A COMPUTATIONAL STUDY ON ACCUSATIVITY AND ERGATIVITY

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ABSTRACT

A COMPUTATIONAL STUDY ON ACCUSATIVITY AND ERGATIVITY

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English is defined as an accusative language with Subject-Verb-Object (SVO) syntactic order. In this study, if children were exposed to hypothetical English, i.e. ergative English, rather than accusative English in the language acquisition process, what would happen was investigated by using a child-directed speech data set taken from the Eve fragment (Brown, 1973) of the Child Language Data Exchange System (CHILDES) database (MacWhinney, 2000). This process was modelled computationally by a training model.

Based on the data set, the standard English grammar was constructed with the syntactic and semantic representations of the words. According to this grammar, correct pairs of sentences and their corresponding logical forms were generated. Subsequently, several models were developed to derive accusative sentences from the grammar. After training, the best model that prioritizes the correct pairs of sentences in the derivation results was obtained. Three experiments were conducted with this model: one exclusively employed accusative grammar, another used accusative grammar and ergative forms of transitive verbs, and the last focused only on syntactically ergative grammar. In these experiments, the trained model corresponded to the child

acquiring the language, and the rank success represented whether the child successfully acquired the target language.

The results of these experiments and the rank success of the model demonstrated that children can be assumed to have acquired accusative English when they are exposed to accusative English, and they can be assumed to have captured ergative English when they are exposed to hypothetical ergative English. These results indicated that each grammatical relation (accusative or ergative) system is equally likely for children in language acquisition, and the exposure to particular linguistic experiences decides which system takes precedence and which falls behind.

Keywords: language acquisition, bootstrapping, accusativity, ergativity, linguistic annotation

ÖZ

BELİRTMELİLİK VE ÖZGEÇİŞLİLİK ÜZERİNE HESAPLAMALI BİR ÇALIŞMA

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İngilizce, Özne-Fiil-Nesne (SVO) sözdizimi düzenine sahip belirtmeli (accusative) bir dil olarak tanımlanır. Bu çalışmada, Child Language Data Exchange System (CHILDES) veritabanının (MacWhinney, 2000) Eve kısmından (Brown, 1973) alınan çocuğa yönelik konuşmalar içeren veri seti kullanılarak, dil edinim sürecinde çocuklar belirtmeli İngilizce yerine varsayımsal bir İngilizceye, yani özgeçişli (ergative) İngilizceye, maruz kalsaydı ne olacağı araştırıldı. Bu süreç bir eğitim modeliyle hesaplamalı olarak modellendi.

Veri setine dayanarak, standart İngilizce dilbilgisi, kelimelerin sözdizimsel ve anlamsal gösterimleriyle oluşturuldu. Bu dilbilgisi doğrultusunda, cümlelerin ve onlara karşılık gelen mantıksal formlarının doğru çiftleri üretildi. Ardından, oluşturulan dilbilgisinden belirtmeli cümleler türetmek için birkaç model geliştirildi. Eğitim sonrasında türetme sonuçlarında doğru cümle çiftlerini önceliklendiren en iyi model elde edildi. Bu modelle üç deney yapıldı: biri yalnızca belirtmeli dilbilgisi kullandı, diğeri geçişli fiillerin özgeçişli formlarını ve belirtmeli dilbilgisini kullandı ve sonuncusu yalnızca sözdizimsel olarak özgeçişli dilbilgisine odaklandı. Bu deneylerde, eğitilmiş model,

dili edinen çocuğa karşılık geldi ve sıralama başarısı, çocuğun hedef dili başarıyla öğrenip öğrenmediğini temsil etti.

Bu deneylerin sonuçları ve modelin sıralama başarısı, çocukların belirtmeli İngilizceye maruz kaldıklarında belirtmeli İngilizceyi edindiklerinin ve varsayımsal özgeçişli İngilizceye maruz kaldıklarında özgeçişli İngilizceyi yakaladıklarının varsayılabileceğini gösterdi. Bu sonuçlar, her dilbilgisel ilişki sisteminin (belirtmeli veya özgeçişli) dil ediniminde çocuklar için eşit derecede olası olduğunu ve belirli dilsel deneyimlere maruz kalmanın, hangi sistemin öncelikli olacağını, hangisinin geride kalacağını belirlediğini gösterdi.

Anahtar Kelimeler: dil edinimi, önyükleme, belirtmelilik, özgeçişlilik, dilbilimsel açıklama

To the little girl in my heart

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LIST OF ABBREVIATIONS

A	Agent
ABS	Absolutive
CHILDES	Children Language Data Exchange System
DG	Dependency Grammar
ERG	Ergative
FLA	First Language Acquisition
NP	Noun Phrase
O	Object
POS	Poverty of Stimulus
S	Subject
SV	Subject-Verb syntactic order in English
SVO	Subject-Verb-Object syntactic order in English
UG	Universal Grammar
V	Verb

CHAPTER 1

INTRODUCTION

First language acquisition (FLA) is a complex process that encompasses the acquisition of the first language(s) of a child at a very young age (Crain and Lillo-Martin, 1999). In this process, every child acquires a language without any special training or any particularly designed language input, which means that a child is expected to gain a series of linguistic features related to phonology, morphology, syntax, semantics, pragmatics and a lexicon based on the sentences of the language to which s/he is exposed (Crain and Lillo-Martin, 1999). Even though every child in a community has unique experiences, each obtains similar results at the end of the first language acquisition process (Crain and Lillo-Martin, 1999). The first thing to be asked here is how all children can perceive and comprehend a language and learn to speak despite facing numerous challenges. Considering all these, FLA is a broad research area in which it is difficult to bring forward a reliable and valid approach for all the intricacies involved in this complex process. However, valuable theories of first language acquisition have been argued for decades.

One of the most prominent theories is Universal Grammar (UG), proposed by Chomsky (1965). It is known that a language is the outcome of a set of rules that define the meaning of numerous sentences in that language (Chomsky, 1965), but the main question here is how children acquire all these rules. Chomsky (1965) posits that a child learning a language seeks to generate the rules of the language from speakers' performances, and s/he attempts to apply these rules in real life owing to the language faculty containing the innate ability for language. In the view of UG (Chomsky, 1965), a child acquires a language by adhering to innate constraints that determine the possible grammatical structures of a language. In other words, when a child is subject to

linguistic stimuli, s/he builds up the linguistic rules considering UG (Chomsky, n.d.).

Some universal properties of language and the poverty of stimulus (POS) argument comprise a basis for the UG theory. However, some linguists question the existence of such universality among languages because of the diversity observed in languages (Evans and Levinson, 2009). Evans and Levinson (2009) argues that hardly any language universals exist in all languages. Rather than emphasizing the universal properties of languages, they claim that diversity is prevalent among various linguistic aspects such as lexicon, grammar, and meaning. Therefore, the theory of UG has still been argumentative from this perspective (Christensen, 2019).

On the other hand, the POS argument offers that children cannot be exposed to all potential language inputs to acquire all linguistic features of a language. Indeed, the input that children face is insufficient for understanding a language's linguistic structure (Chomsky, 1980). However, Yarlett et al. (2008) propose that the POS problem can be coped with when considering that children use similar strategies to deduce the usage of new words based on those they have already learned. Furthermore, Yarlett et al. (2008) argue that ungrammatical structures during language acquisition indicate that language learning is a probabilistic process involving errors rather than a rigid mapping one.

Similarly, Abend et al. (2017) claim that a fundamental challenge in language acquisition is producing new utterances beyond the provided input. Another challenge stems from the complexity of syntactic and semantic structures within the language input. Hence, Abend et al. (2017) says a language acquisition process requires the ability to parse utterances into syntactic and semantic structures, relate these structures to each other, and discern language-specific patterns that enable the production beyond the input. In this regard, Abend et al. (2017) maintains that a child acquires grammar and lexicon depending upon exposure to sentences in the language and their corresponding semantic representations (logical forms).

Based on the abovementioned assumptions, this thesis aims to develop a different perspective on language acquisition. In particular, the study investigates the possible results if children are introduced to a hypothetical form of English, i.e. the ergative version of English rather than accusative English, during the language acquisition

process by utilizing a child-directed speech data set. The investigation was done by computationally simulating the learning process by a learning model. In the initial phase of the study, the grammar of accusative English, including both syntactic and semantic representations, was constructed based on the data set. Correct pairs of sentences and their logical forms were formed based on this grammar. Following this, several models were developed to derive accusative sentences from the grammar, and they were trained to match the surface forms with their corresponding syntactic and semantic structures. Following the training phase, the best model that precedes the accurate pairs of sentences in the derivation results was obtained. Subsequently, some parts of the grammar were modified for hypothetical English, i.e., syntactically ergative English, and these modified structures were incorporated into the data set during specific experiments. After all these procedures, three experiments were carried out using the best model: one involving the accusative version of English grammar, another including the accusative version of English grammar besides ergative forms of transitive verbs, and the last focusing only on the syntactically ergative version of English grammar. In this study, the trained model corresponds to the child acquiring the language, which means the model's rank success represents whether the child has successfully acquired the target language.

The purpose of this study is to make a valuable contribution to the field by questioning whether each system of grammatical relations (accusative or ergative in this study) is equally likely for children at the beginning of language acquisition. Such findings can provide a possible answer to how universal constraints affect language acquisition and whether children can acquire their native language without innate constraints related to the possible grammatical structures of a language.

This thesis also makes a significant contribution by constructing a grammar including linguistic annotations of the Eve fragment (Brown, 1973) of the Child Language Data Exchange System (CHILDES) database (MacWhinney, 2000). The constructed grammar can serve as a resource for following research studies in such a way that facilitates prospective linguistic studies. Chapter 3 will provide a detailed description of the data set and the constructed grammar.

In light of the preceding assumptions and objectives, the research questions below are investigated in the study:

1. What are the potential outcomes if children are exposed to hypothetical English, i.e. syntactically ergative English, rather than accusative English in the first language acquisition process?
2. If the trained model successfully acquires hypothetical English, what does this success indicate?
3. How do universal constraints affect language acquisition and grammar?

This chapter introduces the objectives and significance of the present study and concludes by presenting the research questions. The forthcoming chapter will provide essential background information with a comprehensive literature review.

CHAPTER 2

BACKGROUND

This chapter will provide the required theoretical background information and previous studies conducted in these fields to explain the study well.

2.1 Bootstrapping Language Acquisition

Pinker (1984) proposes that children at the onset of language acquisition acquire the syntactic structures of a language through first learning and identifying its semantic structures and then constructing or bootstrapping from that knowledge. Starting from this semantic bootstrapping theory, Abend et al. (2017) build up a Bayesian probabilistic model of bootstrapping language acquisition relying on computational parsing and interpretation methods of unlimited text. The probabilistic model is trained to learn the mapping between the sentences of the target language and their syntactic and semantic representations from some contextually plausible logical forms. In the training process, the model takes training samples, including all the utterances with the noisy representations of their meaning, and it learns the probabilities of the syntactic and semantic structures of the words. In such a way, the model can recombine these words to comprehend new utterances and produce new meanings, which means that the training model learns how to parse syntactic structures, use syntactic rules, and assign meaning to each word. Abend et al. (2017) apply this model to a data set of the Eve fragment (Brown, 1973) of the CHILDES database (MacWhinney, 2000). They use the linguistic annotations formed by Sagae et al. (2010) and revised by Kwiatkowski (2012). The model exhibits several syntactic bootstrapping effects, such as fast learning of words and word order. Namely, the study by Abend

et al. (2017) emphasizes that syntax is acquired through semantic bootstrapping via the logical forms using a learning algorithm operating over some grammatical probabilities.

Some instantiations of the bootstrapping language acquisition theory have been put forward over the years. One is principles and parameters proposed by Chomsky (1981). According to Chomsky (1981), the syntactic structure of a language is identified by the principles and parameters. For instance, the head position is determined by a parameter that is either on or off for particular languages. Such parameters can be set when a child faces triggers. However, Hyams (1986) claims that a child is supposed to discern whether a word is a verb to decide whether a language is head-initial or head-final, which is the requirement of a stage of semantic bootstrapping. Similarly, Gibson and Wexler (1994) criticizes principles and parameters theory because the significant word order parameters such as specifier-head or complement-head lack adequate triggers to set a parameter.

