'	hɨll-ə	hɨll-ə-ga-da flow-Comp-Dir-Dec flow-Comp-away-Dec 'flow away from (a speaker)'	hɨll-ə-ga-nɨn flow-Comp-Dir-Dec flow-Comp-toward-Dec

This study tests the predictions of paradigm uniformity bias hypothesis. In the results of Experiment 1, the hypothesis is borne out. While the specific ways by which paradigm uniformity is satisfied are different depending on the ages of the child learners, a unified pattern across all production forms is found: four- to seven-year-old children deviate from adults' production in various ways, all of which make paradigms more uniform. The specific way they make uniform paradigms is to innovate forms that are faithful to the base forms, the prevocalic forms, supporting the hypothesis in (12).

The results of Experiment 2 further show that six- to seven-year-old children produce non-alternating forms only when they are able to produce non-alternating forms; otherwise, they successfully inflect verbs in alternating forms as adults do. Interestingly, the non-alternating forms are, on occasion, employed by children even in regular forms, when the regulars involve some sort of phonological alternation. I argue that children assign the alternating forms the highest probability when they are acquiring patterns of alternations, but due to paradigm uniformity bias they still search for alternatives that enable them to produce non-alternating forms.

3. Experiments

3.1. Experiment 1

3.1.1. Participants

Twenty-four native-Korean-speaking children, 13 boys and 11 girls, aged from 4;1 to 7;2 (*M* = 5.75) participated[8]. In addition, eight adult native Korean speakers, four males and four females, participated for the purposes of comparison. All child participants attended public kindergartens in Korea and all adult participants were standard Seoul Korean speakers.

3.1.2. Materials

A picture description task was used to elicit the inflected forms of Korean verbs. Pictures were shown to participants, and a sentence missing a main verb was given below each picture. Because the goal was to elicit verbs, all other sentence components, such as subjects, objects, and adverbs, were given. An example of the picture description task given in the practice session is in (15).

(15)   The picture description task

namtʃa-ga tʃɨlgəp-k'e _____.
man-Nom joyful-Adv _____.
'A man _____ joyfully.'
Expected answer: cʰumcʰu-n-ta 'dance-Pres-Dec'

No additional restriction was posed for the picture description task; participants were able to choose any verbal root and any inflectional structure. The intention behind this test design was to elicit production forms similar to naturalistic data.

The purpose was to elicit inflected forms of verbs exhibiting (a) no alternation, (b) regular alternations, (c) irregular alternations, as in (16). An additional two factors were considered in choosing the verbs. First, the prevocalic form of the verb had to have a token frequency of at least one thousand in the Sejong Corpus of written Korean (Kang and Kim 2004), so that it would be likely to be familiar to young child learners. Second, the verbs saliently express motions (e.g., *walk*, *fly*, *dance*) or visible features of an object (e.g., *round*, *blue*, *long*), so the meaning of the predicates can be clearly presented by pictures. The list of specific target verbs is provided in Appendix 1.

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[8] My literature search has not found any evidence of when young Korean learners have mastered the verbal alternations. One study of children up to the age of 36 months reports no alternating verbal forms in their production (Lee et al. 2003). Personal experience suggests that Korean children around age four still do not productively attempt alternating verbal forms and children around age seven produce various alternating forms, but the patterns of their alternations still deviate from the adult forms. Based on these observations, this study selected participants aged 4;1–7;8.

(16)   The target alternations

Categories of alternations	Alternations	Stem-final segments in prevocalic allomorphs	Frequency
(a) No alternation	None	n	2
	None	m	5
(b) Regular alternations	Intersonorant voicing & Nasalization	b d g	3 1 4
	Coda neutralization & Nasalization	pʰ	3
(c) Irregular alternations	Intersonorant flapping & lateral deletion	ɾ	4
	ll ~ ɾɨ ~ ɾɨ	ll	6
	w ~ p ~ m	w	3
	ɾ ~ t ~ n	ɾ	4
	s ~ t ~ n	s	3
			Total 38

Each picture was designed to elicit an inflected form of a single verb. The pictures were taken from Google images with permission, or if necessary, created as colored illustrations especially for this experiment by a graduate student at the author's university. Seventy-six pictures were first designed to elicit the target verbs and then three adults who did not participate in the experiment were asked to describe each picture in written form. Among the 76 pictures, the 38 that all three adults described using the same verbal roots were selected and used in the production test.

3.1.3. Procedure

Participants were shown 38 pictures, each with a corresponding sentence containing a blank space for the target verb, on a computer screen, one at a time. Parents of child participants attended the test session with their child. The parents read the given sentences to the child participants, and were asked not to give response-contingent feedback. Adult participants completed the test by themselves. All participants were asked to give their answers orally, and the answers were tape-recorded and transcribed later.

Before the test session, both child and adult participants were given three examples of the picture description task as in (15). The three examples showed motions that can be best described with non-alternating verbs, so the participants did not see any instance of the target of the study, stem-final segment alternations, before the task. The participants were then told that they would look at pictures. They were asked to fill in a blank for each picture in the most natural way, and, if they were not sure with which verb they fill in the blank to describe a given picture, to make their best guess. The experimenter was present while the participants were trained with examples, but not during the test session. All participants were asked to complete the full experiment in a single session with no time limit.

