Morphological cues vs. number of nominals in learning verb types in Turkish: Syntactic bootstrapping mechanism revisited

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Abstract

The syntactic bootstrapping mechanism of verb learning was evaluated against child-directed speech in Turkish, a language with rich morphology, nominal ellipsis and free word order. Machine-learning algorithms were run on transcribed caregiver speech directed to two Turkish learners (one hour every two weeks between 0;9 to 1;10) of different socioeconomic backgrounds. Study 1 found that the number of nominals in child-directed utterances plays a small, but significant, role in classifying transitive and intransitive verbs. Study 2 found that accusative morphology on the noun is a stronger cue in clustering verb types. Study 3 found that verbal morphology (past tense and bareness of verbs) is useful in distinguishing between different subtypes of intransitive verbs. These results suggest that syntactic bootstrapping mechanisms should be extended to include morphological cues to verb learning in morphologically rich languages.

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Introduction

Syntactic bootstrapping is one of the learning mechanisms proposed to explain how children determine verb meanings from input. According to this account, children keep track of the number of arguments across utterances to derive general meanings such as transitive or intransitive verb types (Fisher, Hall, Rakowitz, & Gleitman, 1994; Gleitman, 1990; Landau & Gleitman, 1985; Naigles, Gleitman, & Gleitman, 1993; Naigles & Swensen, 2007). For example, a two-argument frame such as "the dog is verb-ing the cat" implies a transitive act, while a one-argument utterance such as "the dog is verb-ing" is likely to be construed as an intransitive act. When language learners encounter a verb mostly in one-argument frames, they would conclude that this verb is an intransitive verb.

There is substantial evidence that two-year-old children make use of argument number and argument placement information in syntactic frames to derive verb meanings (e.g., Hirsh-Pasek, Golinkoff, & Naigles, 1996; Naigles, 1998; see also Lidz, Gleitman, & Gleitman, 2003 for Kannada-speaking children). Gertner, Fisher & Eisengart (2006) found that children as young as 21-months-old use argument order information appropriately to interpret who is doing what to whom in transitive constructions containing nonsense verbs. However, most research on syntactic bootstrapping has involved English learners, and focused on the argument composition of the construction rather than its nominal or verbal morphology (Naigles & Swensen, 2006).

Whether syntactic bootstrapping is a plausible mechanism of language learning crosslinguistically is a topic of current research interest.. Given the variation in grammatical devices of the world's languages, the English language, featuring a strict word order and no nominal ellipsis, reflects an ideal case of correspondences between argument number and verb types. Several criticisms of the syntactic bootstrapping

approach have questioned the generalizability of the syntactic bootstrapping mechanism to languages with non-English-like grammatical properties (e.g., Allen, 2007; Bowerman & Brown, 2007; Goldberg, 2006; Rispoli, 1995; Wilkins, 2007).

In testing the cross-linguistic viability of the syntactic bootstrapping approach with Mandarin learners, Lee and Naigles (2005) examined a corpus of 6,088 utterances directed to children acquiring Mandarin, which allows argument ellipsis and flexible word order, similarly to Turkish. 7,884 tokens of 60 most frequent verbs were manually tagged to reveal that learners hear post-verbal noun phrases more frequently with transitive verbs than intransitive ones, suggesting that the number of arguments surrounding a verb can provide useful information for Mandarin children to classify verb types. Göksun, Küntay, & Naigles (2008) carried out an experimental sentence act-out study with child and adult speakers of Turkish using two-argument and one-argument constructions. They found that the number of arguments affected the likelihood of "transitive" enactments. These findings render the syntactic bootstrapping proposal plausible for languages with ellipsis and flexible word order.

In our study, we administer machine-learning experiments on child-directed Turkish recorded during family interactions to determine further the cross-linguistic feasibility of the syntactic bootstrapping approaches to early verb learning in Turkish child-directed speech and to explore the value of various morphosyntactic cues to distinguish different subclasses of verbs . Although there were previous automated natural-language processing techniques used to categorize verbs into semantic classes (e.g., im Walde, 2006; Stevenson & Merlo, 2001), none of these previous attempts tested theories of language development.