Based on these discussions, our study posits that children can acquire the syntactic structures of any language through semantic bootstrapping, regardless of the constraints regarding the possible grammatical structures of a language, as mentioned in UG (Chomsky, 1965). We further assert that all the systems of grammatical relations (accusative and ergative in this study) are equally likely for children at the beginning of the language acquisition process. Based upon this idea, it can be assumed that if children are exposed to accusative English, they will acquire it. Conversely, if they are exposed to hypothetical ergative English, they will acquire it. These assumptions provide a clear framework for our study, enhancing our understanding of how children acquire language.

Before the details of the present study are described, the next section will provide an introduction to accusative-nominative languages and ergative-absolutive languages.

2.2 Accusativity and Ergativity

2.2.1 Accusative-Nominative Languages

A language is structured in one or more of the following six word orders: SVO, SOV, OSV, OVS, VOS, and VSO. However, English's prominent syntactic word order is SVO (subject-verb-object) in transitive sentences and SV (subject-verb) in intransitive sentences.

In nominative-accusative languages, such as English, case marking, verb agreement, and word order differentiate subjects of transitive and intransitive verbs from objects of transitive verbs. In nominative-accusative languages, subjects take the nominative case while objects take the accusative case. Regarding this, English has nominative-accusative alignment regarding case marking. (Donohue and Wichmann, 2008).

2.2.2 Ergative-Absolutive Languages

In ergative-absolutive languages, the agents of transitive verbs are distinct from the subjects of intransitive verbs and the objects of transitive verbs (Comrie, 1989). Ergativity can be found in both morphological and syntactic manner. Ergative languages are classified into two groups: the ones in the first group are morphologically ergative but syntactically accusative, such as Basque, Pashto, and Urdu, whereas the ones in the second group exhibit both morphological ergativity and syntactic ergativity. However, there is not any recorded language which is both morphologically and syntactically ergative (Dixon, 1994). Dyirbal is regarded as the only representative of syntactic ergativity, although it exhibits accusative alignment with specific pronouns. Some examples for Dyirbal are provided in Section 2.2.2.2.

In the following section, both morphological and syntactic ergativity will be explained in detail for clarity.

2.2.2.1 Morphological Ergativity

If a language possesses morphological case, then the verb arguments are typically marked in the following manner: the agent of a transitive verb (A) receives the ergative case marking and the core argument of an intransitive verb (S) and the object of a transitive verb (O) both bear the absolutive case marking.

In cases without explicit case marking, ergativity may be indicated through alternative methods, such as verbal morphology. For example, languages like Abkhaz and most Mayan languages lack morphological ergative case markings but employ a verbal agreement structure that reflects ergativity.

The following examples can be examined for a clearer understanding of the distinction between accusative and ergative languages.

Accusative English:

a. I (S) see him (O).
b. I (S) run.

Figure 2.1: Examples of accusative English

In the sentences in Figure 2.1, the subjects of both the transitive and intransitive verbs have the same case whereas the object of the transitive verb (him) differs from them.

Hypothetical Ergative English:

a. Him (O) see I (S).
b. Him (S) run.

Figure 2.2: Examples of hypothetical ergative English

In Figure 2.2, the same case is assigned to both the object of the transitive verb (him) and the subject of the intransitive verb (him). The subject of the transitive verb (I) has a different case from them.

Rather than focusing on morphological ergativity, this study delves into only syntactic ergativity in constructing the hypothetical version of English, i.e. ergative English, as elucidated in the following section.

2.2.2.2 Syntactic Ergativity

Syntactic ergativity can be specified through syntax, as seen in sentences like "Walk I" for "I walk." As far as it is known, Dyirbal is the only sample of syntactic ergativity. The following examples taken from Dixon (1994) of ergativity in Dyirbal are provided with the comparison of English.

1. Intransitive Sentences

   (a)

Table 2.1: Intransitive ergative example in Dyirbal

ŋuma banaganʸu.	
ŋuma-∅	banaganʸu
father-ABS	returned
Subject(S)	$\text{VERB}_{\text{intrans}}$
"Father returned."	

In Table 2.1, the absolutive case is assigned to the subject of the intransitive verb.

2. Transitive Sentences

(a)

Table 2.2: Transitive ergative example in Dyirbal

Yabu ŋumaŋgu buṛan.		
yabu-∅	ŋuma-ŋgu	buṛan
mother-ABS	father-ERG	saw
Object(O)	Agent(A)	$\text{VERB}_{\text{trans}}$
"Father saw mother."		

In Table 2.2, the ergative case is assigned to the agent of the transitive verb, while the absolutive case is assigned to its object.

(b)

Table 2.3: Transitive ergative example in Dyirbal

ŋuma yabuŋgu buṛan.		
ŋuma-∅	yabu-ŋgu	buṛan
father-ABS	mother-ERG	saw
O	A	$\text{VERB}_{\text{trans}}$
"Mother saw father."		

In Table 2.3, the ergative case is assigned to the agent of the transitive verb, while the absolutive case is assigned to its object.

3. Coordination

(a)

Table 2.4: Coordination in Dyirbal

ŋuma banaganʸu, ŋuma yabuŋgu buṛan.				
ŋuma-∅	banaganʸu	ŋuma-∅	yabu-ŋgu	buṛan
father-ABS	returned	father-ABS	mother-ERG	saw
S	$\text{VERB}_{\text{intrans}}$	O	A	$\text{VERB}_{\text{trans}}$
"Father returned and mother saw father."				

In Table 2.4, there is a coordination example in Dyirbal. As it is seen, an intransitive verb (return) and a transitive verb (see) are conjoined. Both the subject of the intransitive verb and the object of the transitive verb have the absolutive case. The agent of the transitive verb differs from them since it has the ergative case.

(b)

Table 2.5: Coordination in Dyirbal

ŋuma banaganʸu, yabuŋgu buṛan.				
ŋuma-∅	banaganʸu	———	yabu-ŋgu	buṛan
father-ABS	returned	(deleted)	mother-ERG	saw
S	$\text{VERB}_{\text{intrans}}$	O	A	$\text{VERB}_{\text{trans}}$
"Father returned and was seen by mother."				

In Table 2.5, there is another example of coordination in Dyirbal. In this case, the object of the transitive verb is omitted since the subject of the intransitive verb substitutes for the object of the transitive verb.

As is seen in the above examples, in nominative-accusative languages, both the subject of a transitive and an intransitive verb have the nominative case. In contrast, the object of a transitive verb has the accusative case. On the other hand, in ergative languages, the ergative case is assigned to the agent of a transitive verb. It differs from

the subject of an intransitive verb and the object of a transitive verb since they have the absolutive case.

In light of the above information, this study first aimed to evaluate the child-directed speech data set taken from the Eve fragment (Brown, 1973) of the CHILDES database (MacWhinney, 2000). According to this evaluation, accusative English grammar, including syntactic and semantic annotations, was constructed. As the second step of the study, a grammar for hypothetical ergative English was formed by utilizing only syntactic ergativity without explicit case marking. Therefore, the syntactic word order of some sentences was changed to construct the ergative version of English grammar, as mentioned in Section 3.3 in detail.

In the following section, structural background information for the details of grammar will be provided. The grammar constructed for this study is based on the basic principles of categorial grammar, and the required information about it will be presented below.

2.3 Categorial Grammar

In categorial grammar, there are two essential elements: the first is a categorial lexicon, and the second is a set of rules (Steedman, 1987). The role of the categorial lexicon is to assign a syntactic category to each entry in the lexicon and differentiate between functions (such as verbs) and their arguments. On the other hand, this set of rules, known as combinatory rules, defines how functions and arguments can be combined.

A categorial lexicon includes various syntactic categories, such as NP for noun phrases or S for complete sentences. In this regard, the category of functions combined with arguments to their right is denoted as X/Y. The category of functions combined with arguments to their left is X\Y, meaning that slashes determine the direction of the arguments. For instance, the category of an intransitive verb is S\NP, whereas the category of a transitive verb is (S\NP)/NP. According to the category of a transitive verb, the verb first takes an NP from the right and then takes an NP from the left, which results in S.

In brief, combinatory rules control how these functions can be combined with adjacent arguments and with other functions (Steedman, 1987). A categorial grammar might include several combinatory rules such as functional application, functional composition, and type-raising.

There are two main rules for functional application in a categorial grammar: forward application and backward application, as illustrated in Figure 2.3. Forward application applies the function to its right-side argument, while backward application applies the function to its left-side argument.

a. X/Y: f Y: a $\rightarrow$ X: fa (Forward Application: >)
b. Y: a X\Y: f $\rightarrow$ X: fa (Backward Application: <)

Figure 2.3: Functional Application

It is possible to write a semantic category for each syntactic category in categorial grammar. In this study, each syntactic category has a semantic category defined by lambda calculus (λ-calculus). In the simplest terms, the notation of lambda calculus involves lambda terms and reduction operations on them. Figure 2.4 presents an example of this process. In such a representation, each entry in the lexicon has a surface form (John, loves, Mary), a syntactic category (NP or (S\NP)/NP)), and a corresponding semantic category (John', Mary', $\lambda\mathrm{x}\lambda\mathrm{y}.\mathrm{loved}'\mathrm{xy}$).

John := NP : John'
loves := (S\NP)/NP : $\lambda\mathrm{x}\lambda\mathrm{y}.\mathrm{loves}'\mathrm{xy}$
Mary := NP : Mary'

Figure 2.4: An example of a categorial grammar

With the syntactic structure and its semantic representation in Figure 2.4, the meaning of the sentence can be derived in a bottom-up manner by using functional applications outlined in Figure 2.3 as seen in Figure 2.5.

John	loves	Mary
NP	(S\NP)/NP	NP
:John'	:$\lambda x \lambda y.\mathrm{loves}' xy$	:Mary'
	S\NP : $\lambda y.\mathrm{loves}'\mathrm{Mary}'y$	
	S : $\mathrm{loves}'\mathrm{Mary}'\mathrm{John}'$	

Figure 2.5: Bottom-up parsing example

Additionally, two functional composition rules exist in a categorial grammar: forward composition and backward composition. Forward composition (B>) is applicable when the first function seeks a constituent of type Y on the right and the second function provides a constituent of type Y as its result. Conversely, backward composition (B<) is applied when the first function seeks a constituent of type Y on the left and the second function seeks a constituent of type Y on the left. Both composition rules are presented in Figure 2.6.

a. X/Y: f Y/Z: g $\rightarrow$ X/Z: $\lambda x.f(gx)$ (Forward Composition: B>)
b. Y\Z: g X\Y: f $\rightarrow$ X\Z: $\lambda x.f(gx)$ (Backward Composition: B<)

Figure 2.6: Functional Composition

An example of functional composition can be seen in the forward composition of a modal verb and a verb as in Figure 2.7.

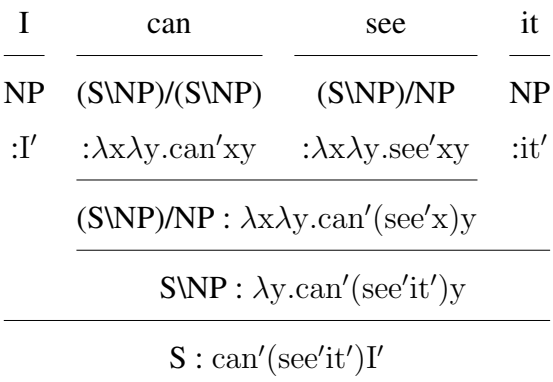

Figure 2.7: Functional composition example

Type-raising is one of the common forms of combinators, which converts arguments into functional categories. Type-raising enables the creation of intermediate elements that do not directly map to traditional constituents in the language. There are two types of type-raising: forward type-raising and backward type-raising, as presented in Figure 2.8.

a. X: *a* → T/(T\X): *λp.pa* (Forward Type-raising: T>)
b. X: *a* → T\(T/X): *λp.pa* (Backward Type-raising: T<)

Figure 2.8: Type-raising

In this study, forward type-raising is applied in the accusative version of English grammar, as shown in Figure 2.9, while backward type-raising is used in the ergative version, as in Figure 2.10.