3.1.4. Results

In total, 1,216 participants' answers were collected. Sixty-three answers (5.2%) were eliminated because the participants either did not answer the question (1.3%) or did not produce the intended target verb (0%–18%, *M* = 3.9%)[9]. The remaining recorded materials were digitized as wav files, and then transcribed by the experimenter and, separately, by a Korean graduate student trained in phonetic transcription who did not know the purpose of the experiment. There was 97% agreement between the two transcribers, and tokens on which the transcribers disagreed were thrown out. After this process, 1,118 tokens remained for analysis, comprising 818 tokens from the child participants and 300 tokens from the adult participants.

To preview, the results of the child participants' performance confirmed the hypothesis presented in section 2.2.2: the children created innovative uniform paradigms by inflecting verbs faithful to the prevocalic forms, the base of Korean verb paradigms, supporting the hypothesis in (12).

The adult participants inflected the verbs using the simplest morphological structures, a verbal stem followed by a present tense morpheme and a declarative morpheme, for most of their answers (93%–100%, *M* = 98%). In the simplest structures, the correct stem allomorphs are the preconsonantal forms, which introduce stem-final alternations from the base forms. Adult participants always used the correct form of the preconsonantal allomorphs, as shown in (17).

(17)   Examples of adults' production

Prevocalic allomorphs   Inflected forms
cab-   cam-nɨn-da
                             catch-Pres-Dec
jəɾ-   jə-n-da
                             open-Pres-Dec
oll-   oɾi-n-da
                             climb-Pres-De
kuw-   kum-nɨn-da
                             bake-Pres-Dec
s'is-   s'in-nɨn-da
                             wash-Pres-Dec

The morphological structures found in the children's verbal inflections differed depending on the types of alternations involved in the target verbs. First, when the verbs do not involve any alternation, the children always used the simplest morphological structures (*n* = 145) such as /sin-nɨn-ta/ [sin-nɨn-da] 'wear-Pres-Dec', suggesting that the child participants completely understood the task. Second, when the verbs undergo only regular alternations, the child participants used not only the simplest structures such as /cap-nɨn-ta/ [cam-nɨn-da] 'catch-Pres-Dec' but also the extended structures such as / cap-a-po-n-ta/ [cab-a-bo-n-da] 'catch-Comp-try-Pres-Dec'; when the proportion of the responses are considered, they predominantly used the simplest morphological structures (*n* = 189, 81.8%) over the extended structures (*n* = 42, 28.2%). Third, when the verbs undergo irregular alternations, the

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[9] An additional analysis including the 48 answers (3.9%) that were eliminated for using verbal roots different than the targets was conducted, and found the same general tendencies of production patterns that are reported in this section.

15

extended morphological structures such as /tɨɾ-ə-po-n-ta/ [tɨɾ-ə-bo-n-da] 'listen to-Comp-try-Pres-Decl' were significantly preferred (*n* = 274, 61.9%) to the simplest structures such as /tɨɾ-nɨn-da/ [tɨn-nɨn-da] 'listen to-Pres-Dec' (*n* = 168, 39.1%). The results are shown in the graphs in (18).

(18)   Verbs' morphological structure by type of alternation
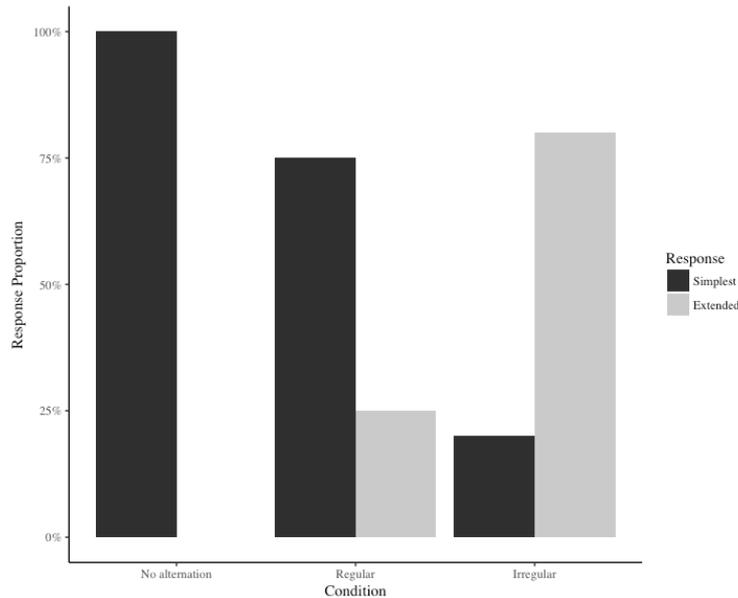
To test if the participants' responses (simplest structures vs. extended structures) in the three conditions (no alternation vs. regular alternations vs. irregular alternations) are significantly different, a mixed-effects logistic regression model was fitted using lme4 (Bates, Maechler, Bolker, Walker 2015). The model included response types as a dependent variable (simplest structures vs. extended structures) with the simplest structures as the reference level. The conditions of alternations were an independent variable, which had three levels (no alternation vs. regular alternations vs. irregular alternations). Regular alternations were assumed to be the reference level. Random intercepts were included for participants and items, and a random slope for place by participants. The results show that choosing the simplest structures was significantly encouraged when the target verbs involve no alternation (*β* = 2.525e+05, *SE* = 2.098-03, *z* = 120314209, *p(z)* < 2e-16 ***), suggesting the effect of alternations on the choice of morphological structures. Choosing the simplest structures, on the other hand, was significantly discouraged when the target verbs involve irregular alternations (*β* = -2.867+00, *SE* = 2.967E-03, *z* =-966, p*(z)* < 2e-16 ***), suggesting the effect of regularity. In sum, the results show the effect of alternations and the effect of the regularity of alternations in the child participants' choices of morphological structures.