Turkish, unlike English and Mandarin, is a language that (a) relies on morphology, not so much on argument ordering, to assign grammatical relations in a clause, and similarly to Mandarin (b) allows extensive argument ellipsis and word order alternations. As Naigles and Swensen (2007) state, experimentation within the syntactic bootstrapping model has mostly been limited to English, and not yet

adequately applied to languages with complex morphology. Therefore, Turkish language provides a good testing ground for the syntactic bootstrapping mechanism in a language that mainly employs morphological means for indicating "who-does-what-to-whom."

Turkish is an SOV language, where verbs typically appear at the end of utterances. However, Turkish allows omission of both the subject and the object, and has flexible word order. Being an agglutinating language, Turkish marks case (accusative, dative, locative, ablative, instrumental), possessive and plurality on nouns, which include pronouns. Verb morphology includes tense/aspect/modality markers, negation, subject agreement and voice morphemes (passive, causative, reflexive and reciprocal). Verbs can appear in the bare form in the imperative mood.

The current study addresses three questions using machine-learning algorithms on child-directed speech: (1) Is the number of nominals in a sentence informative for classifying transitive and intransitive verb types in Turkish child-directed speech? (2) Does nominal morphology facilitate distinguishing transitive versus intransitive verbs? (3) Does verbal morphology play any role in distinguishing between different subtypes of transitive and intransitive verbs?

Method

Dataset Preparation

Child-caregiver interaction was video-recorded at the homes of two female Turkish learners (Irmak and Elif), for one hour every two weeks. Irmak's parents both had 8 years of education; Elif's parents both had doctoral degrees. Table 1 provides the basic characteristics of the datasets The Irmak corpus and the Elif corpus respectively contained 12,276 and 20,687 morphologically coded child-directed utterances, which were the data used by our machine learning programs. (Table 1 about here)

Trained native speakers transcribed and morphologically coded the spoken language from the

videotapes using the CHAT transcription format provided by the CHILDES project (MacWhinney, 2000). Below is a sample utterance from the child-directed data and its morphological coding tier.

(1) NAN-CHI: kuş-lar-ı-mı arı-yo(r)-sun?

%mor: N|kuş-PL-ACC-QUE V|ara-PROG-2S

'Are you looking for the birds?

The datasets for the two children exhibited remarkable differences as well as similarities. Table 2 shows the most frequent 10 verbs in each child's data set, 8 of which are common. Even though the total number of utterances was approximately the same, the number of child-directed utterances is higher in the Elif dataset. The frequency distribution of verbs in the Elif dataset is flatter: The top 10 verbs in the Elif dataset account for 45% of all verb occurrences, whereas in the Irmak data this ratio is 55%. These factors result in more verb types in the Elif dataset above a frequency threshold (170 verbs appearing >= 10 times) compared to the Irmak data set (124 verbs appearing >= 10 times). These differences can be due to somewhat different language environments created by families of different socio-educational backgrounds. However from a verb learning perspective, our study suggests that the algorithms work well on both datasets. (Table 2 about here)

Verb Categorization

We manually tagged each verb that occured 10 times or more in our corpora according to their argument structure as unaccusative , unergative, and transitive. Our argument structure categorization of Turkish verbs was based on a modified version of Ketrez (1999), which adopted an analysis based on Grimshaw's (1992) Prominence Theory. We used the transitive-intransitive classification as our primary learning target. The transitive category included Grimshaw's (1992) transitive agentive verbs (x_{agent} (y_{theme})) such as *aç-* 'open,' *kır-* 'break,' *ye-* 'eat,' which involve an agent and a theme that was acted upon by the agent, and ditransitive verbs (x_{agent} (y_{goal} (z_{theme})) that include *koy-* 'put,' *ver-* 'give,' where a third argument in the

form of a goal is included in the event. We also experimented with splitting the intransitive verbs into unaccusatives ((x_{theme})) that have only a 'theme' argument such as *düş-* 'fall' and unergative (x_{agent}) verbs that has an agent as the sole argument, such as *koş-* 'run.'