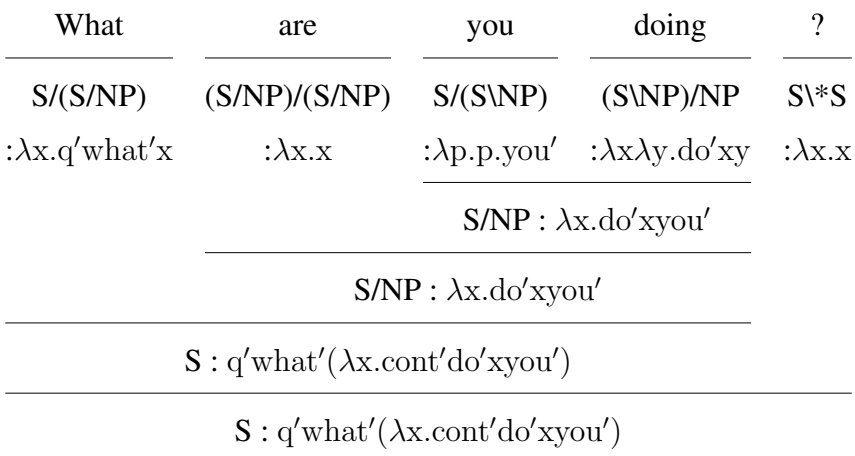

Figure 2.9: Forward type-raising example

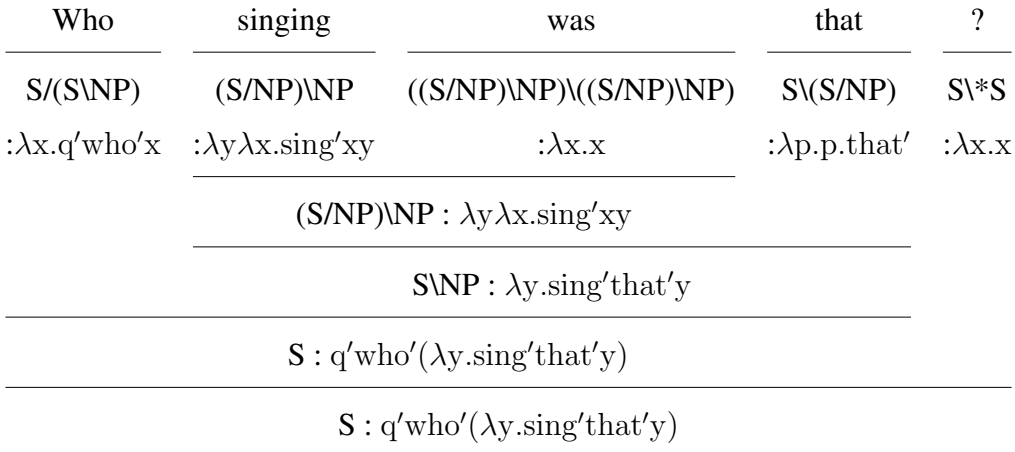

Figure 2.10: Backward type-raising example

Indeed, additional combinators such as substitution combinator (S) or variations involving both forward and backward composition allow for more advanced derivations. However, they are beyond the scope of the current study since the sentences in the child-directed speech data set used in the study consist of basic utterances with considerably straightforward syntactic structures.

2.3.1 Coordination in a Categorial Grammar

Two arguments with the same syntactic category can be conjoined via conjunction to form a new single instance of the same category, denoted as (X\X)/X. The representation of coordination is provided in Figure 2.11, and the example use of it is demonstrated in Figure 2.12.

and := (X\X)/X : $\lambda p.\lambda q.\lambda x.\mathrm{and}'(px)(qx)$

Figure 2.11: The representation of coordination

You	go	and	ask	Fraser
NP	S\NP	(X\X)/X	(S\NP)/NP	NP
:you′	:$\lambda x.\mathrm{go}'x$	:$\lambda p\lambda q\lambda x.\mathrm{and}'(px)(qx)$	:$\lambda x\lambda y.\mathrm{ask}'xy$	:Fraser'
			S\NP : $\lambda y.\mathrm{ask}'\mathrm{Fraser}'y$	
		(S\NP)\(S\NP) : $\lambda q\lambda x.\mathrm{and}'((\lambda y.\mathrm{ask}'\mathrm{Fraser}'y)x)(qx)$		
	S\NP : $\lambda x.\mathrm{and}'((\lambda y.\mathrm{ask}'\mathrm{Fraser}'y)x)((\lambda x.\mathrm{go}'x)x)$			
S : $\mathrm{and}'(\mathrm{ask}'\mathrm{Fraser}'\mathrm{you}')(\mathrm{go}'\mathrm{you}')$				

Figure 2.12: Coordination example

The following section will provide some required information about the CHILDES database and the Eve fragment before the details of the grammar construction process and the experiments conducted in the current study.

2.4 The Eve Fragment of CHILDES Database

The CHILDES database is recognized as an extensive resource for the data on first language acquisition. In the present study, we used a data set of child-directed speech taken from the Eve fragment (Brown, 1973) within the CHILDES database (MacWhinney, 2000). The Eve fragment is part of a study of the progression of English as a first language by Roger Brown, Ursula Bellugi and Colin Fraser between 1962 and 1966 (Brown, 1973). Throughout the study, they conducted interviews for about 2 hours every two weeks with three children: Adam, Eve, and Sarah. The Eve fragment includes the transcriptions of the natural speech of Eve, her mother, sometimes her father, and investigators in their home. In this study, only the child-directed speech data set of the Eve fragment is used, but the transcriptions of the sessions with the other two children can be found in the CHILDES database. The study started in 1962 when Eve was 18 months old and finished when she was 27 months old since Eve's family moved to another city. Investigators annotated the utterances by focusing on grammatical aspects and some phonetic features. The transcriptions reveal many repeating patterns (e.g., 'What? What? What?'), letter spellings (e.g., 'el-vl-el'), assimilations (e.g., 'gonna' or 'gimme'), baby talk (e.g., 'racketyboom' or 'choochoo'), and some indistinct words. Namely, some assumptions may have been made while transcribing and annotating the data. However, this can be acceptable when the subject is as complex as language acquisition.

After all the required background information related to the current study is provided, the research questions and methodology will be presented in detail in the following chapter. In particular, the grammar construction process and the experiments will be explained.

CHAPTER 3

THE DATA SET AND THE GRAMMAR CONSTRUCTION PROCESS

This chapter revisits the statement of the research questions and provides a detailed description of the data set and the grammar construction process.

3.1 Research Questions

1. What are the potential outcomes if children are exposed to hypothetical English, i.e. syntactically ergative English, rather than accusative English in the first language acquisition process?

2. If the trained model successfully acquires hypothetical English, what does this success indicate?

3. How do universal constraints affect language acquisition and grammar?

Given the aforementioned previous studies, regarding the first research question, we expect that children will be able to acquire hypothetical English, i.e., syntactically ergative English, in the first language acquisition at an approximate rate as those exposed to accusative English. As for the second question, if the trained model acquires the hypothetical English successfully, it will indicate that each system of grammatical relation (accusative and ergative in this study) is approximately equal for the first language(s) learners. This will answer the final research question, and we can say that children will be able to learn the language they are exposed to without any innate constraint related to the grammar of a language. That is to say, we suppose that the experiences children are exposed to help them decide which syntactic category comes

to the forefront and which syntactic category falls behind rather than any innate constraint.

3.2 Data Set

As mentioned in the previous sections, a child-directed speech data set taken from the Eve fragment (Brown, 1973) of the CHILDES database (MacWhinney, 2000) is used to conduct this study. The original data set was generated by Brown (1973) and revised by MacWhinney (2000). Subsequently, the linguistic annotation of the data set was made by Sagae et al. (2010) and by Kwiatkowski (2012). Lastly, it was used in the studies conducted by Abend et al. (2017) and Şakiroğulları (2019). In this study, the most recent version of the original Eve is used.

The data set in the study conducted by Abend et al. (2017) includes 5123 utterances of the original Eve fragment, and they were selected according to their practicality on semantic bootstrapping in language acquisition. However, Şakiroğulları (2019) partitioned certain complex utterances and made some adjustments that will be discussed in detail below. Hence, there are 5133 sentences in this study.

The data set contains no complicated structure because such complex sentences were divided into two by Brown (1973), and some were excluded by Abend et al. (2017). Consequently, there is no conditional structure in the current data set. The sentences in the data set commonly have a simple structure; most of the time, they have single-word utterances and repetitions. Within the scope of the current study, there has yet to be an attempt to evaluate the utterances in terms of pragmatics or discourse. Namely, each utterance is individually assessed, and logical forms are formed in this way.

In this version of the data set, Şakiroğulları (2019) replaced abridged phrases such as 'don't, won't, or you're' with their unabridged forms. In other words, the surface forms were simplified to smooth the derivation process. Moreover, all the dots (.) were changed into hyphens (-) in Şakiroğulları (2019). However, in this study, all the hyphens at the end of the sentences are excluded to facilitate the experiments since they do not have any significance in terms of syntax and semantics in the language acquisition process. On the other hand, no change is made to the question marks be-

cause they are semantically important. In addition, some missing words, unintended repetitions, and erroneous punctuation were corrected by Şakiroğulları (2019) and used as the same in this study.

In brief, the present study was conducted by using the utterances taken from Şakiroğulları (2019); however, the grammars, including the syntactic and semantic representations of the sentences, were constructed by us. This decision was made because some categories regarding verbs and auxiliary verbs are not suitable for the aim of this study. The process of grammar construction will be explained in a detailed way in Section 3.3.

Based on the utterances in the data set, the grammar of accusative English, including syntactic structures and logical forms, was constructed as the first step of the study. As the second step, the grammar of ergative English with its syntactic structures and logical forms were formed. Throughout the grammar construction process, the syntactic representations of the words were formed by following the fundamental principles of categorial grammar and the dependency notion, while the semantic representations of these words were formed by using lambda terms (Church, 1941).

In the upcoming section, the steps of the grammar construction will be represented in detail.

3.3 Grammar Construction

The grammars constructed for this study are grounded on the fundamental principles of categorial grammar and the notion of dependency. Categorial Grammar (Ajdukiewicz, 1934, Bar-Hillel, 1953) offers a relation between syntax and semantic composition by assuming that every syntactic category is matched with its semantic category. Likewise, in these grammars, every syntactic category has a semantic category defined by lambda terms (Church, 1941).

Another basis of these grammars is the notion of dependency. Dependency grammar (DG) is one of the modern grammatical theories based on the dependency relation, unlike the constituency relation of phrase structure (Tesnière et al., 2015). According

to the perspective of dependency grammar, a sentence has a main verb (de Marneffe et al., 2021), and these verbs include some arguments as nominals. Also, both nominals and verbs can be refined by modifiers such as adjectives or adverbs (de Marneffe et al., 2021). Concisely, dependency grammar assigns each phrase a head, and other elements depend on that head. While constructing these grammars, the dependency relation between the predicates and their arguments was considered.

After explaining the basic idea of categorial grammar and the notion of dependency, the following sections will define every linguistic component and rule in these grammars.

3.3.1 Sentence Types in the Grammars

The data set contains four different sentence types: declarative sentences, interrogative sentences, imperative sentences, and various other utterances that are not complete sentences. Below, each type of sentence will be explained with the relevant examples from the Eve fragment.

3.3.1.1 Declarative Sentences

The Eve fragment used in the study includes many declarative sentences, such as "Eve has a hat" or "You read the book." Such sentences are defined as s[type=decl] in these grammars. The features related to tense and aspect are excluded in the logical forms to facilitate the training process, so these grammars have no specific information about the tense-aspect relation.

3.3.1.2 Interrogative Sentences

The data includes a lot of interrogative sentences since it is child-directed speech data. The logical forms of interrogative sentences include q', and they are formed by using three different ways: auxiliary verbs, question words (such as what, where, or who), and question marks. All of them will be explained with examples in the upcoming sections.

3.3.1.3 Imperative Sentences

It is supposed that there is an interlocutor in imperative sentences. In the accusative system, a rule is generated for such sentences as 's\np : lf –> s : λlf.imp (lf interlocutor)'. According to this rule, a verb turns into a sentence with an interlocutor. An example of it is demonstrated in Figure 3.1

Drink	the	water
(S\NP)/NP	NP/NP	NP
:λxλy.drink′xy	:λx.the′x	:water′
	NP : the′water′	
S\NP : λy.drink′the′water′y		
S : imp(drink′(the′water′)interlocutor)		

Figure 3.1: An imperative sentence example in the accusative system

On the other hand, some other rules are written for imperative sentences in the ergative system since sentences have different syntactic orders in the accusative and ergative systems.

a. s[type=decl]/np : lf –> s[type=imp] : λlf.imp (lf interlocutor)

   The rule (a.) is written for intransitive verbs in the ergative system, such as 'go' or 'come'. In such sentences, the subject comes after an intransitive verb since the subject of an intransitive verb is assigned the same case as the object of a transitive verb in the ergative system. Thus, the rule (a.) is only used for intransitive verbs of imperative sentences in the ergative system, and the rule (b.) below is generated for transitive verbs of imperative sentences in this system.

b. (s[type=decl]/np)\np : lf –> s[type=imp]/np : λlf.imp (lf interlocutor)

   The rule (b.) is formulated for transitive verbs in the ergative system, such as 'drink' or 'watch'. Understanding this rule is crucial as it helps us to structure sentences correctly in the ergative system. In this system, the object of a tran-

sitive verb and the subject of an intransitive verb have the same case. Hence, a transitive verb takes the subject first, and then it takes the object, as seen in the rule above. Since there is no subject in imperative sentences, the rule (b.) says that an interlocutor substitutes for the subject, and then, a transitive verb of an imperative sentence only takes an object.