The child participants frequently produced erroneous forms when verbs with an irregular alternation were inflected using the simplest morphological structure (58.9%, *n* = 99/168). Examples of these errors are shown in (19). No error was found in which verbs with no alternation or with regular alternations were inflected using the simplest structure.

(19)   Errors with incorrect stem allomorphs

Prevocalic allomorphs	Inflected forms[10]	
jəɾ-	*jəɾɨ-n-da open-Pres-Dec	jə-n-da
oll-	*ollɨ-n-da climb-Pres-Dec	oɾɨ-n-da
kuw-	*kuw-n-da bake-Pres-Dec	kup-nɨn-da
s'is-	*s'isɨ-n-da wash-Pres-Dec	s'in-nɨn-da

When the verbs were inflected using extended morphological structures, they either involved additional morphemes such as an auxiliary morpheme or were serial verb constructions. Examples are given in (20). No errors were observed in forms using extended morphological structures.

(20)   Morphologically extended forms

Prevocalic allomorphs	Extended forms
jəɾ-	jəɾ-ə-bo-n-da open- Comp-Aux-Pres-Dec open- Comp-try-Pres-Dec 'try to open'
oll-	oll-a-ga-n-da climb- Comp-Dir -Pres-Dec climb- Comp-away -Pres-Dec 'climb away (from a speaker)'
kuw-	kuw-ə-cu-n-da bake- Comp-Root -Pres-Dec bake- Comp-give -Pres-Dec 'bake and give'
s'is-	s'is-ə-ne-n-da wash- Comp-remove-Pres-Dec wash- Comp-remove-Pres-Dec 'wash and remove'

Notably, a unified pattern appeared in the erroneous forms involving incorrect stem allomorphs, as in (19), and the forms using extended morphological structures, as in (20): the inflected forms systematically show the use of the prevocalic allomorphs – the allomorphs found in the bases of Korean verb paradigms. Specifically, the children incorrectly chose prevocalic forms where preconsonantal forms were required, but not vice versa. Also, they inflected verbs using morphologically extended structures that allowed the use of the prevocalic stem allomorphs. In other words, the child participants showed two different ways to inflect verbs using the prevocalic allomorphs, which are the stem allomorphs found in the base forms.

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[10] The child participants inserted vowels to avoid illegal CCC clusters, which shows their knowledge of the relevant phonotactic regulations.

Additionally, most of the erroneous forms were from four- to five-year-old children (n = 91/99) while most of the extended forms were produced by six- to seven-year-old children (n = 282/316). Numbers of errors and extended forms from each participant are given in Appendix 2.

To sum up, the results of Experiment 1 show that children inflected verbs differently from adults when the target verbs require alternations. The child participants sometimes chose the extended morphological structures when inflecting verbs involving regular alternations. The tendency for choosing the extended structures was especially higher when they inflected verbs with irregular alternations. Also, it was found that they produced erroneous forms and older children (six- to seven-year-olds) are more likely to use the morphologically extended forms than the erroneous forms, compared to younger children (four- to five-year-olds). Crucially, both erroneous forms involving incorrect stem allomorphs and morphologically extended forms enabled them to inflect the verbs using the prevocalic stem allomorphs.

3.1.5. Discussion

When the child participants' production deviated from that of adults, they inflected verbs in such a way as to use the prevocalic stem allomorphs, the stem allomorphs found in the base forms. The younger children preserved the stem allomorphs in the base forms mainly by producing errors. The older children did so mainly by incorporating additional morphemes in the verbal conjugation.

This use of additional morphemes cannot be attributed to children's tendency to imitate adults' usage of verbal inflections. Recall that the adult participants in the experiment almost always used the morphologically simplest structure. In addition, evidence from corpus data including conversations between a Korean child and her mother in CHILDES (MacWhinney 2000) suggests that the morphologically simplest structure is the predominant form in child-directed speech[11]. The analysis of conversations in naturalistic settings between ten child–caregiver pairs in Do (2013) also suggests that the morphologically simplest structure is the most frequent for all of the verbs produced by the adult speakers. Yet, for the inflections of the verbs with the irregular alternations, six- to seven-year-old children tended to use morphologically extended structures.

