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Comparison of the RC Model and the WR Model Based on CHILDES*

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***Abstract*—The acquisition of the verb past tense has often been used to help to figure out children's real process of language acquisition. This paper aims to make a comparison between Charles Yang's Rules and Competition Model (the RC model) and Steven Pinker's Words and Rules Model (the WR model) based on real language acquisition data selected from CHILDES (Child Language Data Exchange System). Chomsky's Universal grammar is the foundation of both models. The comparison has been done from three aspects: the role of input frequency, overregularization errors, and the origin of irregular past tense. The finding of the study indicates that the RC model can well explain the role of input frequency in verb classes and the similarity between verb and the past tense while the WR model's explanation is vague in this point. Overregularization errors are more like an inevitable learning phenomenon that sheds light on phonological rules in the RC model instead of simple memory failures in the WR model. The WR model well explains the origin of irregular past tense while the RC model does not mention this point.**

***Index Terms*—verb past tense acquisition, Rules and Competition Model, Words and Rules Model, CHILDES**

I. Introduction

Children's unique ability to acquire grammar remains at the heart of linguistic inquiry. Their errors like "goed" and "doed" have been treated as evidence that human beings are a pattern-loving species. Acquisition of past tense verb has drawn much attention because it has two characteristics: the regular form is very productive; there are also about 180 verbs that have irregular past tense forms (Berko, 1958; Marcus, 1992). It represents the regular and irregular forms that exist in English and many other languages. Research into this issue can illustrate acquisition and cognitive mechanisms of language rules.

There are three systematic patterns in children's verb past tense acquisition that should be mentioned. First, in general, children inflect novel verbs with the "–ed' suffix. Second, young children sometimes over-regularize the "–ed' suffix. On average, over-regularization occurs in "about 10% of all instances of irregular verbs" (Marcus, 1992). Third, errors that children "misapply and overapply irregular past tense forms, are exceeding rare, accounting for 0.2% of all instances of irregular verb uses" (Xu & Pinker, 1995).

In this field, there are two prominent theoretical schools: the innate model and the connectionist ones. The former consists of the Chomsky-Halle model (Chomsky & Halle, 1968) and their followers (Halle & Mohanan, 1985; Halle & Marantz, 1993; Yang, 2002, 2006, 2010). Yang's Rules and Competition Model (the RC model) is a branch in this school. They propose that past tense forms are generated by affixing a morpheme to the stem and applying rules that change the stem's phonological structure. The latter, Rumelhart-McClelland model (Rumelhart & McClelland, 1986) and other connectionist models (Plunket & Marchman, 1993; Elman et al., 1996), explain the past tense form by associating the phonological features of the stem with the phonological features of the past-tense form. Later the Words and Rules Model (the WR model) is put forward to combine the previous two schools together (Pinker, 1984; 1994; 1999; 2007; Pinker & Prince, 1988; 1994; Pinker & Ullman, 2002).

This paper tries to use a qualitative approach to find out which theory, Yang's RC model or Pinker's WR model, is much closer to the real process of verb past tense acquisition. Based on Chomsky's Universal Grammar (UG), Yang (2002) proposes to model language acquisition as a population of competing grammars competing to match the external linguistic evidence presented to the learner, much in the manner of natural selection. Meanwhile, Pinker (1999) stands on the side of UG partially, saying regular past-tense forms can be inflected by making use of a default phonological rule whereas irregular forms are stored in the lexicon memory. This paper aims to make a contrastive analysis of these two models in the acquisition of past tense of English verbs to further the study of language acquisition.

The comparison is based on authentic data from CHILDES, which is the biggest international corpus of children's language collection launched by MacWhinney and Snow (1985). This paper has chosen a set of authentic records of children's language development collected by Fletcher in 2004. In order to find out the impact of age on language acquisition, this set of data has been collected from speeches of 74 children in three different age groups: children aged 3, 5, and 7. The data are appropriate for explaining how English-speaking children acquire past tense of verbs.

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II. Review of Yang's Rules and Competition Model

On the basis of Chomsky's Universal Grammar and Darwin's variational approach to evolution, Yang (2002) puts forward the Variational Model which believes: Universal Grammar is the innate mechanism which consists of all the possible grammars; these grammars compete with each other in language environment; only the proper grammar, i.e. the grammar of native language, retains eventually. Thus, language acquisition can be modeled as:

$$L: (S_0, E) \longrightarrow S_T$$

In this learning function, L maps the initial state of the learner, S_0, to the terminal state S_T, on the basis of experience E in the environment. To explain the gradualness of child language acquisition, Yang (2002) introduces statistic notions into the learning model. Each grammar Gi is paired with a weight Pi, which can be viewed as the measure of prominence of Gi in learner's language faculty. In a linguistic environment E, the weight Pi (E, t) is determined by the learning function L, the linguistic evidence in E, and the time variable t, the time since the outset of language acquisition. Learning stops when the weights of all grammars are stabilized. Upon the presentation of an input datum s, the child:

a. selects a grammar Gi with the probability Pi.
b. analyzes s with Gi.
c. if successful, rewards Gi by increasing Pi;
or otherwise, punishes Gi by increasing Pi.