Feature Evaluation

To determine if the utterance context of a verb carries sufficient information to correctly classify its argument structure, we used machine learning methods to evaluate different features of the verb context. We considered several different types of noun and verb features that may facilitate identification of the verb argument structures. Table 3 presents the features evaluated in three different studies:

- Study 1: The average number of nominals that occur with the verb in a given utterance
- Study 2: The frequency with which the verb is observed with arguments with different types of case markers
- Study 3: The frequency with which the verb occurs with different types of inflectional and derivational morphemes (Table 3 about here)

The WEKA machine learning toolkit (Witten & Frank, 2005) was used to systematically evaluate different subsets of these features and rank them according to their performance in discriminating transitive from intransitive verbs, and within intransitives discriminating unaccusatives from unergatives. We took the distance between two verbs to be the Euclidean distance between their feature vectors. We used the k-means clustering algorithm (Bishop, 2006) to measure the performance of each feature subset considered. The k-means algorithm partitioned the given verbs into k clusters (k=2 in our case) minimizing the distance of each verb to the centroid, or prototype of its cluster. We then compared the resulting cluster assignments with the manually tagged actual categories of the verbs to see how well a particular feature set performs.

The following results focus on the features which proved most useful in providing verb clusters, among those considered in this study and listed in Table 3.

Results and Discussion

Study 1: Number of nominals is moderately effective in verb categorization

In Study 1, we assessed whether the number of nominals that surround a verb in an utterance was a useful cue in distinguishing between transitive and intransitive verbs. Among nominals we included words that might act as verb arguments such as nouns, pronouns, and some wh-words that had pronominal properties (i.e., "who" and "what"). If an utterance contained a single verb, we assigned all the nouns in that utterance to that verb. If an utterance included multiple verbs, we assigned each noun to the nearest verb on its right as Turkish is right-headed. In those cases where there was no verb on the right, we used the nearest verb on the left.

Table 4 presents the mean number of nominals surrounding transitive and intransitive verbs in both datasets. The number of nominals around the transitive verbs is significantly higher than around the intransitive verbs, with small-to-moderate effect sizes for both datasets (Elif: $t(168) = 4.30$, $p < .0001$, Cohen's $d = 0.66$; Irmak: $t(122) = 4.16$, $p < .0001$, $d = 0.75$). (Table 4 about here)

The number of nominals was used as input to the k-means clustering algorithm to determine the extent to which this feature facilitates the prediction of the transitive-intransitive distinction in child-directed speech. On the basis of a majority class baseline measure, which always predicts the most frequent category (i.e., the transitive), the accuracies for detecting the right verb category would be 57.1% and 61.3 % for Elif and Irmak, respectively. The usage of the feature of the number of nominals around the verb would increase these predictions up to 68.2% and 71.8%, only about 10% better than the baseline.

Study 2: Nominal morphology strongly signals transitivity

In Study 2, we assessed whether accusative marking was a stronger indicator of the transitive-intransitive distinction. Table 5 presents the proportion of accusative-marked nominals that accompany transitive and intransitive verbs for the Elif and Irmak datasets. The frequency of accusative-marked nominals is significantly higher for transitive verbs compared to intransitive verbs, with large effect sizes for both datasets (Elif: $t(168) = 14.02$, $p < .0001$, $d = 2.32$; Irmak, $t(122) = 9.88$, $p < .0001$, $d = 2.01$). (Table 5 about here)

Using the frequency of accusatives as input to the k-means clustering algorithm, we can distinguish transitives from intransitives correctly at 92% of the time in the Elif dataset and 90% of the time in the Irmak dataset. The accusative morphology on the noun increases the accuracies for detecting the verb category by about 30% compared to majority class baseline predictions (i.e., 57.1% for Elif and 61.3% for Irmak). Study 1 and Study 2 results demonstrate that although number of nominals plays some role in distinguishing between verb classes, the presence or absence of accusative morphology on the noun constitutes a stronger cue.

Study 3: Further subcategorization with verb morphology

As a third question, we explored whether verbal morphology would be useful in distinguishing between different classes of verbs. Among the features considered (see Table 3), the past morpheme and lack of verbal morphology on the verb, which is used for imperatives in Turkish, contributed criterial value in subcategorizing intransitive verbs into unaccusatives and unergatives.