It is also important to note that the six- to seven-year-old children produced many correct forms. This fact may indicate that children have partial knowledge of adult-like inflection of verb forms. Why do six- to seven-year-old children sometimes incorporate additional morphemes into verbal inflections despite sometimes successfully alternating verbs in morphologically simpler ways? This study's hypothesis is that the children are influenced by a paradigm uniformity bias, because producing morphologically extended forms allows them to use the prevocalic allomorphs, the allomorphs in the base forms. In other words, although children may assign the alternating forms the highest probability, just as adults do, a strong paradigm uniformity bias leads them to search for alternatives that will allow them not to produce the alternating forms. Alternatively, their behavior could be simply due to the

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[11] The dataset is composed of 12 conversations, each collected on a different day, from when the child is between 2;0 and 2;3. CHILDES has no production data from Korean children over 2;3, so it was not possible to look at whether morphologically extended structures are more frequently used in child-directed speech for older children.

children's imperfect knowledge of phonological alternations: they might have learned the morphological system of verbal inflections, and thus are able to produce both the simplest and the extended structures, while not yet having fully mastered which stem allomorphs are required for each morphological structure.

Experiment 2 was conducted in order to examine whether some of the six- to seven-year-olds' inflection patterns observed in Experiment 1 were driven by a lack of knowledge of phonological alternations or by a preference for producing non-alternating forms. If children have good knowledge of verbal alternations, they will correctly produce preconsonantal allomorphs, as in (21), when the option of using prevocalic allomorphs is not available.

(21)   Expected forms from children who know preconsonantal allomorphs

Prevocalic allomorphs	Inflected forms
jəɾ-	jə-n-da
	open-Pres-Dec
oll-	oɾɨ-n-da
	climb-Pres-Dec
kuw-	kum-nɨn-da
	bake-Pres-Dec
s'is-	s'in-nɨn-da
	wash-Pres-Dec

Specifically, if the children are given a controlled condition in which they are prevented from employing the morphologically extended structures that enabled them to use prevocalic allomorphs in Experiment 1, they will produce forms with preconsonantal allomorphs. If the children are not yet able to produce the correct forms of preconsonantal allomorphs, a high rate of incorrect stem allomorphs will be observed in this controlled setting, as in (22).

(22)   Expected errors from children who do not know preconsonantal allomorphs

Prevocalic allomorphs	Inflected forms
jəɾ-	*jəɾ-nɨn-da
	open-Pres-Dec
oll-	*oll-nɨn-da
	climb-Pres-Dec
kuw-	*kuw-nɨn-da
	bake-Pres-Dec
s'is-	*s'is-nɨn-da
	wash-Pres-Dec

The results of Experiment 2 show that six- to seven-year-old children correctly produce the preconsonantal allomorphs when they must do so. This finding suggests that the non-alternating verb forms observed from the same age group in Experiment 1 are indeed due to their phonological preference for retaining paradigm uniformity, not to their ignorance of phonological alternations. Experiment 2's results further suggest that paradigm uniformity bias does not necessarily prevent learners from acquiring alternations. Instead, even after learners assign the highest probability to the alternating forms, they still tend to search for morphological structures that allow them not to introduce phonological alternations.

3.2. Experiment 2

3.2.1. Participants

Thirteen Korean children, six boys and seven girls, from age 6;2 to age 7;3 ($M = 6.5$) participated in Experiment 2. None of them had participated in Experiment 1. The eight adults, four males and four females, who participated in Experiment 1 also participated in Experiment 2.

3.2.2. Materials

A controlled experimental setting was designed in which participants were required to inflect verbs using specific morphological structures. In order to restrict the participants' selection of morphological structures, a syntactic constraint in Korean grammar was employed.

When two clauses are coordinated within a sentence, the order of suffixes is same as in a single clause, but tense and mood morphemes are marked only in the final clause (Yoon 1997) as in (23). Within a coordinated sentence, the morphological structures of the coordinated clauses must be identical. For instance, if a clause in a coordinated sentence is inflected without an auxiliary verb, the other clause must also be inflected without an auxiliary verb, as in (23). If a clause in a coordinated sentence is inflected with a directional morpheme, the other clause must have a corresponding morpheme as well, as shown in (23). If an additional morpheme is incorporated in only one clause within a coordinated sentence as in (23), it is unnatural. Because this is a structural requirement, the specific meaning of corresponding morphemes in the two clauses may differ as in (24b). I call this syntactic constraint the "structural parallelism constraint."

(23)   Structural parallelism constraint in Korean
a. Stem-Conj, Stem-Tense -Mood.
   kət-ko, t'jɪ-n-ta
   walk-Conj, run- Pres-Dec
   'walk and run'

b. Stem-Dir-Conj, Stem-Dir-Tense-Mood.
   kəɾə-o-ko, t'jɪə-ga-n-ta
   walk-toward-conj, run-away- Pres-Dec
   'walk toward (a speaker) and run away from (a speaker)'

c. ??? Stem-Aux-Conj, Stem-Tense-Mood.
   kəɾə-o-ko, t'jɪ-n-ta
   walk-toward-Conj, run-Pres-Dec
   'walk toward (a speaker) and run'

A paired-picture description test was designed so that the participants' production was controlled by the structural parallelism constraint. This design assumed that participants know the structural parallelism constraint, and that the constraint is undominated in Korean speakers' production grammar. If these assumptions hold, the morphological structure in one phrase should constrain the morphological structure in the other phrase. The prediction is that participants may produce the forms as in (24a) without additional morphemes in both clauses or in (24b) with additional morphemes in both clauses. If participants correctly apply alternation patterns, verbal stems not only in the structure of (24b) also in the structure of (24b) will be correct.