Therefore, grammars that succeed in analyzing a sentence are rewarded and those that fail are punished. As the learning proceeds, grammars that have overall more successes will be more prominent represented in the learner's hypothesis space (Yang, 2002).

The Rules and Competition Model (the RC model) derives from the previously mentioned Variational Model. It holds that systematic errors in child language acquisition are reflections of coexisting hypotheses in competition and the weights, or the distribution of the grammars, change along with learning process (Yang, 2002). The RC model treats both irregular and regular verbs within one single component of the cognitive system: generative phonology. In the model, irregular past tense is also formed by phonological rules and overgeneralization errors result from failure to apply appropriate irregular phonological rules over the default one.

Yang (2002) also compares acquisition of irregular verbs to the number pair learning task. The RC model, based on a system of generative phonological rules, employs the strategy that irregular verbs are organized by rules that apply to a class of individuals:

a. {feed, shoot, …} → $R_{\text{Vowel Shortening}}$
b. {bring, think, …} → $R_{\text{t suffixation \& Rime}}$ → a
c. …

In an information-theoretic sense, the rule-based strategy, which allows a more compact description of the data, is the more efficient one. Yang's RC model serves the purpose of saving storage space in mental lexicon.

III. Review of Words and Rules Model

Pinker (1994) partially believes in innateness theory and proposes that there is a linguistic organ inside human mind and the computation of human mind is under the control of UG. At the same time, Pinker (ibid.) is against the hypothesis that language is evolved by mechanisms. He (1994) further assumes that language has its own independent nerve system used for language communication. Language evolves from generation to generation through the grammar gene, and UG exists in grammar gene and is passed down and inherited as a kind of human feature in the process of human evolution. The human language faculty is a complex biological adaptation that evolved by natural selection for communication in a knowledge-using, socially interdependent lifestyle (Pinker & Bloom, 1990). Pinker (2007) insists that "natural selection is the most plausible explanation of the evolution of language".

The Words and Rules model originates from the lexicalist theories of Jackendoff (1975), Aronoff (1976), Lieber (1980), and etc. In Pinker's WR model, the computational system for past tense consist of two parts: the "word" component and the "rule" component, the former being a stretch of sound that has to be memorized because it cannot be generated by rules and the latter the rules of morphology that build complex words. In the "word" component, irregular verbs are stored in the lexicon, a division of declarative memory which works like a connectionist network, by direct association/memorization of the pairing between a stem and its past tense. In the "rule" component that follows the tradition of generative linguistics, regular verbs are computed by making use of a default morphological rule, which adds "–d/ed" to the root. The premise of this model is that two tricks – words and rules – function with different principles. They are learned and used in different ways and may even reside over different parts of the brain.

Thus, irregulars have the psychological, linguistic and neuropsychological signatures of lexical memory, whereas regulars often have the signatures of grammatical processing. The strength of association is conditioned upon the frequencies of irregular verbs that children hear. It takes time and experience to perfect memorization of irregulars.

IV. Discussion on Selected Verb Acquisition Data and Comparison of the RC Model and the WR Model

A. Verb Acquisition Data Collected by Flecher

Out of curiosity about language learning, linguists have kept records of children's speech, which has enabled the generalizability of the nature of child language acquisition. Children's acquisition of language is a gradual process. The child begins to use verb past tense since 2 years old. With the development of language ability, the child becomes to use verb past tense correctly when they are 6 to 7 years old. We need to focus on samples that begin before the onset of overregularization and continue long enough to the performance marking to approach adult levels, so data of the study have been selected from speeches uttered by children aged 2 to 7 years old. This paper has chosen a set of records collected by Fletcher during a mutual communication process between him and the target children in 2004: speeches of 74 children at the age of 3, 5, and 7. According to the different ages, the whole samples have been divided into 3 groups: 25 language samples from children aged 3, 25 from children aged 5, and 24 from children aged 7.

Every occurrence of verb regular and irregular past tense has be manually counted and the statistics have be made into tables, including the correct usage rate (CUR) and the overregularization rate as following.

$$\text{The correct usage rate (CUR)} = \frac{\textit{total number of correct past tense of } x}{\textit{total number of past tense of } x}$$

$$\text{The overregularization rate} = \frac{\textit{number of overregularization past tense}}{\textit{number of overregularization past tense} + \textit{number of correct irregular past tense}}$$

The CUR and the overregularization rate of the three groups of children will be calculated separately. The study of CUR in different ages can help us get the detailed features of the whole process of children language acquisition. The overregularization rate has been used to calculate children's opportunities to make such errors at certain stages. These errors reveal important clues on how phonology is structured and learned.