In both rules above, no subject exists; an interlocutor substitutes for it. This is just one aspect of the ergative system's comprehensive rules for imperative sentences. These rules, along with some other related ones, are presented in Appendix A.

3.3.1.4 Other Utterances

The data set includes numerous utterances that do not constitute complete sentences since a child-directed speech consists of simple utterances and predominantly one or two-word noun phrases. Such expressions are considered noun phrases, and some punctuation (such as hyphens) at the end of them are excluded for the convenience of experiments. However, question marks are kept since they have significance in terms of meaning. Figure 3.2 provides an example.

Eve	?
NP	S\NP
:eve′	:λx.q′x
S : q′eve′	

Figure 3.2: One-word question example

3.3.2 Nominals

In all languages, nominals are one of the fundamental units as arguments of predicates. In the simplest terms, nominals include noun phrases, proper names and pronouns. In this regard, all nominals are defined as noun phrases (NPs) because when a head is extracted from the lexicon and introduced into syntax, it must project a phrase

(Chomsky, 1982). In the lexicon, nominals are syntactically categorised according to their count (singular or plural), agreement, and sometimes their case. Figure 3.3 provides some examples of NPs.

a. cup | np :: np[agr=3,count=sg] : cup

b. here | np :: np[case=loc]

c. eve | pn :: np[agr=3] : eve

d. juice | un :: np[agr=3] : juice

e. ducks | pln :: np[agr=3,count=pl] : pl duck

f. you | pro :: np[agr=2] : you

g. yourself | pro :: np[agr=3] : yourself

Figure 3.3: Examples of nominals

Compound nouns such as baby sister, birthday cake, or mud pies are united in these grammars to create only one entry like *birthday-cake*. These forms of compound nouns are taken from Şakiroğulları (2019).

3.3.3 Determiners

Noun phrases headed by a noun can often include determiners such as articles (a, an, the), demonstrative pronouns (this, that, these, those, etc.), and quantifiers (some, many, more, etc.). In these grammars, the category of the determiners is defined as NP/NP because the head of the noun phrases is accepted as a noun. Figure 3.4 provides some examples of determiners. In item (f) of Figure 3.4, there is a category for a raised determiner required for such a sentence: "What does your baby-sister do?" Furthermore, a derivation example of determiners is demonstrated in Figure 3.5.

a. a | det :: np[agr=?y,count=?z]/np[agr=?y,count=?z] : λx.a′x

b. any | det :: np[agr=?y,count=?z]/np[agr=?y,count=?z] : λx.any′x

c. no | det :: np[agr=?y,count=?z]/np[agr=?y,count=?z] : λx.no′x

d. the | det :: np[agr=?y,count=?z]/np[agr=?y,count=?z] : λx.the′x

e. your | det :: np[agr=?y,count=?z]/np[agr=?y,count=?z] : λx.your′x

f. your | det :: (s/(s\np))/np : λxλp.p(your′x)

Figure 3.4: Examples of determiners

3.3.4 Adjectives and Adjuncts

Adjectives are composed with the head of a noun as illustrated in 3.5. Unlike determiners, adjectives can be more than one in a phrase.

a	good	idea
NP/NP	NP/NP	NP
:λx.a′x	:λx.good′x	:idea′
	NP : good′idea′	
NP : a′(good′idea′)		

Figure 3.5: A determiner and an adjective derivation example

In the data set, there are some examples in which the head of nominal is modified by another nominal as exemplified in Figure 3.6, which illustrates an example of the genitive case.

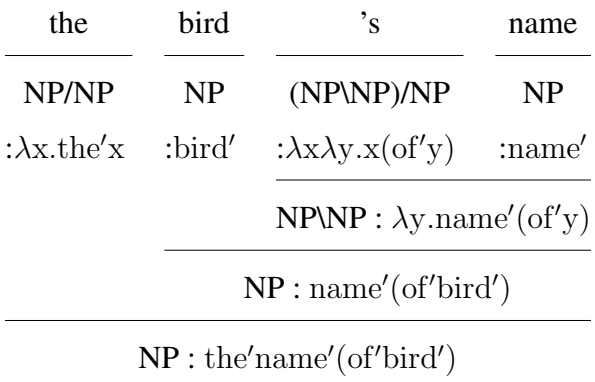

Figure 3.6: A nominal modifier example

3.3.5 Copula Verbs and Predicate Phrases

A copula verb can be defined as a verb or a verb-like element (Pustet, 2003). In general terms, the role of a copula verb is to link the subject of a sentence to a subject complement, as seen in the word *is* in the sentence "That **is** right" or the word *was* in the sentence "That **was** a man."

As well as copula verbs can be used with noun phrases, as in the sentence "That was a man", they can also be used with predicate phrases that refer to denotations of words or phrases and relations over arguments, such as the word *right* in the sentence "That is **right**" or the word *hungry* in the sentence "Eve is **hungry**."

The current data set has six copula verbs (am, is, are, be, was, were). They are used with both noun phrases, as indicated in Figure 3.7 and predicate phrases, as in Figure 3.9. The versions of them in the ergative system are shown in Figure 3.8 and 3.10. In the ergative system, the object of a transitive verb and the subject of an intransitive verb have the same case. Thus, the copula verbs in Figure 3.8 and 3.10 take the noun phrase and the predicate phrase before the subject.

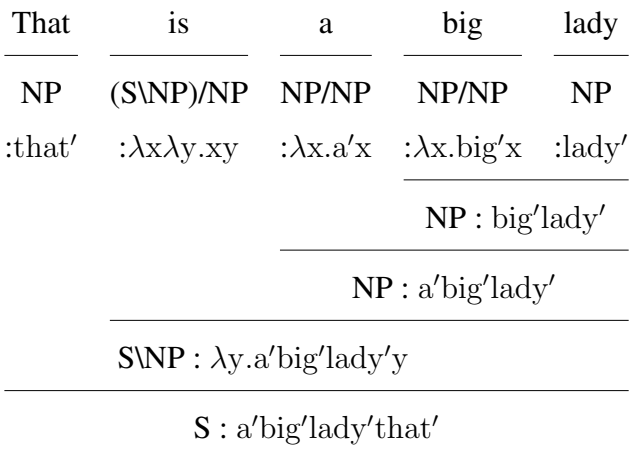

Figure 3.7: A copula verb derivation example with a noun phrase in the accusative system

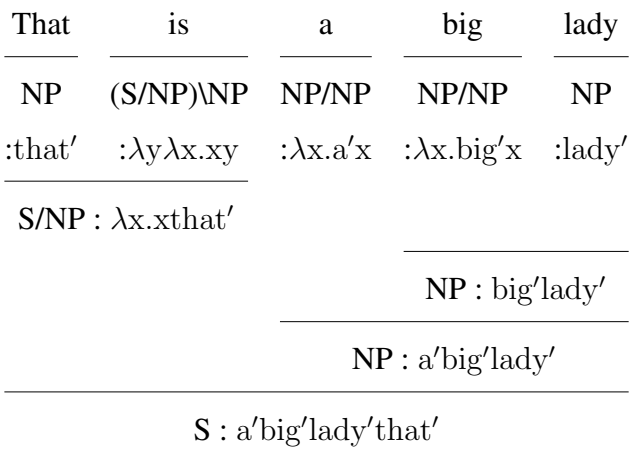

Figure 3.8: A copula verb derivation example with a noun phrase in the ergative system

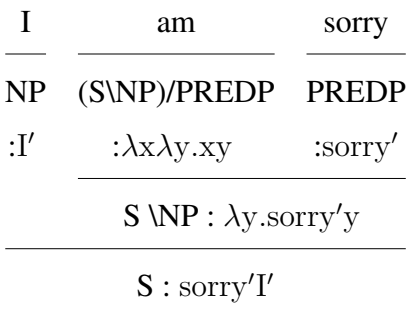

Figure 3.9: A copula verb derivation example with a predicate phrase in the accusative system

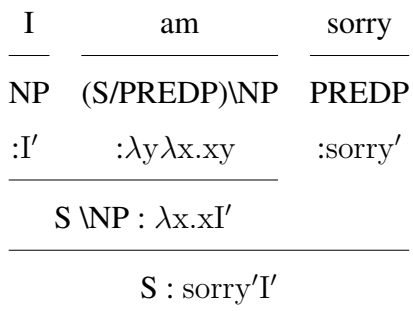

Figure 3.10: A copula verb derivation example with a predicate phrase in the ergative system

3.3.6 Verbs

Most of the utterances in the data set consist of a verb, its arguments, and, if any, modifiers. Verbs have considerable importance in the present study since this study aims to compare systems of grammatical relations (accusative and ergative). In the current data set, three different types of verbs, i.e. transitive, intransitive and ditransitive, can be seen. As said earlier, one of the critical parts of this study relies on the alignment of verbs, so each verb has a category for both accusative and ergative systems. While defining the part of speech of the verbs, the verbs in the accusative system are marked as '>', and the ones in the ergative system are marked as '<'.

3.3.6.1 Transitive Verbs

Transitive verbs are annotated depending on their arguments. According to the syntactic category of transitive verbs in accusative English, they first take the object from the right and then the subject from the left. In contrast, transitive verbs in the ergative system take the subject from the left and then the object from the right since an object of a transitive verb and a subject of an intransitive verb have the same case in a syntactically ergative system. Even though the syntactic representations of structures in the accusative and ergative systems differ, they have the same logical forms. Thus, the derivations obtained from these syntactic structures can bring forth a meaningful unit. A sample sentence in the accusative system is indicated in Figure 3.11, and the one in the ergative system is in Figure 3.12.

You	color	a	girl
NP	(S\NP)/NP	NP/NP	NP
:you′	:λxλy.color′xy	:λx.a′x	:girl′
		NP : a′girl′	
	S\NP : λy.color′a′girl′y		
	S : color′a′girl′you′		

Figure 3.11: A transitive verb derivation in the accusative system

You	color	a	girl
NP	(S/NP)\NP	NP/NP	NP
:you′	:λyλx.color′xy	:λx.a′x	:girl′
		NP : a′girl′	
S/NP : λx.color′xyou′			
	S : color′a′girl′you′		

Figure 3.12: A transitive verb derivation in the ergative system

3.3.6.2 Intransitive Verbs

As it is known, intransitive verbs have only one argument: the subject, as illustrated in Figure 3.13. In the syntactically ergative system, intransitive verbs take the subject from the right as opposed to the ones in the accusative system as in Figure 3.14 because, in ergative languages, the same case is assigned to the subject of an intransitive verb and the object of a transitive verb. Therefore, the word order of sentences in the data has also been changed for the experiments related to the ergative system.

You	swim
NP	S\NP
:you′	:λx.swim′x
S : swim′you′	

Figure 3.13: An intransitive verb derivation in the accusative system

Swim	you
S/NP	NP
:λx.swim′x	:you′
S : swim′you′	

Figure 3.14: An intransitive verb derivation in the ergative system

3.3.6.3 Ditransitive Verbs

Ditransitive verbs are annotated in the same way as transitive verbs. The only difference is that ditransitive verbs have more than one object. An example of ditransitive verbs in the accusative system is shown in Figure 3.15, and an example in the ergative system is in Figure 3.16.