The target verbs in Experiment 1 were employed and paired. A transitive verb was paired with another transitive verb, and an intransitive verb was paired with another intransitive verb, so that the processing load, or syntactic structure, of the two clauses would be similar. Recall that in Experiment 1, the verbs with no alternation or with regular alternations were predominantly inflected using the simplest morphological structure, and the verbs with the irregular alternations were predominantly inflected using morphologically extended structures. I call the former group of verbs "regulars" and the latter group of verbs "irregulars." There were 11 regulars, which were paired with 11 irregulars. Among these 11 combinations, five pairs of pictures were designed to elicit a regular in the first clause as in (24), and six pairs of pictures were designed to elicit an irregular in the first clause as in (24). The remaining eight irregulars were paired with each other as in (24) and served as fillers. To balance the experimental conditions, eight new pictures expected to elicit descriptions using simplest-form preferring verbs were included and paired into four stimuli as in (24). The pairs of pictures were randomly ordered, and the same condition was never presented twice in a row. The number of each type of stimuli is provided within parenthesis in (24), and the full list of the pairs is in Appendix 2.

(24)   Four conditions and their numbers in Experiment 2

a. regular, irregular (5)
b. irregular, regular (6)
c. irregular, irregular (4)
d. regular, regular (4)

As in Experiment 1, only verbs were elicited. The other sentence components such as subjects, objects, and adverbs were given. The same three adults who helped design and select the pictures in Experiment 1 participated in confirming the appropriateness of the picture pairing for Experiment 2. An example of the paired pictures is given in (25).

(25)   The paired-picture description test

wen-tʃʼok ai-ga pʼal-li _____, orɨn-tʃʼok ai-ga cʰuncʰun-hi
left-side boy-nom fast-ADJ _____, right-side boy-nom slow-ADJ____.
A child on the left _____ fast, a child on the right _____ slowly.
Expected answers: tjui-go 'run-and', kən-nɨn-ta 'walk-Pres-Dec'

The expectation was that participants would use a connective suffix such as *-ko* 'and', *-ciman* 'but', or *-nɨnde* or *-nɨnbanmyən* 'on the contrary' at the end of the inflection of the first verb to indicate the coordination of the two clauses. Crucially, the morphological structure selected for one clause will constrain the morphological structure of the other coordinated clause; thus, all four types of stimuli were expected to elicit answers in the form of either <simplest-form, simplest-form> or <extended-form, extended-form>.

3.2.3. Procedure

The procedure of the test and the methods used for data recording and transcription were identical to those in Experiment 1. In total, 248 tokens from the children and 151 tokens from the adults were collected, each of which were composed of two verbs. The between-transcriber agreement rate in Experiment 2 was 98%. Eight tokens that the two transcribers did not agree on were thrown out. The remaining 239 tokens from the children and 151 tokens from the adults were analyzed.

3.2.4. Results

The results of Experiment 2 show that the structural parallelism constraint is undominated in Korean speakers' production: all participants, both children and adults, inflected the two verbs within each coordinated sentence with identical morphological structures. Adults always employed the simplest morphological structure, as shown in (26), such as a verbal stem followed by a present tense morpheme and a declarative morpheme. The stem allomorphs were always correct; no erroneous forms were found.

(26)　　　The adults' production in coordinated sentences

a. regular, irregular (5)
cap-k'o, cum-nɨn-da
catch-Conj, pick-Pres-Dec
'catch and pick'

b. irregular, regular (6)
sit-k'o, maŋ-nɨn-da
wash-Conj, block-Pres-Dec
'wash and block'

c. irregular, irregular (4)
jəl-go, orɨ-n-da
open-Conj, climb-Pres-Dec
'open and climb'

d. regular, regular (4)
sin-k'o, cam-nɨn-da
wear-Conj, roll-Pres-Dec
'wear and roll'

The child participants produced two types of morphological structure: the simplest and the extended structures, as in (27).

(27)　　　The children's production in coordinated sentences

a. Simplest structures
sin-k'o, cam-nɨn-da
wear-Conj, roll-Pres-Dec
'wear and roll'

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cap-k'o, cum-nɨn-da
catch-Conj, pick-Pres-Dec
'catch and pick'

b. Extended structures
jəɾ-ə-bo-go, oll-a-ga-n-da
open-Comp-Aux-Conj, climb-Comp-Aux-Pres-Dec
open-Comp-try-and, climb-Comp-try-Pres-Dec
'try opening and try climbing'

sis-ə-ne-go, mag-a-du-n-da
wash-Comp-remove-and, block-Comp-keep-Pres-Dec
'remove by washing, and keep blocking'

The simplest structures were identical to those produced by the adult participants: the verbal
stem, a present tense morpheme, and a declarative morpheme. As in Experiment 1, the
extended structures included an auxiliary verb, a directional morpheme, or an additional
verbal stem to create serial verb constructions.