The CURs and overregularization rates of all irregular verbs, averaged over all 74 children in three age groups, are given in Table 1:

TABLE 1
CUR AND OVERREGULARIZATION RATE OF IRREGULAR PAST TENSE VERBS

Age	Correct past tense	Past tense	CUR	Overregularization rate
3	412	424	97.2%	3.8%
5	346	387	89.4%	6.5%
7	462	473	97.7%	2.1%

Table 1 shows that children can use the irregular past tense almost correctly. At the same time, we can catch another feature of these statistics that is the CUR of children aged 5 is a little below that of children aged 3 and 7. Berko (2005) defines past tense acquisition as a sequence of three stages: in Stage 1, children use only a small number of verbs in the past tense; in Stage 2, evidence of implicit knowledge of a linguistic rule emerges; in Stage 3, the regular and irregular forms coexist. It may mislead us to believe that the performance in each stage is sharply distinguished from ones in other stages. But in fact, from the analysis of the data, we can get that the acquisition process is quite gradual and there are no such clear-cut stages.

B. Interpretation from the Perspective of the RC Model

In the RC model, the irregular verb past tense is formed by phonological rules. Errors such as overregularization are not memory lapses. Instead, they result from failure to apply appropriate irregular phonological rules over the default one. The RC model derives from the variational approach to language acquisition, which holds that systematic errors in child language are reflections of coexisting hypothesis in competition.

Yang (2002) divides verbs into different classes and proposes that verbs in the same class groups enjoy the same CUR performance. According to Yang's classification, we have analyzed the CUR of verbs grouped by classes in the data collected by Fletcher in 2004 and all the results have been put in Tables 2, 3, and 4.

TABLE 2
DATA ANALYSIS OF CHILDREN AGED 3

Phonological rules	CUR of verbs grouped by classes	Input frequency
[-t & Vowel Shortening]	lose (3/5)=60%	lost (63)
	leave (22/23)=95.6%	left (53)
[-t & Rime → a]	catch (2/2=100%)	caught (36)
	think (0)	thought (363)
	bring (2/2=100%)	brought (77)
	buy (3/3=100%)	bought (70)
[-Ø & No Change]	put (40/42=95.2%)	put (2,248)
	hit (0)	hit (66)
	hurt (0)	hurt (25)
	cut (1/1=100%)	cut (21)
[-Ø & Vowel Shortening]	shoot (3/4=75%)	shot (14)
	bite (2/2=100%)	bit (13)
[-Ø & Backing Ablaut]	get (170/171=99.4%)	got (1511)
	take (21/22=95.5%)	took (154)
	write (0)	wrote (28)
	win (0)	win (36)
[-Ø & Rime → u] ▼	know (0)	knew (49)
	throw (0)	threw (28)

TABLE 3
DATA ANALYSIS OF CHILDREN AGED 5

Phonological rules	CUR of verbs grouped by classes	Input frequency
[-t & Vowel Shortening]	lose (4/5)=80%	lost (63)
	leave (5/6)=83.3%	left (53)
[-t & Rime → a]	catch (1/1=100%)	caught (36)
	hink (9/10=90%)	thought (363)
	bring (1/1=100%)	brought (77)
	buy (2/4=50%)	bought (70)
[-Ø & No Change]	put (22/23=95.6%)	put (2,248)
	hit (0)	hit (66)
	hurt (0)	hurt (25)
	cut (1/1=100%)	cut (21)
[-Ø & Vowel Shortening]	shoot (0)	shot (14)
	bite (0)	bit (13)
[-Ø & Backing Ablaut]	get (76/77=98.7%)	got (1511)
	take (0)	took (154)
	write (1/1=100%)	wrote (28)
	win (1/1=100%)	win (36)
[-Ø & Rime → u] ▼	know (3/4=75%)	knew (49)
	throw (1/1=100%)	threw (28)

TABLE 4
DATA ANALYSIS OF CHILDREN AGED 7

Phonological rules	CUR of verbs grouped by classes	Input frequency
[-t & Vowel Shortening]	lose (1/1)=100%	lost (63)
	leave (4/5)=80%	left (53)
[-t & Rime → a]	catch (2/2=100%)	caught (36)
	think (2/2=100%)	thought (363)
	bring (0)	brought (77)
	buy (11/13=84.6%)	bought (70)
[-Ø & No Change]	put (32/33=97%)	put (2,248)
	hit (3/3=100%)	hit (66)
	hurt (0)	hurt (25)
	cut (2/3=66.7%)	cut (21)
[-Ø & Vowel Shortening]	shoot (1/1=100%)	shot (14)
	bite (2/2=100%)	bit (13)
[-Ø & Backing ablaut]	get (68/70=97%)	got (1511)
	take (9/10=90%)	took (154)
	write (1/1=100%)	wrote (28)
	win (1/1=100%)	win (36)
[-Ø & Rime → u] ▼	know (2/2=100%)	knew (49)
	throw (2/2=100%)	threw (28)

The RC model emphasizes the importance of the input frequency: the high input frequency improves child's language performance. From the above tables, we can find that the whole trend of the irregular verb past tense supports the prediction that the input frequency plays a role in CUR.