You	give	me	the	pencils
NP	((S\NP)/NP)/NP	NP	NP/NP	NP
:you′	:λxλyλz.give′xyz	:me′	:λx.the′x	:pencils′
			NP : the′pencils′	
	(S\NP)/NP : λyλz.give′me′yz			
	S\NP : λz.give′me′the′pencils′z			
S : give′me′the′pencils′you′				

Figure 3.15: A ditransitive verb derivation in the accusative system

You	give	me	the	pencils
NP	((S/NP)/NP)\NP	NP	NP/NP	NP
:you′	:λzλxλy.give′xyz	:me′	:λx.the′x	:pencils′
			NP : the′pencils′	
(S/NP)/NP : λyλx.give′xyyou′				
S/NP : λy.give′me′yyou′				
S : give′me′the′pencils′you′				

Figure 3.16: A ditransitive verb derivation in the ergative system

3.3.7 Phrasal Verbs

While writing categories for phrasal verbs, it is assumed that prepositions are arguments of the predicates since verbs and prepositions together are meaningful in phrasal verbs. Hence, the categories for intransitive phrasal verbs are structured as in Figure 3.17. In such kinds of derivations, the categories of prepositions are accepted as PP since when a head is plucked from the lexicon and introduced into syntax, it must project a phrase (Chomsky, 1982) as mentioned earlier.

You	sit	down
NP	(S\NP)/PP_{down}	PP_{down}
:you′	:λxλy.sit′xy	:down′
	S\NP : λy.sit′down′	
	S : sit′down′you′	

Figure 3.17: An intransitive phrasal verb derivation in the accusative system

For the experiments, intransitive phrasal verbs in the ergative system are generated as in Figure 3.18.

You	sit	down
NP	(S/PP_{down})\NP	PP_{down}
:you′	:λyλx.sit′xy	:down′
	S/PP_{down}: λx.sit′xyou′	
	S : sit′down′you′	

Figure 3.18: An intransitive phrasal verb derivation in the ergative system

An example of transitive phrasal verbs in the accusative system can be seen in Figure 3.19 and the one in the ergative system is in Figure 3.20.

We	look	at	the	pictures
NP	(S\NP)/PP_{at}	PP_{at}/NP	NP/NP	NP
:we′	:λxλy.look′xy	:λx.at′x	:λx.the′x	:pictures′
			NP : the′pictures′	
		PP_{at} : at′the′pictures′		
	S\NP : λy.look′at′the′pictures′y			
S : look′at′the′pictures′we′				

Figure 3.19: A transitive phrasal verb derivation in the accusative system

We	look	at	the	pictures
NP	(S/PP_{at})\NP	PP_{at}/NP	NP/NP	NP
:we′	:λyλx.look′xy	:λx.at′x	:λx.the′x	:pictures′
S/PP_{at} : λx.look′xwe′				
			NP : the′pictures′	
		PP_{at} : at′the′pictures′		
S : look′at′the′pictures′we′				

Figure 3.20: A transitive phrasal verb derivation in the ergative system

Another point related to phrasal verbs is that there can be a noun phrase between the verb and the preposition as in Figure 3.21 and the ergative version of such phrasal verbs is shown in Figure 3.22.

You	pick	them	up
NP	((S\NP)/PP_{up})/NP	NP	PP_{up}
:you′	:λxλyλz.pick′xyz	:them′	:up′
	(S\NP)/PP_{up} : λyλz.pick′them′yz		
	S : λz.pick′them′up′z		
	S : pick′them′up′you′		

Figure 3.21: A phrasal verb derivation with a noun phrase in the accusative system

You	pick	them	up
NP	((S/PP_{up})/NP)\NP	NP	PP_{up}
:you′	:λzλxλy.pick′xyz	:them′	:up′
(S/PP_{up})/NP : λxλy.pick′xyyou′			
S/PP_{up} : λy.pick′them′yyou′			
S : pick′them′up′you′			

Figure 3.22: A phrasal verb derivation with a noun phrase in the ergative system

3.3.8 Auxiliary Verbs

Auxiliary verbs contribute functional or grammatical meaning to sentences in terms of tense, aspect, modality, etc. However, as mentioned earlier, features like tense and aspect are excluded in these grammars to facilitate the experiments. Thus, such features are not mentioned in logical forms. As indicated in the rules below, each auxiliary verb typically has three different syntactic categories in accusative and ergative systems.

a. is | aux> :: (s[type=decl]\np)/(s[type=decl]\np) : $\lambda x \lambda y.xy$

The first rule is written for the sentences in canonical order within the accusative system. Figure 3.23 shows an example of it.

Eve	is	having	lunch
NP	(S\NP)/(S\NP)	(S\NP)/NP	NP
:eve′	:$\lambda x \lambda y.xy$	:$\lambda x \lambda y.\text{have}'xy$	:lunch′
		S \NP : $\lambda y.\text{have}'\text{lunch}'y$	
	S \NP : $\lambda y.(\lambda y.\text{have}'\text{lunch}'y)y$		
S : $\text{have}'\text{lunch}'\text{eve}'$			

Figure 3.23: An example of the auxiliary verbs in canonical order in the accusative system

b. is | aux> :: (s[type=q]/(s\np))/np : $\lambda x \lambda y.q'yx$

The second rule is for interrogative sentences in which the auxiliary verb functions to make a question. Figure 3.24 demonstrates this type of auxiliary verb in the accusative system.

Is	Eve	eating	?
(S/(S\NP))/NP	NP	S\NP	S*S
:$\lambda x \lambda y.q'yx$	:eve′	:$\lambda x.\text{eat}'x$	
S/NP : $\lambda y.q'y(\text{eve}')$			
S : $.q'(\text{eat}'\text{eve}')$			
S : $.q'(\text{eat}'\text{eve}')$			

Figure 3.24: An example of the auxiliary verbs in interrogative sentences in the accusative system

c. is | aux> :: (s/np)/(s/np) : λx.x

The final rule is for auxiliary verbs in interrogative sentences with wh-questions in the accusative system. In these sentences, wh-question words turn a sentence into a question, not the auxiliary verb, as opposed to Figure 3.24. In interrogative sentences with wh-questions, the subject is type-raised since the structure of such sentences does not allow for the conventional composition of the words. An example of the auxiliary verbs with wh-questions is provided in Figure 3.25.

What	is	she	eating	?
S/(S/NP)	(S/NP)/(S/NP)	S/(S\NP)	(S\NP)/NP	S*S
:λx.q′what′x	:λx.x	:λp.pshe′	:λxλy.eat′xy	
		S/NP : λx.eat′xshe′		
	S/NP : λx.eat′xshe′			
S : q′what′(λx.eat′xshe′)				
S : q′what′(λx.eat′xshe′)				

Figure 3.25: An example of the auxiliary verbs with wh-questions in the accusative system

Furthermore, some exceptional rules for the auxiliary *did* are constructed as follows.

a. did | aux> :: s[type=q]/np : λx.q′x

This rule is formed for such a sentence as "Did you ever?", unusual use of the auxiliary *did*. It only takes a noun phrase; here, 'ever' is an adverb.

b. did | aux> :: (s[type=q]/s)/np : λxλy.q′(yx)

This rule is written for the sentence "Did you what?" The following sentence in the data set is "vegetable-soup", and so this incomplete sentence probably tries to say "Did you want what?" Typically, it is possible to form the category 'S/NP' for 'want what.' However, there is no verb phrase here. Therefore, in this case, *what* is assumed as a sentence.

On the other hand, several rules are formulated for the auxiliary verbs in the ergative system. As previously mentioned, the rules for the sentence 'I will sit' are indicated in the table below. In this case, the ergative system has two alternatives for the auxiliary verbs.

The accusative system	**Alternative 1**	**Alternative 2**
I: NP	sit: S/NP	will: (S/NP)/(S/NP)
will: (S\NP)/(S\NP)	will: (S/NP)\(S/NP)	sit: S/NP
sit: S\NP	I: NP	I: NP

To decide which of the above alternatives is more appropriate, it is necessary to consider the category of auxiliary verbs of transitive sentences in the ergative system, as shown in the table below, because there should be only one category for each auxiliary verb.

The accusative system	**Alternative 1**	**Alternative 2**
I: NP	I: NP	I: NP
will: (S\NP)/(S\NP)	read: (S/NP)\NP	will: (S/NP)/(S/NP)
read: (S\NP)/NP	will: (S/NP)\(S/NP)	read: (S/NP)\NP
the book: NP	the book: NP	the book: NP

When both tables are analyzed, it is more reasonable to choose the category in Alternative 1 because Alternative 1 is more appropriate for topicalization in ergative English, which is 'I, sit will'. Besides, 'will read' in Alternative 2 requires cross-composition, which is unnecessary when functional composition can be applied.

In light of the discussion above, the syntactic categories below are formulated for the auxiliary verbs in the ergative system.

a. is | aux< :: (s[type=decl]/np)\(s[type=decl]/np) : $\lambda x \lambda y.xy$

   The rule (a.) is formulated for the sentences in a canonical order within the ergative system. In this system, the auxiliary verb and the main verb have been replaced, as seen in Figure 3.26 since the main verb first takes the subject

contrary to the accusative system.

Eve	having	is	lunch
NP	(S/NP)\NP	(S/NP)\(S/NP)	NP
:eve′	:λyλx.have′xy	:λxλy.(xy)	:lunch′
	S/NP : λx.have′xeve′		
	S/NP : λy.(λx.have′xeve′)y		
	S : have′lunch′eve′		

Figure 3.26: An example of the auxiliary verbs in canonical order in the ergative system

b. is | aux< :: (s[type=q]/np)/(s[type=decl]/np) : λxλy.q′xy

The rule (b.) is for interrogative sentences where the auxiliary verb is used to form a question. Figure 3.27 illustrates an instance of such an auxiliary verb in the ergative system.

Is	eating	Eve	?
(S/NP)/(S/NP)	S/NP	NP	S*S
:λxλy.q′xy	:λx.eat′x	:eve′	
	S/NP : λy.q′(λx.eat′x)y		
	S : .q′(eat′eve′)		
	S : .q′(eat′eve′)		

Figure 3.27: An example of the auxiliary verbs in interrogative sentences in the ergative system

c. is | aux< :: (s/np)/(s/np) : λx.x

The last rule pertains to auxiliary verbs in interrogative sentences with wh-questions, and this rule is used in both accusative and ergative systems; however, there are some differences regarding verbs, as seen in Figure 3.28. In

these sentences, wh-question words transform a statement into a question, not the auxiliary verb, which contrasts with Figure 3.27.

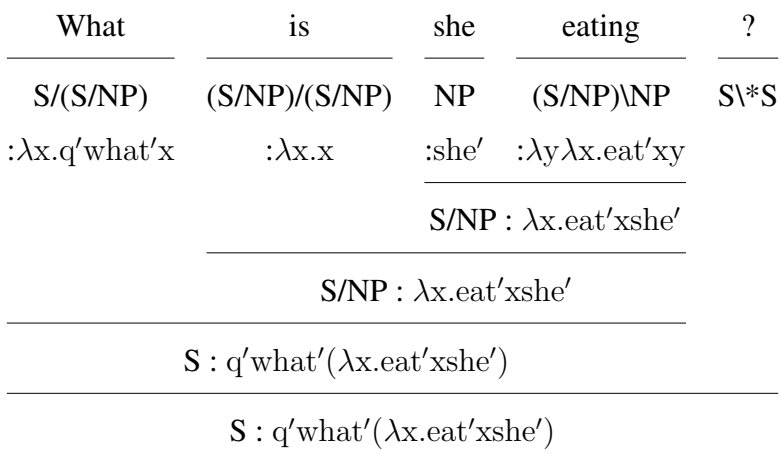

Figure 3.28: An example of the auxiliary verbs with wh-questions in the ergative system

3.3.9 Modal Verbs

A modal verb can be defined as a verb that adds a modality to the meaning of a sentence, such as ability, possibility, request, obligation, suggestion, etc. In general, modal verbs are used with the bare infinitive form of a main verb (Palmer, 2001). This data set has nine modal verbs (can, could, 'd better, 'd like, may, might, must, shall, should). They share similar syntactic categories as the auxiliary verbs as illustrated in Figure 3.29 and Figure 3.30.

a. can | mod> :: (s[type=decl]\np)/(s[type=decl]\np) : $\lambda x \lambda y.\text{can}'xy$

b. can | mod> :: (s[type=q]/(s\np))/np : $\lambda x \lambda y.\text{q}'\text{can}'yx$

c. can | mod> :: (s/np)/(s/np) : $\lambda x.\text{can}'x$

Figure 3.29: Rules for the modal verb *can* in the accusative system

a. can | mod< :: (s[type=decl]/np)\(s[type=decl]/np) : $\lambda x \lambda y.\mathrm{can}'xy$

b. can | mod< :: (s[type=q]/np)/(s[type=decl]/np) : $\lambda x \lambda y.\mathrm{q}'\mathrm{can}'xy$

c. can | mod< :: (s/np)/(s/np) : $\lambda x.\mathrm{can}'x$

Figure 3.30: Rules for the modal verb *can* in the ergative system

Furthermore, some additional categories for modal verbs are generated in the ergative system since sentences have different word orders in this system. These categories are explained below in detail.

a. can | mod< :: (s[type=decl]/pp)\(s[type=decl]/pp) : $\lambda x \lambda y.\mathrm{can}'xy$

The rule (a.) is written for sentences including modal verbs along with phrasal verbs in the ergative system, and an instance of it is shown in Figure 3.31.