Importantly, the selection between the two types of morphological structures relied on the
phonological properties of the verbs in the first clause within the coordinated sentence.
Specifically, the types of alternations found in the first verbs determined the preferred
morphological structure of the coordinated clauses. First, the simplest structures were
predominantly selected when no alternation was involved in the first verb. Second, compared
to the no alternation condition, the extended structures were produced more frequently when
the first verb involved a regular alternation. Third, the extended morphological structure was
selected most frequently when the first verb involved an irregular alternation. Numbers of the
simplest and the extended morphological structures depending on the type of the first verb
are shown in (28).

(28)   Simplest vs. extended structures depending on the first verbs
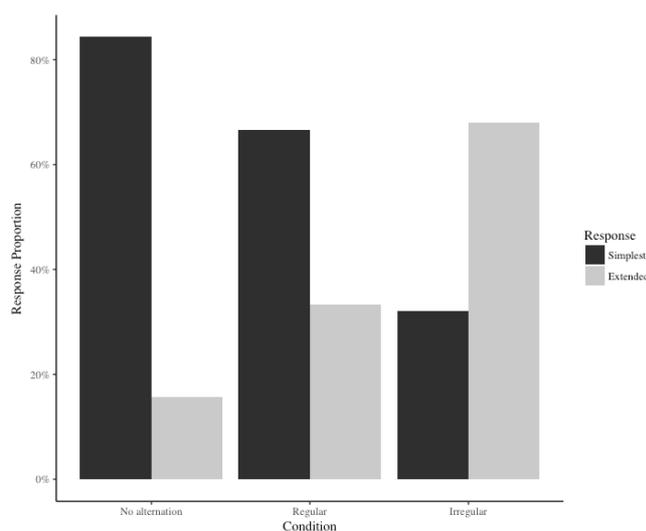
To test if the participants' response types (simplest structures vs. extended structures) are
significantly different depending on the first verbs, a mixed-effects logistic regression model

was fitted using lme4 (Bates, Maechler, Bolker, Walker 2015). As in the analysis of Experiment 1, the model included response type as a dependent variable (simplest structures vs. extended structures) with the simplest structures as the reference level. The condition of alternations of the first verb within a sentence was an independent variable, which had three levels (no alternation vs. regular alternations vs. irregular alternations). The condition of regular alternations was assumed to be the reference level. Random intercepts were included for participants and items, and a random slope for place by participants. The results show that choosing the simplest structures is significantly encouraged in the condition with no alternation compared to the condition with regular alternations ($\beta = 2.4355$, *SE*$= 0.6848$, $z = -3.557$, *p(z)* $= 0.000376$ ***), suggesting the effect of alternations. However, choosing the simplest structures, was significantly discouraged when the target verbs involve irregular alternations compared to when the verbs involve regular alternations ($\beta = -2.0914$, *SE* $= 0.5680$, $z = 3.682$, p*(z)* $= 0.000231$ ***), suggesting the effect of regularity. In sum, the results show the effect of alternations as well as the effect of regularity of alternations in the child participants' choices of morphological structures. The findings of Experiment 2 are consistent with those of Experiment 1.

The majority of the children's answers were correct (92%), but five included errors, all of which were in the second verbs of the coordinated sentences in simple-form-preferring verb, irregular pairs. These errors showed a systematic, incorrect use of the prevocalic allomorphs where the preconsonantal allomorphs are required, as in (29). In no case did a child erroneously use a preconsonantal allomorph where a prevocalic allomorph was needed. The error pattern in Experiment 2 is consistent with the error pattern in Experiment 1.

(29)   Errors

Correct forms	Errors (numbers of errors)	Prevocalic allomorphs
cum-nɨn-da pick up-Pres-Dec	*cuw-nɨn-da (1)	cuw-
kum-nɨn-da bake-Pres-Dec	*kuw-nɨn-da (1)	kuw-
tɨn-nɨn-da listen to-Pres-Dec	*tɨɾɨ-n-da (3)	tɨɾ-

Except for the five error tokens, all of the other irregulars were correctly conjugated. Recall that in Experiment 1, the six- to seven-year-old children produced non-alternating verb forms by employing morphologically extended structures when they inflected the irregulars (i.e., the verbs with exceptional or lexically-restricted alternations). But note that in Experiment 2, children in the same age range inflected alternating forms of the same verbs by correctly using the preconsonantal stem allomorphs in most cases. In other words, when the structural parallelism constraint was imposed, so that the children did not have the choice of incorporating additional morphemes, they showed they were able to use the stem allomorphs found in the base forms in Experiment 1. In this controlled condition in Experiment 2, the children obeyed the structural parallelism constraint and thus used the simplest morphological structure when inflecting irregulars. Notably, when the children inflected the verbs using the simplest morphological structure, they almost always made correct use of the prevocalic stem allomorphs. This result shows that children are able to correctly produce the

alternating verb forms – not only the regulars (the verbs with no alternation or regular alternations) but also the irregulars (the verbs with irregular alternations).