From the above tables, we can also find some past tense verbs share the free--rider effect. Despite the comparable different input frequencies and different age groups, the verbs in the same classes show the same feature in CUR. For example, two words "get" and "take", the latter having considerably lower input frequencies than the former, enjoy the similar CUR. The same situation happens between "go" and "come".

C. Interpretation from the Perspective of the WR Model

Different from phonological rules that Yang (2002) uses to explain irregular verb past tense, Pinker (1999) proposes that the irregular forms are fossils of rules that died long ago and they could be only memorized by today's generation without any help from phonological rules. In the WR model (Pinker, 1999, 2002), irregular verbs are learned in the "word" component, which works like a connectionist network, by direct association/memorization of the pairing between a stem and its past tense. The strength of association is conditioned upon the frequencies of irregular verbs that children hear, thus it takes time to perfect the memorization of irregular verbs. When the child's memory of an irregular form fails, the default "–d" form is used. This accounts for overregularization errors in child language.

Pinker (2002) proposes that the rating of irregular past tense forms depends highly on the ratings of the stems. He (ibid. p.59) believes that "half of the irregular past tense end in "t" or "d" because they originally took some version of the regular "–ed" suffix but then fell off the regular rule for one reason or another ". To check the correctness of the this proposal, this paper has four groups of verbs that have shared stems and analyzed the CUR of their past tense.

TABLE 5
CUR OF WORDS THAT SHARE STEMS

Shared stems	Verbs and past tense	CUR		
		aged 3	aged 5	aged 7
ow-ew	blow - blew	66.7%	71.4%	80%
	grow - grew	100%	100%	100%
	know - knew	--	75%	100%
	throw - threw	--	100%	100%
ink-ank	drink – drank	66.7%	100%	100%
	shrink – shrank	100%	100%	100%
end-ent	send - sent	100%	--	100%
	spend – spent	--	--	100%
ing-a/ung	sing – sang	100%	66.7%	100%
	string- strung	100%	100%	100%

From the above table, we can find words with the same stem enjoyed similar overregularization rate.

D. Comparison of the RC Model and the WR Model

Although both the RC model and the WR model are built on Chomsky's universal grammar and the idea of rule-forming mechanism in children's mind, they disagree with each other upon the details of the mechanism.

First, both the RC model and the WR model pay attention to the role of input frequency. From tables 2-4, we can find out that some past tense verbs that have very low input frequency enjoy a high level CUR. Yang (2002) tries to explain this phenomenon by the free-rider effect: he classifies verbs into classes according to phonological rules and proposes; the high input frequency of one verb will improve the CUR performance of verbs in the whole class. All the data in above analysis goes with this hypothesis. Inspired by associative theory of connectionism, Pinker puts forward that verbs that share the same stem will be associated and they will increase each other's CUR. Since irregular verbs are learned by associative pairing in the WR model, it is crucial to have a precise statement of how such associative pairing is established. However, we can find WR model is still vague. In this point, the RC model is more concrete, convincing, and much easier to test than the WR model.

Second, from tables 2-5, we can see that children's overregularization errors reveal more important clues on phonological rules, which the RC model views as a learning stage, and should not be regarded as simple memory retrieval failures in Pinker's WR model.

Third, the WR model well attributes the origin of irregular verb past tense to the past regular forms while the RC model does not mention this point.

V. SUMMARY

Based on the data from CHILDES, this paper has compared the RC model and the WR model through analyzing three distinctive features in children's verb past tense acquisition: the role of input frequency, overregularization errors, and the origin of irregular past tense. The finding of the study indicates that the RC model can well explain the role of input frequency in verb classes and the similarity between verb and the past tense with WR model's explanation being vague. Overregularization errors are more like an inevitable learning phenomenon that sheds light on phonological rules in the RC model instead of simple memory failures in the WR model. The WR model well accounts for the origin of irregular past tense while the RC model does not mention this aspect.

This article has analyzed fundamental principles and language mechanisms of these two models and compared the similarities and differences of them in the hope of better elaborating the language rules and the language knowledge processing mechanism in this field.

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