We	put	it	can	in
NP	((S/PP$_{in}$)/NP)\NP	NP	(S/PP)\(S/PP)	PP$_{in}$
:we′	:$\lambda z.\lambda x.\lambda y.\mathrm{put}'xyz$	:it′	:$\lambda x \lambda y.\mathrm{can}'xy$	:in′
(S/PP$_{in}$)/NP) : $\lambda x.\lambda y.\mathrm{put}'xywe'$				
S/PP$_{in}$: $\lambda y.\mathrm{put}'it'ywe'$				
S/PP$_{in}$: $\lambda y.\mathrm{can}'(\lambda y.\mathrm{put}'it'ywe')y$				
S: $\mathrm{can}'(\mathrm{put}'it'in'we')$				

Figure 3.31: An example of the modal verb *can* used with a phrasal verb in the ergative system

b. can | mod< :: (s[type=decl]/predp)\(s[type=decl]/predp) : $\lambda x \lambda y.\text{can}'xy$

The rule (b.) is to modify a verb taking a predicate phrase as an argument as illustrated in Figure 3.32.

You	be	can	not	goldrush
NP	(S/PREDP)\NP	(S/PREDP)\(S/PREDP)	(S/PREDP)\(S/PREDP)	PREDP
:you′	:$\lambda y.\lambda x.\text{be}'xy$	:$\lambda x \lambda y.\text{can}'xy$	:$\lambda p \lambda x.\text{not}'px$	:$\text{goldrush}'$
S/PREDP : $\lambda x.\text{be}'x\text{you}'$				
S/PREDP : $\lambda y.\text{can}'(\lambda x.\text{be}'x\text{you}')y$				
S/PREDP : $\lambda x.\text{not}'(\lambda y.\text{can}'(\lambda x.\text{be}'x\text{you}')y)x$				
S: $\text{not}'(\text{can}'(\text{be}'\text{goldrush}'\text{you}'))$				

Figure 3.32: An example of the modal verb can modifying a verb taking a predicate phrase in the ergative system

c. can | mod< :: ((s[type=decl]/np)\np)\((s[type=decl]/np)\np) : $\lambda x.\text{can}'x$

The rule (c.) is formulated for the modal verb *can* in interrogative sentences including the question word *who* as seen in Figure 3.33. In such a sentence, the question word *who* is in the subject position. Also, the noun phrase 'them' should be type-raised since the structure of the sentence does not allow combining words typically.

Who	read	can	them	?
S/(S\NP)	(S/NP)\NP	((S/NP)\NP))\((S/NP)\NP))	S\(S/NP)	S *S
:λx.q′who′x	:λy.λx.read′xy	:λx.can′x	:λp.pthem′x	
	(S/NP)\NP : can′(λy.λx.read′xy)			
	S\NP : can′(λy.read′them′y)			
S : q′who′(can′(λy.read′them′y))				

S : q′who′(can′(λy.read′them′y))

Figure 3.33: An example of the modal verb can in interrogative sentences including the question word who

3.3.10 Negation

Negation represents a statement's negativity. In the accusative system, there are three different forms of negation. Below, each form is presented and explained in detail, with examples from the Eve data set.

a. not | neg :: (s[type=decl]\np)\(s[type=decl]\np) : λpλx.not′(px)

In Figure 3.34, negation is combined with the auxiliary verb *is*.

She	is	not	crying
NP	(S\NP)/(S\NP)	(S\NP)\(S\NP)	S\NP
:she′	:λxλy.xy	:λpλx.not′(px)	:λx.cry′x
	(S\NP)/(S\NP) : λx.not′(λxλy.xy)x		
	(S\NP) : not′(λy.(λx.cry′x)y)		
S : not′(cry′she′)			

Figure 3.34: Negation in finite sentences in the accusative system

b. not | neg :: @x/@x : λx.not′x

In Figure 3.35, the syntactic structure of the negation notifies that negation takes an argument and gives the negative form of the same argument in the same category.

Not	the	furniture
X/X	NP/NP	NP
:λx.not′x	:λx.the′x	:furniture′
	NP : the′furniture′	
NP : not′(the′furniture′)		

Figure 3.35: Negation with noun phrases in the accusative system

c. not | neg :: s\+s : λx.not′x

In Figure 3.36, negation is combined with the question form of the copula verb *is*.

Is	not	that	blue	?
(S/PREDP)/NP	S\+S	NP	PREDP	S*S
:λxλy.q′yx	:λx.not′x	:that′	:blue′	
(S/PREDP)/NP : not′λxλy.q′yx				
S/PREDP : not′λy.q′ythat′				
S : not′q′blue′that′				
S : not′q′blue′that′				

Figure 3.36: Negation in questions in the accusative system

On the other hand, the ergative system has five different categories regarding negation. The rules (b.) and (c.) above are used in the same way in the ergative system, and the other three categories are explained below with related examples.

a. not | neg< :: (s[type=decl]/np)\(s[type=decl]/np) : $\lambda p \lambda x.\mathrm{not}'(px)$

The rule (a.) in the ergative system is quite similar to the rule (a.) written for the accusative system. The only difference is related to the directions of the categories, which stems from the differences in the accusative and the ergative systems. One of the examples of this rule is shown in Figure 3.37.

Crying	is	not	she
S/NP	(S/NP)\(S/NP)	(S/NP)\(S/NP)	NP
$:\lambda x.\mathrm{cry}'x$	$:\lambda x \lambda y.xy$	$:\lambda p \lambda x.\mathrm{not}'(px)$	$:\mathrm{she}'$
S/NP : $\lambda y.(\lambda x.\mathrm{cry}'x)y$			
S/NP : $\lambda x.\mathrm{not}'(\lambda y.(\lambda x.\mathrm{cry}'x)y)x$			
S : $\mathrm{not}'(\mathrm{cry}'\mathrm{she}')$			

Figure 3.37: Negation in finite sentences in the ergative system

b. not | neg< :: (s[type=decl]/pp)\(s[type=decl]/pp) : $\lambda p \lambda x.\mathrm{not}'(px)$

The rule (b.) is written for negation within sentences such as 'You spit it do not out.' In this type of sentence, the category of the verb 'spit' is '((S/PP)/NP)\NP'. According to this rule, the verb initially takes the subject and subsequently the object. Next, it merges with the auxiliary verb and the negation, respectively. Therefore, the necessity for such a rule arises.

c. not | neg< :: (s[type=decl]/predp)\(s[type=decl]/predp) : $\lambda p \lambda x.\mathrm{not}'(px)$

The rule (c.) is formulated for negation in sentences such as 'I am not Cromer' or 'That is not a man.' In such sentences, copula verbs (like 'is' in these sentences) first take the subject and then the predicate phrase. Negation is combined with the copula verb 'is' in these sentences.

3.3.11 Adverbs

Adverbs usually modify verbs, clauses, adjectives, other adverbs, or sentences. This data set has several different kinds of adverbs, all of which are explained below in detail with examples from the current data set.

a. absolutely | adv :: predp/predp : λx.xabsolutely$'$

In the rule above, the function of the adverb is to modify a predicate phrase and the derivation of it is indicated in Figure 3.38. This rule for adverbs is used in accusative and ergative systems.

That	is	absolutely	right
NP	(S\NP)/PREDP	PREDP/PREDP	PREDP
:that$'$	:λxλy.xy	:λx.xabsolutely$'$	:right$'$
		PREDP : right$'$absolutely$'$	
	S\NP : λy.right$'$absolutely$'$y		
S : right$'$absolutely$'$that$'$			

Figure 3.38: An example of an adverb modifying a predicate phrase

b. fast | adv> :: (s\np)\(s\np) : λxλy.xfast$'$y

In rule (b.), the adverb modifies the verbs in the accusative system and the derivation of it is illustrated in Figure 3.39.

You	were	running	fast
NP	(S\NP)/(S\NP)	S\NP	(S\NP)/(S\NP)
:you′	:λxλy.xy	:λx.run′x	:λxλy.xfast′y
		S\NP : λy.(λx.run′fast′x)y	
	S\NP : λy.(λy.(λx.run′fast′x)y)y		
S : run′fast′you′			

Figure 3.39: An example of an adverb modifying a verb in the accusative system

c. fast | adv< :: (s/np)\(s/np) : $\lambda x \lambda y.xfast'y$

The rule (c.) is the ergative version of the rule (b.). Since the category of verbs differs in each system, the category of adverbs modifying verbs differs. An example of this rule is shown in Figure 3.40.

Running	fast	were	you
S/NP	(S/NP)\(S/NP)	(S/NP)\(S/NP)	NP
:λx.run′x	:λxλy.xfast′y	:λxλy.xy	:you′
S/NP : λy.(λx.run′x)fast′y			
S/NP : λy.(λy.(λx.run′x)fast′y)y			
S : run′fast′you′			

Figure 3.40: An example of an adverb modifying a verb in the ergative system

d. later | adv :: s/s : $\lambda x.xlater'$

In the data set, some adverbs modify the whole sentence and are defined as sentential adverbs. Figure 3.41 shows an example of them. This particular rule for adverbs is utilized in both accusative and ergative systems.

Later	we	will	have	a	cookie
S/S	NP	(S\NP)/(S\NP)	(S\NP)/NP	NP/NP	NP
:λx.xlater′	:we′	:λxλy.xy	:λxλy.have′xy	:λx.a′x	:cookie′

NP : a′cookie′

S\NP : λy.have′(a′cookie′)y

S\NP : λy(λy.have′(a′cookie′)y)y

S : have′(a′cookie′)we′

S : (have′(a′cookie′)we′)later′

Figure 3.41: An example of an adverb modifying a sentence

e. quite | adv :: @x/@x : λx.x

The rule above is for the adverbs modifying the adverbs, which is used in both accusative and ergative systems, and the example of it is in Figure 3.42.

You	are	doing	quite	well
NP	(S\NP)/(S\NP)	S\NP	@X/@X	(S\NP)\(S\NP)
:you′	:λxλy.xy	:λx.do′x	:λx.x	:λxλy.xwell′y

(S\NP)\(S\NP) : λxλy.xwell′y

S\NP : λy.(λx.do′well′x)y

S\NP : λy.(λy.(λx.do′well′x)y)y

S : do′well′you′

Figure 3.42: An example of an adverb modifying another adverb

Furthermore, there are two more rules specific to the ergative system, which are explained below with examples from the data set.

a. awhile | adv< :: (s[type=decl]/pp)\(s[type=decl]/pp) : $\lambda x \lambda y.xawhile'y$

   The rule (a.) is formulated for sentences like 'We take it better along'. In this sentence, the verb is phrasal, 'take along', categorized as '((S/PP)/NP)\NP'. According to this rule, the verb first takes the subject, followed by the object. After that, it merges with the adverb 'better' and, finally, the prepositional phrase 'along'. That is why such a rule is required in the ergative system.

b. yet | adv< :: (s[type=decl]/predp)\(s[type=decl]/predp) : $\lambda x \lambda y.xyet'y$

   The rule (b.) is written for sentences such as 'It is not yet finished'. Here, the adverb 'yet' modifies the copula verb 'is', categorized as '(S/PREDP)\NP'. Following this rule, the copula verb is combined with the subject, then merges with the adverb 'yet', and ultimately, takes the predicate phrase 'finished'. Thus, this rule is necessary to construct such sentences.

3.3.12 Prepositions

Prepositions are generally combined with noun phrases to state spatial or temporal relations (in, on, at, etc.) or assign several semantic roles (for, through, of, etc.) (Huddleston et al., 2002). This data set includes several different kinds of prepositions, and they are presented below, along with sample derivations. Besides, in these grammars, prepositions are combined with phrasal verbs; the details can be found in Section 3.3.7.

a. on | pre> :: ((s[type=decl]\np)\(s[type=decl]\np))/np : $\lambda x \lambda y.y(on'x)$

   The prepositions, as in rule (a.), are composed with first a noun phrase and then a verb phrase, and an example of it in the accusative system is shown in Figure 3.43.