3.2.5. Discussion

Experiment 2 demonstrates a crucial pattern: six- to seven-year-old children are able to produce alternating verb forms not only for the verbs with regular alternations but also for those with irregular alternations. Why then did children prefer not to produce alternating verb forms in Experiment 1, when they are capable of producing them, as observed in Experiment 2? The additional structural constraint imposed in Experiment 2 requires the inflection structure of the second verb to be identical to that of the first verb, and is apparently undominated, as it was not violated by any of the participants. This structural parallelism constraint requires that when the first verb is inflected in the simplest morphological structure, the second verb should be inflected using the same structure. Once children inflected a verb with no alternation or a regular alternation in the first clause by employing the simplest morphological structure, they could not inflect a verb with an irregular alternation in the second clause with a different morphological structure, such as a morphologically extended one. In other words, the only option left to the participants was to use the simplest structure in inflecting the second verb. Crucially, to create the simplest structure, the preconsonantal allomorphs, allomorphs in non-base forms, are required. Experiment 2 found that under this controlled condition, children successfully produced correct alternating verb forms.

These results suggest that the children's production patterns demonstrated in Experiment 1 are motivated by paradigm uniformity bias as well as the regularity effect, not by their ignorance of alternating verb forms: when children are free to choose a morphological structure of verbal inflection reflecting their own preferences as in Experiment 1, they preferred to produce non-alternating forms, supporting paradigm uniformity bias effect. They produced the forms with regular alternations just as adults, while they did not produce forms involving irregular alternations, supporting the regularity effect. In Experiment 2 where they were constrained to produce forms with irregular alternations, they correctly produce alternating forms. The results therefore suggest that children who successfully assign the alternating forms the highest probability, as adults do, still prefer to seek alternative ways of inflecting verbs in the interest of producing non-alternating verb forms specifically when the inflection can potentially incur irregular alternations.

4. Discussion and conclusion

This paper has presented ways in which Korean children deviate from adults in verbal inflections, and has provided a unified account of the data obtained from two experiments. Four- to five-year-old children show an overall tendency to produce erroneous forms of irregular verbs by selecting incorrect stem allomorphs, while six- to seven-year-olds tend to employ extended morphological structures that are legal but not preferred among adult participants. A unifying factor that held across all children's verbal inflection patterns was that the verb forms are more faithful to the base form of Korean verbal paradigms compared to adult forms. The current results support the claim that children prefer uniform paradigms due to the high ranking of OO-Faith constraints in the early stages of learning alternations when the patterns of alternations have not been mastered. It is worth noting that the children deploy morphologically longer verb forms to avoid alternation not only in irregular forms but

even in perfectly regular forms. Avoidance of alternation even in regular forms can provide a stronger support for paradigm uniformity bias among child learners.

To the best of my knowledge, the current study is the first to provide empirical evidence from natural L1 acquisition that supports the existence of an *a priori* paradigm uniformity bias. More explorations are needed to confirm paradigm uniformity bias in phonological acquisition and its role in the trajectory of learning alternations.

4.1. Demotion of the OO-Faith constraints

If the OO-Faith constraints are ranked too high in child learners' grammar, they should be demoted during the course of acquisition, because the initial grammar does not predict the production of alternating forms. This study's findings provide evidence for a learning trajectory for which the demotion of the OO-Faith constraints can account: from an initial stage where no alternation is produced, through an intermediate stage where regular alternations are produced, and then to the final stage where all types of alternations are produced. One approach to theoretically explaining the observed learning trajectory would be to combine a model in which constraint rankings depend on frequencies in the data, such as the Gradual Learning Algorithm (Boersma 1997; Boersma and Hayes 2001) and the paradigm uniformity hypothesis (Hayes 2004; McCarthy 1998). The next step needs to be a formal analysis or attempt to create a model to show how the demotion of OO-Faith constraints accounts for the current findings.

Note, however, that it is also possible to imagine that learners initially rank a set of Markedness constraints at the phonotactic learning stage, and promote the Markedness constraints that are supported by patterns of alternations at the later stage of learning alternations. It is conceivable that the promotion of the Markedness constraints supported by phonotactically driven alternations might facilitate the learning of alternations, even if the relevant OO-Faith constraints are not fully demoted.

Korean verb paradigms are not a good test case to investigate to what extent the promotion of Markedness constraints and the demotion of OO-Faith constraints contribute to the learning of alternations, because phonotactically predictable alternations are frequent as well (Do 2013; A. Albright and Kang 2009). To better understand the specific role of Markedness constraints' promotion and OO-Faith constraints' demotion in determining the acquisition of morphophonological alternations, investigations are needed in languages in which the phonotactic predictability and the frequency of alternations make different predictions about the order in which the various alternations will be learned.

4.2. The nature of paradigm uniformity bias

This study has shown that six- to seven-year-old Korean children are capable of producing a variety of alternating verbs. Their production of alternating verbs can be explained by changing constraint rankings in which OO-Faith constraints are demoted below the relevant Markedness constraint at an intermediate learning stage.