Unaccusative verbs, such as *düş-* 'fall,' that usually denote states and whose subjects have the 'theme' role are practically never used in the bare imperative form, so the frequency of the use of the bare form of the verb distinguishes unaccusatives from unergatives well. Table 6 provides the proportion of unaccusative and unergative verbs that appear with no inflectional morphology in the Elif and Irmak datasets. The frequency of having no morphology on the verb is significantly higher for unergative verbs compared to unaccusative

verbs, with large effect sizes for both datasets (Elif: $t(71) = 4.08$, $p < .0001$, $d = 1.03$; Irmak: $t(46) = 6.39$, $p < .0001$, $d = 2.06$).

Using the frequency with which verbs are used in their bare form as input to the k-means algorithm, we were able to predict the unaccusative-unergative distinction with 74% accuracy in the Elif dataset, and 83% accuracy in the Irmak dataset. Both numbers are above the baseline of always predicting the most frequent category (58% for Elif and 60% for Irmak). (Table 6 about here)

Table 7 provides the proportion of unaccusative and unergative verbs that appear with past morphology in the Elif and Irmak datasets. The frequency of having past morphology on the verb, which marks the perfective aspect as well as the past tense, is significantly higher for unaccusative verbs compared to unergative verbs, with large effect sizes for both datasets (Elif, $t(71) = 4.30$, $p < .0001$, $d = 0.99$ and Irmak, $t(46) = 5.37$, $p < .0001$, $d = 1.48$). The unaccusative-unergative distinction was predicted with 73% and 64% accuracy for Elif and Irmak datasets respectively and these numbers are again above the baseline of always predicting the most frequent category (58% for Elif and 60% for Irmak). (Table 7 about here)

Unaccusative verbs are mostly used in contexts that describe the final state of the objects (e.g., the toy fell/broke). In this sense, the present finding is not surprising and it is in line with the observation in Aksu-Koç (1988, 1998), who reports that in both child and child-directed speech, achievement verbs that overlap with the unaccusatives in the present study mostly appear with past morphology *–DI,* denoting completed action and final state of the objects. This correlation between verbal morphology and aspectual properties of verbs in child language is observed in other languages as well, as early as in 1970s (Antunicci & Miller. 1976, Bloom, Lifter & Hafitz, 1980, Clark, 1996)

Conclusion

Recent work with non-English languages (e.g., Göksun, Küntay, & Naigles, 2008; Lee & Naigles, 2005; Lidz, Gleitman, & Gleitman, 2003) has shown that the number of arguments in a sentence plays a role in distinguishing transitive verbs from intransitive verbs in languages that allow nominal ellipsis. What remains unclear is whether morphological features constitute a stronger cue in morphologically complex languages.

We have shown that in a language with agglutinative morphology such as Turkish, number of nominals surrounding a verb is not the only cue for determining verb categories. In classifying verb types, morphological cues provide more reliable cues than the number of nominals in speech to two female children of different socioeconomic backgrounds. The presence of accusative case marking in child-directed utterances leads to better clustering of transitive and intransitive verbs compared to the number of nouns. In addition, absence of verbal morphology found in imperatives and past tense morphology appear criterial in partitioning between different types of intransitive verbs. The evidence we have so far from early language production of Turkish children makes these findings not very surprising. The accusative is the first nominal inflection and the past tense is the first verbal inflection to appear in early child language (Aksu-Koç & Slobin 1985, Ketrez 1999, Aksu-Koç & Ketrez 2003, among others). The frequency and the regularity of these morphological cues probably render them highly learnable morphosyntactic devices.