She	is	sitting	on	the	floor
NP	(S\NP)/(S\NP)	S\NP	((S\NP)\(S\NP))/NP	NP/NP	NP
:she′	:λxλy.xy	:λx.sit′x	:λxλy.y(on′x)	:λx.the′x	:floor′
				NP : : the′floor′	
			(S\NP)\(S\NP) : λy.y(on′the′floor′)		
	S\NP : λy.(λx.sit′x)y				
	S\NP : λy.(λx.sit′x)y(on′the′floor′)				
S : sit′she′(on′the′floor′)					

Figure 3.43: An example of a preposition composed with a verb phrase in the accusative system

b. on | pre< :: ((s[type=decl]/np)\(s[type=decl]/np))/np : λxλy.y(on′x)

The rule (b.) is quite similar to the rule (a.) above. The only difference between these rules is related to word order and the categorical distinctions since word order and the categories of verbs differ in the accusative and ergative systems. The application of this rule is illustrated in Figure 3.44.

Sitting	on	the	floor	is	she
S/NP	((S/NP)\(S/NP))/NP	NP/NP	NP	(S/NP)\(S/NP)	NP
:λx.sit′x	:λxλy.y(on′x)	:λx.the′x	:floor′	:λxλy.xy	:she′

NP : : the′floor′

(S/NP)\(S/NP) : λy.y(on′the′floor′)

S/NP : λx.sit′x(on′the′floor′)

S/NP : λy.(λx.sit′x(on′the′floor′))y

S : sit′she′(on′the′floor′)

Figure 3.44: An example of a preposition composed with a verb phrase in the ergative system

c. after | pre :: (s\s)/np : $\lambda x \lambda y.y(after'x)$

In the data set, there are some prepositions composed with first a noun phrase and then the whole sentence as seen in the rule (c.) and an example of it can be found in Figure 3.45. This type of preposition is used in both accusative and ergative systems.

We	will	sing	that	after	lunch
NP	(S\NP)/(S\NP)	(S\NP)/NP	NP	(S\S)/NP	NP
:we′	:λxλy.xy	:λxλy.sing′xy	:that′	:λxλy.y(after′x)	:lunch′

S\NP : λy.sing′that′y

S\NP : λy(λy.sing′that′y)y

S\NP : sing′that′we′

S\S : λy.y(after′lunch′)

S : sing′that′we′(after′lunch′)

Figure 3.45: An example of a preposition composed with a sentence

d. for | pre :: (np\np)/np : $\lambda x \lambda y.y(for'x)$

In the rule (d.), the preposition 'for' is combined with noun phrases. In such cases, the preposition is the complement of the noun phrase. One of the examples including this kind of preposition is shown in Figure 3.46. In both accusative and ergative systems, this type of rule is used.

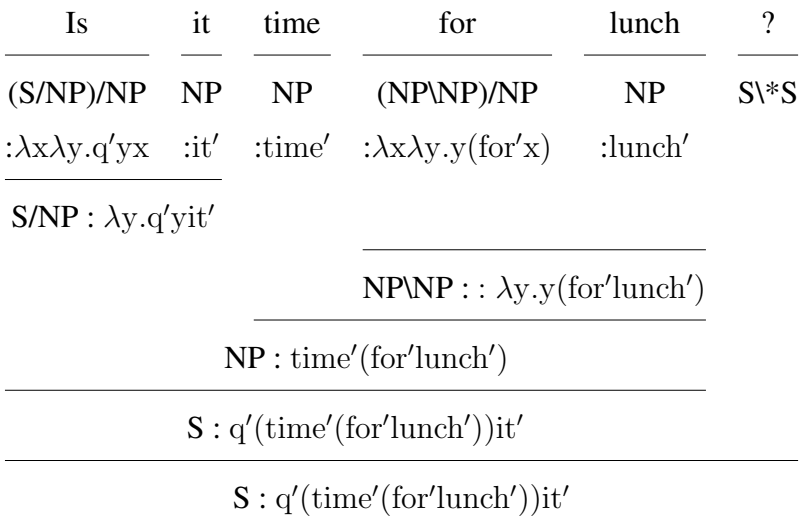

Figure 3.46: An example of a preposition composed with a noun phrase

3.3.13 Question Words

The function of the question words is to turn a sentence into a question form and add question meaning to sentences. Question words in this study are represented in Figure 3.47, and the examples of each rule can be seen below.

a. what | q :: s[type=q]/(s/np) : λx.q′what′x

b. where | q :: s[type=q]/(s/pp) : λx.q′place′x

c. which | q :: (s[type=q]/(s/np))/np : λxλy.q′which′xy

d. who | q :: s[type=q]/(s\np) : λx.q′who′x

e. who | q :: s[type=q]/(s/np) : λx.q′who′x

f. who | q :: s[type=q]\(s/np) : λx.q′who′x (only used in the ergative system)

g. whose | q :: s[type=q]/(s/np) : λx.q′whose′x

Figure 3.47: Question words

In Figure 3.48, *what* is an interrogative word. The syntactic form of it implies that it seeks a noun phrase on the right, so there is a λ-calculus symbol at the final logical form of the sentence. In the derivation below, the subject is type-raised since the structure of interrogative sentences does not permit combining words traditionally.

What	am	I	doing	?
S/(S/NP)	(S/NP)/(S/NP)	S/(S\NP)	(S\NP)/NP	S *S
:λx.q′what′x	:λx.x	:λp.pI′	:λxλy.do′xy	
		S/NP : λx.do′xI′		
	S/NP : λx.do′xI′			
S : q′what′(λx.do′xI′)				
S : q′what′(λx.do′xI′)				

Figure 3.48: A derivation example of the question word *what* in the accusative system

In Figure 3.49, the ergative form of Figure 3.48 can be seen. In this derivation, the verb category differs from that in the accusative system above. Here, the subject is not type-raised because the verb can typically take it.

What	am	I	doing	?
S/(S/NP)	(S/NP)/(S/NP)	NP	(S/NP)\NP	S*S
:λx.q′what′x	:λx.x	:I′	:λyλx.do′xy	
		S/NP : λx.do′xI′		
	S/NP : λx.do′xI′			
S : q′what′(λx.do′xI′)				
S : q′what′(λx.do′xI′)				

Figure 3.49: A derivation example of the question word *what* in the ergative system

Apart from this, the question word *what* has some other categories in the data set as in Figure 3.50.

a. what | interj :: s[type=q]/np[agr=?x,count=?x] : λx.q′what′x
   (as in the sentence "What sweetie?")

b. what | np :: np : what′
   (as in the sentence "Man have what?")

c. what | qw :: s[type=q] : q′what′
   (as in the sentence "What?")

d. what | raisedpro :: s/(s\np[agr=1,count=sg]) : λp.pwhat′
   (as the subject in the sentence "What is what doing?")

Figure 3.50: Other categories of the question word *what*

In Figure 3.51, the question word *where* makes the sentence a question. It generally seeks a prepositional phrase on the right because of the meaning of *where*. The use of this question word is the same in accusative and ergative systems.

Where	is	it	?
S/(S/PP)	(S/PP)/NP	NP	S*S
:λx.q′place′x	:λxλy.yx	:it′	
	S/PP : λy.yit′		
S : q′place′(λy.yit′)			
S : q′place′(λy.yit′)			

Figure 3.51: A derivation example of the question word *where*

In Figure 3.52, the question word *which* is followed by a noun phrase, unlike the other question words. Nonetheless, the remaining steps of the derivation process are pretty similar. The same category for *which* is used in the ergative system. However, there are differences in the categories of the auxiliary verb *do* and the verb *like*. The category of auxiliary verbs can be found in Section 3.3.8, while the category of verbs can be seen in Section 3.3.6.1.

Which	story	do	you	like	?
(S/(S/NP))/NP	NP	(S/NP)/(S/NP)	S/(S\NP)	(S\NP)/NP	S*S
:λxλy.q′which′xy	:story′	:λx.x	:λp.pyou′	:λxλy.like′xy	
S/(S/NP) : λy.q′which′story′y					
			S/NP : λx.like′xyou′		
		S/NP : λx.like′xyou′			
S : q′which′story′(λx.like′xyou′)					
S : q′which′story′(λx.like′xyou′)					

Figure 3.52: A derivation example of the question word *which*

Besides, there exists another category for *which*, denoted as 'which | adj :: np/np : λx.which′x'. In this category, the word class of *which* is accepted as an adjective. It takes a noun phrase on the right and gives a noun phrase, as exemplified in the sentence "Which window?" Here, the question mark adds interrogative meaning to the sentence.

In Figure 3.53, the question word *who* substitutes for the subject of the sentence. Thus, the auxiliary verb *is* has the same category as a sentence in a canonical order.

Who	is	making	that	noise	?
S/(S\NP)	(S\NP)/(S\NP)	(S\NP)/NP	NP/NP	NP	S*S
:λx.q′who′x	:λxλy.xy	:λxλy.make′xy	:λx.that′x	:noise′	
			NP : that′noise′		
		S\NP : λy.make′that′noise′y			
	S\NP : λy.(λy.make′that′noise′y)y				
S : q′who′(λy.(make′that′noise′y))					
S : q′who′(λy.(make′that′noise′y))					

Figure 3.53: A derivation example of the question word *who* in the accusative system

Figure 3.54 is the ergative version of Figure 3.53. Here, the category of the question word *who* remains unchanged; however, there are differences in the categories of the auxiliary verb *is* and the main verb *making*. Also, the noun phrase 'that noise' is type-raised since the conventional combination is not possible.

Who	making	is	that	noise
S/(S\NP)	(S/NP)\NP	((S/NP)\NP)\((S/NP)\NP)	(S\(S/NP))/NP	NP
:λx.q′who′x	:λyλx.make′xy	:λxλy.xy	:λxλp.p(that′x)	:noise′
			S\(S/NP) : λp.p(that′noise′)	
	(S/NP)\NP : λy.(λyλx.make′xy)y			
	S\NP : (λy.make′that′noise′y)			
S : q′who′(λy.(make′that′noise′y))				

Figure 3.54: A derivation example of the question word *who* in the ergative system

Figure 3.54 is for the sentences, including a question word questioning the subject and a transitive verb, such as 'make', in the ergative system. However, another rule is necessary for the sentences, including a question word questioning the subject and an intransitive verb such as 'come', as shown in Figure 3.55. This requirement arises due to the different positions of the subject in transitive and intransitive sentences within the ergative system.

Coming	is	who	?
S/NP	(S/NP)\(S/NP)	S\(S/NP)	S*S
:λx.come′x	:λxλy.xy	:λx.q′who′x)	
S/NP : λy.(λx.come′x)y			
S : q′who′(λx.come′x)			
S : q′who′(λx.come′x)			

Figure 3.55: A derivation example of the question word *who* in the ergative system

As a side note, *who* has two other categories, as shown below.

a. who | np :: np : who′
   (as in the sentence "That is who?")
b. who | qw :: s : q′who′
   (as in the sentence "Who?")

In Figure 3.56, the question word *who* substitutes for the object of the sentence. Therefore, the auxiliary verb *are* is in the question form as opposed to the one in Figure 3.53. This type of question word is used in both accusative and ergative systems.

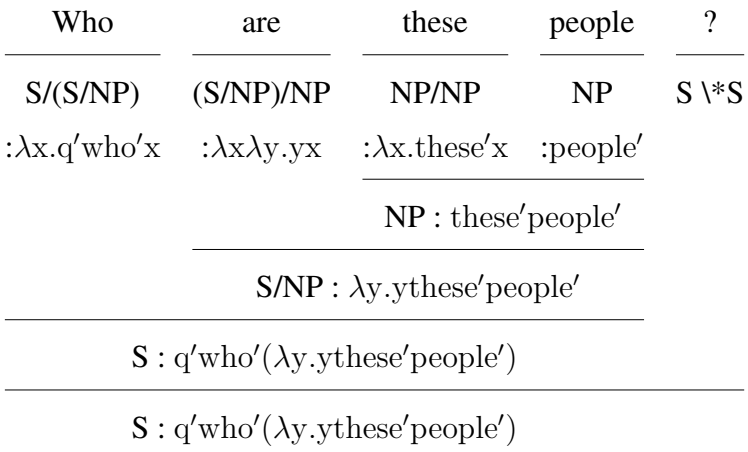

Figure 3.56: A derivation example of the question word *who*

In Figure 3.57, *whose* is an interrogative word, giving question meaning to the sentence. This interrogative word is common in the accusative and ergative systems.