Although some OO-Faith constraints apparently are demoted to their proper low rankings at some intermediate learning stage, as shown by the children's production of some of the alternating verb forms, the study's results also show that children tend to not produce alternating forms if possible. They instead choose to produce extended morphological

structures of verbal inflections that retain paradigm uniformity. Considering only the constraint ranking that matches children's production of alternating forms (M >> OO-Faith), it is impossible to account for the observed tendency of children to avoid alternating verbs at the same learning stage, which can, however, be accounted for by the opposite constraint ranking (OO-Faith >> M). This account for the study's results has an interesting implication regarding biased phonological learning.

To the best of the author's knowledge, all of the proposals on learning biases in the literature so far have focused on the *learnability* of patterns, not on the role of bias in determining learners' *preferences* at the stage of production. For example, it has been found that learning biases can result in learners being less sensitive in learning certain patterns (Becker, Ketrez, and Nevins 2011; Moreton 2008), or able to learn only partial systems (Hayes, Siptár, Zuraw, and Londe 2009). An important finding of this study is that learners prefer to produce non-alternating verb forms that maintain paradigm uniformity even after they assign higher probability to the alternating forms. This finding indicates that the role of learning biases in phonology is not limited to their power to determine a pattern's learnability. When learners have acquired an alternation pattern, and achieved the M >> OO-Faith ranking, the learners may still tend to produce patterns that satisfy the initial constraint ranking, namely OO-Faith >> M, which is preferred due to paradigm uniformity bias. The observed discrepancy between being able to produce alternating verb forms and preferring to produce non-alternating forms suggests that learning biases in phonology play a role not only in determining learnability but also in shaping learners' production preferences.

Work on other types of phonological learning biases, such as substantive biases, has also focused mainly on their roles in learnability (See Moreton and Pater 2012 for an overview). Further investigation is required on how learning biases influence learners' preferred production patterns, and possibly their preferred perception patterns as well, in order to better understand the nature of biases in phonological learning.

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Appendix 1A. Target verbs in Experiment 1

Stem-final alternation Vstem ~ C$_{obs}$stem ~ C$_{nas}$stem	Frequency in Experiment 1	Target verbs*
Regular alternations		
Voicing and nasal alternations b ~ p ~ m d ~ t ~ n g ~ k ~ ŋ	3 1 4	cab-a 'catch', ib-ə 'put on', cəb-ə 'fold' tad-a 'close' məg-ə 'eat', cəg-ə 'write', mag-a 'block' nog-a 'melt'
Coda neutralization and nasal alternations pʰ ~ p ~ m	3	əpʰ-ə 'turn over', ciph-ə 'hit', noph-a 'be high'
Lateral alternation ɾ ~ l ~ Ø	4	yəɾ-ə 'open', miɾ-ə 'push', uɾ-ə 'cry', kiɾ-ə 'long'
Irregular alternations		
ll ~ ɾɨ ~ ɾɨ	6	hɨll-ə 'flow', pull-ə 'call', oll-a 'climb', call-a 'cut', mall-a 'be thin', null-ə 'push'
w ~ p ~ m	3	cuw-ə 'pick up', tow-a 'help', kuw-ə 'bake, roast'
ɾ ~ t ~ n	4	kəɾ-ə 'walk', tɨɾ-ə 'listen to', muɾ-ə 'ask', siɾ-ə 'load'
s ~ t ~ n	3	pəs-ə 'take off', s'is-ə 'wash', pis-ə 'comb'
No alternation		
n ~ n ~ n m ~ m ~ m	2 5	sin-ə 'put on', an-a 'hug' sim-ə 'plant', kam-a 'wash hairs', nəm-ə 'go over', tam-a 'put on a plate', sum-ə 'hide'
Total	38	

*Verbs are given in the prevocalic forms.

Appendix 1B. Pairs of target verbs in Experiment 2

Combination	Meaning
Simple-form-preferring V, Simple-form preferring V	an-a 'hug', sum-ə 'hide' sin-ə 'put on', kam-a 'wash hairs', sim-ə 'plant', nəm-ə 'go over', tam-a 'put on a plate', pʰum-ə 'hold'
Simple-form-preferring V, Extended-form-preferring V	cab-a 'catch', cuw-ə 'pick up' ib-ə 'put on', tow-a 'help' cəb-ə 'fold', kuw-ə 'bake, roast' tad-a 'close', tɨɾ-ə 'listen to' məg-ə 'eat', pəs-ə 'take off'
Extended-form-preferring V, Extended-form-preferring V	s'is-ə 'wash', hɨll-ə 'flow' pull-ə 'call', kəɾ-ə 'walk' pis-ə 'comb', miɾ-ə 'push' yəɾ-ə 'open', oll-a 'climb'
Extended-form-preferring V, Simple-form-preferring V	uɾ-ə 'cry', nopʰ-a 'high' null-ə 'push', cəg-ə 'write' mall-a 'be thin', nog-a 'melt' muɾ-ə 'ask', əpʰ-ə 'turn over' siɾ-ə 'load', mag-a 'block' call-a 'cut', cipʰ-ə 'hit'

*Verbs are given in prevocalic forms.

Appendix 2. Errors and extended forms from each participant (Experiment 1)