There is nothing in the syntactic bootsrapping account that precludes morphological cues from being considered as cues to verb argument structure, however, the existing literature mostly focuses on the number and semantic types of arguments without seriously relying on morphology. The syntactic bootstrapping mechanism would be more viable if the role of morphological features such as case and tense are taken into consideration in the acquisition of verb meanings, at least for morphologically rich languages. For example, the Göksun et al. (2008) study evaluates morphology and argument number, concluding that accusative morphology is a salient device employed by Turkish learners to determine construction meaning. In this current work, the most potent device we find in child-directed speech to tell apart transitive verbs from

intransitive verbs is the accusative casemarking The experimental work carried out by Göksun et al. (2008) with real Turkish learners shows that nominal morphology is relevant for children interpreting Turkish sentences (also Slobin &Bever, 1982).More research is needed to determine how different linguistic devices interact in different ways across different languages and at different developmental points of language development (Dittmar, Abbot-Smith, Lieven & Tomasello, 2008).

Table 1: Characteristics of the databases

	Irmak	Elif
Number of sessions	30	27
Start age	0;9,0	0;9,10
End age	2;0,16	1;9,28
Total number of utterances	32362	32933
Child-directed utterances	15781	22425
Child-directed with morphological analysis	12276	20687
Number of verb lemma tokens	18162	22195
Number of unique verb lemmas	601	795
Verb lemmas with count > 10	124	170

Table 2: Most frequent verbs in Irmak and Elif datasets

Irmak			Elif		
Root	Gloss	Freq	Root	Gloss	Freq
gel	come	2809	*gel*	come	1900
bak	look	2302	*yap*	do	1848
al	take	1016	*bak*	look	1835
git	go	865	*ol*	be	1196
yap	do	857	*git*	go	742
de	say	576	*iste*	want	625
ol	be	459	*al*	take	604
ye	eat	398	*koy*	put	490
otur	sit	362	*ver*	give	444
ver	give	352	*ye*	eat	433
TOTAL		9996			10117

Table 3: Noun and verb features evaluated in Studies 1 to 3

	Feature	Explanation
NOUN FEATURES	N-NOM	nominative
	N-ACC	accusative
	N-DAT	dative
	N-LOC	locative
	N-ABL	ablative
	N-COM	comitative
	N-INSTR	instrumental
	ACC+DAT	accusative, dative
	ACC+NOM	accusative, nominative
	DAT+NOM	dative, nominative
	ACC+DAT+NOM	accusative, dative, nominative
	ACC|DAT|NOM	at least contains one of three cases
	ACC|DAT	at least contains one of two cases
	W-COUNT	number of words in the domain of the verb
	N-COUNT	number of nouns in the domain of the verb
	NO-NOUN	no nouns attached to the verb
VERB FEATURES	CAUS	causative
	DCAUS	double causative
	VR	verb derived from noun
	PASS	passive

REFL	reflexive
RECIP	reciprocal
IMPER	imperative/bare form of the verb.
FREQ	frequency of the verb
PAST	past
IPFV	imperfective *-Iyor*
QUE	question particle
NEG	negation
AOR	aorist
OPT&1P	optative, first person plural
FUT	future tense
OPT&1S	optative, first person singular
PFV	perfective *-mIş*
ABIL	abilitative

Table 4: The number of nominals surrounding transitive and intransitive verbs in the Elif and Irmak datasets

	Elif	Irmak
Transitive	1.03 (.07)	.73 (.07)
Intransitive	.79 (.08)	.49 (.10)

The 95% confidence interval of the mean number of nominals is shown in parentheses.

Table 5: The proportions of transitive and intransitive verbs accompanied by accusative morphology in the Elif and Irmak datasets

	Elif	Irmak
Transitive	.34 (.04)	.27 (.04)
Intransitive	.02 (.007)	.02 (.008)

The 95% confidence interval of the mean proportions is shown in parentheses.

Table 6: The proportions of unaccusative and unergative appearing with no verbal morphology in the Elif and Irmak datasets

	Elif	Irmak
Unaccusative	.03 (.02)	.04 (.04)
Unergative	.19 (.07)	.53 (.12)

The 95% confidence interval of the mean proportions is shown in parentheses.

Table 7: The proportions of unaccusative and unergative appearing with past morphology in the Elif and Irmak datasets

	Elif	Irmak
Unaccusative	.39 (.08)	.41 (.12)
Unergative	.19 (.05)	.09 (.05)

The 95% confidence interval of the mean proportions is shown in parentheses.

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