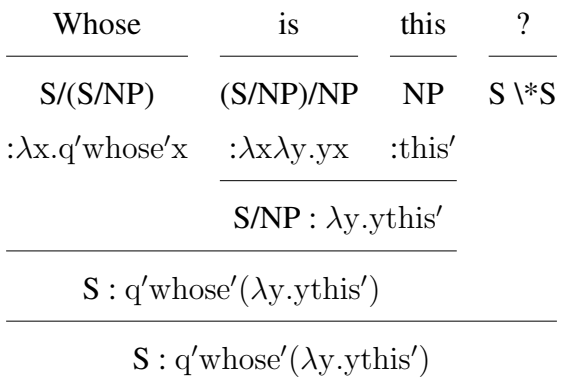

Figure 3.57: A derivation example of the question word *whose*

Besides, *whose* has another syntactic category in the grammars, which is 'whose | pro :: np/np : λx.whose′x' This category is constructed for such sentences as "Whose coffee?" In such sentences, the question's meaning is supposed to come from the question mark. The subject of punctuation will be discussed in 3.3.14.

3.3.14 Punctuation Marks

As previously stated, punctuation marks except for question marks are excluded in these grammars for the convenience of the experiments in the study. Question marks are kept because they have significance for logical forms, and they have a function to turn a sentence into a question. Three different categories exist for question marks in these grammars, as demonstrated in Figure 3.58.

a. ? | pun :: s[type=q]\s[type=q] : : λx.x

   According to this rule, question marks do not play a role in forming questions. In the data set, such question marks can be observed in sentences like "What is that?" or "Do you like it?". In these sentences, questions are constructed via question words (such as what, who, where, etc.) or auxiliary verbs (such as do, did, have, etc.). Eventually, question marks at the end of these sentences do not have a syntactic or semantic importance.

b. ? | pun :: s[type=q]\np : : λx.q′x

   The significance of the question mark in rule (b) lies in its semantic role within the logical forms of sentences since it has a function to form a question. This rule can be seen in sentences like "More juice?" or "Eve?". In such sentences, question mark turns noun phrases into questions and adds a questioning meaning to the logical forms.

c. ? | pun :: s[type=q]\s[type=decl] : : λx.q′x

   The purpose of the question mark in rule (c) is to convert a declarative sentence into a question, as seen in sentences "It does not work?" or "They were?". In this conversion, it adds a questioning aspect to the logical forms of the sentences.

Figure 3.58: Rules for question marks

3.3.15 Conjunctions

In the data set, the function of conjunctions is to link words, phrases, or sentences together. This data set has several conjunctions, some of which are explained below with examples.

a. because | conj :: s[type=decl]/s : $\lambda \mathrm{x}.\mathrm{because}'\mathrm{x}$

   According to the rule in (a), the conjunction *because* takes a sentence and produces another sentence as a result, as seen in examples such as "Because I am busy" or "Because they are green".

b. and | conj :: (np\np)/np : $\lambda \mathrm{x} \lambda \mathrm{y}.\mathrm{and}'(\mathrm{xy})$

   This conjunction connects two noun phrases, as observed in sentences like "You and Papa are sharing the sandwich" or "Becky and Nancy are busy".

c. and | conj :: np/np : $\lambda \mathrm{x}.\mathrm{and}'\mathrm{x}$

   The rule in (c) is quite similar to the rule in (b). This conjunction takes a noun phrase and gives a noun phrase, as seen in the sentence "And Eve-cummings." It is a follow-up sentence that adds more information to the previous one.

d. and | conj :: (@x\@x)/@x : $\lambda \mathrm{p} \lambda \mathrm{q} \lambda \mathrm{x}.\mathrm{and}'(\mathrm{px})(\mathrm{qx})$

   The function of the conjunction in (d) is to connect two sentences having the same subject to each other, as in the sentence "Go and get your telephone". The derivation of this sentence is demonstrated in Figure 2.12. However, such a conjunction cannot be used in the ergative system since the subject of an intransitive verb (such as the subject of the verb *go*) and the subject of a transitive verb (such as the subject of the verb *get*) have different cases. Thus, such sentences cannot be coordinated in the ergative system. This data set has two sentences like this; "Now you go and ask Fraser" and "Go in and get them."

e. instead-of | conj :: @x/@x : $\lambda \mathrm{x}.\mathrm{instead} - \mathrm{of}'\mathrm{x}$

   The rule (e) is constructed for the utterance "Instead of going for a nap right away" According to this rule, the conjunction *instead-of* takes a syntactic category and gives the same one as a result.

CHAPTER 4

EXPERIMENTS AND RESULTS

In this chapter, the stages of the experiments and their results will be provided, and the research questions will be discussed in detail.

4.1 Stages Before the Experiments

This section explains the stages before the experiments conducted in this thesis and provides details regarding the training process.

Before conducting our experiments, we meticulously generated the gold pairs of surface forms and logical forms. This process involved deriving logical forms using the accusative grammar outlined in Section 3.3 and then carefully selecting the correct pairs of surface forms and logical forms to compose the gold pairs. This rigorous approach ensures the validity and reliability of our grammar.

Thanks to the gold pairs, each sentence in our data set has one correct derivation, leading to a 100% recall rate of the grammar. This high recall rate is a testament to the effectiveness of our grammar. After composing the gold pairs, we compared the ranking of the supervision data and the gold pairs. As a result, when all parameters in the grammar were the same, we found that the ranking of the correct derivations achieved a respectable 60% rank success. The rank success is the performance metric that measures the rate of how many correct pairs of sentences and their corresponding logical forms are positioned at the top of the derivation results.

Subsequently, several models were developed to derive accusative sentences from the grammar, including only accusative versions of the entries. We trained these models

using a tool named THEBENCH by Bozşahin (2023). Before explaining the details of the experiments, the required information about THEBENCH will be provided.

4.1.1 THEBENCH

THEBENCH is a tool designed to examine monadic structures in natural languages by Bozşahin (2023). The purpose of the tool is to facilitate writing monadic grammars for the exploration of analyses and the training of models.

During the experiments, we used THEBENCH to train our models. The system first assigns probabilities to pre-analyzed entries and then applies sequence learning, inspired by Zettlemoyer and Collins (2005). Throughout the training, THEBENCH uses a training scheme with a gradient ascent methodology, updating the parameters to increase the model's performance.

These methods were used in the experiments, and the following section will explain the details of the experiments and their results.

4.2 Stages of the Experiments and Their Results

Following the training process, the best-performing model that comes closest to the recall rate of the grammar in terms of prioritizing accurate sentence pairs in the derivation results was obtained. Subsequently, three experiments were conducted by employing this model: one used only the accusative grammar, another included the accusative grammar along with the ergative forms of transitive verbs, and the last concentrated only on ergative grammar. In these experiments, the trained model simulates a child's language acquisition, and the rank success represents to what extent the child learned the target language.

In the first phase of the experiments, which focuses on only the accusative version of the grammar, the best model obtained an 81% rank success, meaning that the model produced the correct logical forms at the top of the derivation results at an 81% rate. This rank success also indicates the grammar's overall success. Based on the results of the first experiment and the rank success of the model, children can be assumed to

have acquired accusative English when they are exposed to accusative English.

In the second phase of the experiments, we introduced the ergative forms of transitive verbs to the accusative grammar to see whether the model would primarily produce correct pairs of accusative sentences even though the grammar included some ergative forms as distractors. After this experiment, the model achieved a 71% rank success, predominantly generating accusative sentences despite including the ergative forms of transitive verbs in the training set. This remarkable outcome underscores the model's successful acquisition of accusative English, leading us to conclude that when children are exposed to accusative English, they can be assumed to have acquired accusative English even though the grammar includes some parts of the ergative grammar. In this experiment, the decline of the rank success is acceptable since the ergative forms of transitive verbs were incorporated into the accusative grammar as distractors.

To delve deeper into our research questions - specifically, 'What are the potential outcomes if children are exposed to hypothetical English, i.e. ergative English, in their first language acquisition process?' and 'If the trained model successfully acquires hypothetical English, what does this success signify?' - we conducted the last phase of the experiments with only the ergative version of the grammar. A hypothetical English, i.e., ergative English, was formed to conduct this experiment, as mentioned in Section 3.3. Furthermore, in this phase of the experiments, the syntactic word order of the sentences in the data set was changed to form syntactically ergative English, as seen in some examples in Section 3.3. At the end of this experiment, the model obtained 75% rank success, which means that it mainly produced the correct logical forms at the top of the ranking when it was exposed to ergative grammar. Namely, children can be assumed to have captured ergative English when they are exposed to hypothetical ergative English.

Since the trained model successfully acquired syntactically ergative English, we can deduce that each system of grammatical relation (accusative and ergative in this study) is equally likely for first-language learners. This also addresses our final research question: 'How do universal constraints affect language acquisition and grammar?' In this regard, we can assert that children can learn the language they are exposed to

without any innate constraint related to the potential grammar of a language. From this point of view, we can claim that learners' experiences determine which syntactic category takes precedence and which falls behind rather than any innate constraint associated with the possible grammatical structures of a language.

CHAPTER 5

CONCLUSION

The current study examined the potential implications of exposing children to hypothetical English, specifically syntactically ergative English, instead of accusative English, during the first language acquisition. This investigation utilized a dataset of child-directed speech sourced from the Eve fragment (Brown, 1973) within the Child Language Data Exchange System (CHILDES) database of MacWhinney (2000). This process was modelled computationally by training a model to simulate the learning process of a child.

Using the data set, we constructed an English grammar with the syntactic and semantic representations of the words. Correct pairs of sentences and their corresponding logical forms were generated accordingly. Subsequently, several models were developed to derive accusative sentences from this grammar. After training, the best-performing model prioritizing correct pairs in the derivation results was obtained. Three experiments were conducted using this model: the first involved accusative grammar, the second included accusative grammar and the ergative forms of only transitive verbs, and the last contained only syntactically ergative grammar.

In the first experiment, only the accusative version of the grammar was used, and we observed that the model mainly produced the correct logical forms at the top of the ranking, implying that the model acquired accusative English when it was exposed to it. In other words, children can be assumed to have acquired accusative English when they are exposed to it.

In the second experiment, the research findings revealed that the model predominantly generated accusative sentences, even with the ergative forms of transitive verbs. This

finding highlighted that children can be assumed to have acquired accusative language when they are exposed to it, even when some distractors exist.

In the final experiment, the model was trained using the syntactically ergative grammar constructed for this phase of the study. The model generally produced the correct logical forms at the top of the ranking, emphasizing that children can be assumed to have captured ergative English when they are exposed to it.

Reiterating the study's key findings, we can conclude that both grammatical relation systems (accusative and ergative) are equally probable for children during language acquisition. Ultimately, the study claims that children's exposure to specific linguistic experiences determines the dominance of one category over the other. In other words, children can be assumed to acquire whichever language they are exposed to, as convincingly demonstrated by the model in our experiments.

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APPENDIX A

RULES FOR IMPERATIVE SENTENCES IN THE ERGATIVE SYSTEM

a. s[type=decl]/np : lf –> s[type=imp] : λlf.imp (lf interlocutor)

b. s[type=decl]/np : lf –> s[type=decl] : λlf.lf interlocutor

c. (s[type=decl]/np)\np : lf –> s[type=decl]/np : λlf.lf interlocutor

d. ((s[type=decl]/pp)/np)\np : lf –> (s[type=decl]/pp)/np : λlf.lf interlocutor

e. (s[type=decl]/predp)\np : lf –> s[type=imp]/predp : λlf.imp (lf interlocutor)

f. (s[type=decl]/s)\np : lf –> s[type=imp]/s : λlf.imp (lf interlocutor)

g. (s[type=decl]/pp)\np : lf –> s[type=decl]/pp : λlf.lf interlocutor

h. (s[type=decl]/np)/pp : lf –> s[type=imp]/pp : λlf.imp (lf interlocutor)

i. (s[type=decl]/np)\np : lf –> s[type=imp]/np : λlf.imp (lf interlocutor)

j. ((s[type=decl]/np)/np)\np : lf –> (s[type=imp]/np)/np : λlf.imp (lf interlocutor)

k. (s[type=decl]/pp)\np : lf –> s[type=imp]/pp : λlf.imp (lf interlocutor)

l. ((s[type=decl]/pp)/np)\np : lf –> (s[type=imp]/pp)/np : λlf.imp (lf interlocutor)

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