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Cutler Cannon April 12, 2022

A Theoretical Account of Whale Song Syntax:
A New Perspective for Understanding Human Language Structure

by

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An abstract of
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Abstract

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It is a common belief among linguists that the use of language is a species-specific phenomenon belonging only to humans. However, there is no doubt that there are non-human communication systems within the animal kingdom that are amazingly complex and share certain properties with human language (Berwick et al., 2011). The current thesis calls to attention the intricacy of one such system used among humpback whale (*Megaptera novaeangliae*) communities, where recent debates among biologists and acousticians have established an unpredictable sequence of bidirectional egressive and ingressive sounds in whale song but question whether it utilizes the same hierarchical framework observed in human language (Mercado & Perazio, 2021). Modern linguistic theories do not currently present models for representing paralanguage or certain syntactic anomalies, but whale songs have the potential to reveal information about these phenomena that could be insightful and more relevant than other non-human communication systems. Drawing from recent literature about animal communication at large, whale singing behavior, and bidirectional sound production, I propose a theoretical, two-channel mechanism for the acoustic and structural nature of whale song. Using the two-channel mechanism, I further present a catalog of possibilities surrounding the potential for whale song compositionality to establish parallels with human language and ultimately argue a structural context for issues surrounding the modeling of paralinguistic computation, syntactic amalgams, and parentheticals.

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I am a product of those who have influenced me, and I am ever grateful for those who have shaped me into the scholar and person I am today. Because of them, I am reminded to –

Shoot for the moon
Because
Even if I miss
I will land
Among the stars

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Chapter 1

An Introduction

1.1 A Disclaimer

Unconventional in nature, this undergraduate thesis is not a product of empirical research involving personally-conducted fieldwork followed by data analysis and subsequent conclusions. Instead, this thesis offers a thought experiment to contribute to the discussion of the relationship between non-human animal communication and human language in a way that is more unifying than discriminating. This thesis, while not a literature review, seeks to add new arguments in response to debates that currently exists in the fields of whale song research, linguistic theory, and animal communication more broadly.

1.2 Research Motivation and a Consideration for Discovery

To fully understand the purpose of the thesis, I encourage an initial consideration for the process and evolution of discovery. For example, prior to the 1600s, the microscopic world was not one of consideration. Tucked away in ignorance, it remained unknown, and disease was perceived as nothing more than some sort of spiritual imbalance or attack. It wasn't until after the microscope was created in the 1600s that Robert Hooke and Antoni van Leeuwenhoek discovered microorganisms (Gest, 2004). When this discovery was made, and such tools that made it possible existed, a whole other field of scientific research had been born.

Despite the widely-accepted belief among linguists that language is a species-specific capability belonging only to humans, I encourage readers of this thesis to think of whale song in the same way I have outlined microbiology above. For yes, there is currently no evidence convincing enough to definitively support how exactly the songs are influencing behavior or transmitting information, if at all, and there may never be, but that doesn't mean that the presence of language is null (Janik, 2009; Mercado, 2018).

As opposed to other communications systems discussed in this thesis, the problem with whale song analysis arises with the limits for studying whale behavior. With communication systems such as birdsong and bee waggle dances, it has been easier to determine the behavioral implications of such behaviors because of the size of the organisms and the fact that they are not ocean dwellers. This is because experiments can be readily designed. For example, if a honey bee[1] dances at a certain speed and direction, it can be empirically observed how perceiving honey bees behave in a certain predictable way in response to the dance. The honey bee waggle dance, then, can be decoded and studied from a linguistic frame-of-mind; it can be questioned whether it is a language and more easily falsified as not one based on its constructions and how it works. Yet, given the fact that whales live in the ocean, cannot be held in captivity, and have shown to stop singing and/or change their song patterns based on shipping noise, it can be difficult to design experiments to accommodate for these factors (Tsujii et al., 2018).

However, just because whales cannot as easily be studied does not mean that something more profound – more complex, more revolutionary – does not exist within their songs. In fact, recent research involving whale song has revealed interesting syntactic and phonological properties that could provide insight into the emergence and structure of human language (Allen

[1] This thesis adopts the spelling of *honey bee* (as opposed to *honeybee*) per the Entomological Society of America

et al., 2019; Mercado & Handel, 2012; Mercado & Perazio, 2021). At this point in time, however, there may simply not exist the tools nor technology needed to understand what information, or lack thereof, these syntactic and phonological properties are transmitting. As it stands, there is no evidence to suggest that whales have language in the same capacity that humans do, *but there is also no evidence to suggest that they don't.*

Consider a hypothetical reality in which whales were the ones studying human language. Now imagine two people neutrally having a conversation in a coffee shop without exhibiting any behavioral responses to the language being spoken. In this case, a whale unknowing of the meaning of human language may be tempted to say that the 'language' is non-linguistic, reflexive, or for reproductive purposes (e.g., the attraction of mates and/or competition with same-sex competitors). Yet speakers of human language would know that this assumption would be false, for it is assuredly the case that the two people in the coffee shop could be exchanging ideas, telling stories, or expressing opinions – executing language that is cognitively engaged with. A pressing question, then, is if whale song is in fact a language, how would it be determined to be so?

While an important question to consider, the purpose of this thesis is not to provide an answer. For there may not be one, given the current status in technological advancement for studying marine animal behavior. Instead, my motivation for research is to offer a range of possibilities for how whale song *could* resemble human language, and to reveal how human language isn't as far removed from animal communication systems as often postulated. In doing so, I hope to [re]stimulate conversation surrounding non-human language and give insight into how such possibilities can influence how human language structure is studied.

1.3 Thesis Statement and Objectives

In this paper, I will explore the different theories surrounding language uniqueness and synthesize different perspectives founded on the phonological analysis of whale song. After presenting a hypothetical model for whale song structure, I argue that, based on acoustic properties, whales utilize two channels of communication and that three possibilities exist regarding their meaning. First, I adopt the possibility that both channels are meaningless and non-syntactic; second, that one channel is meaningful and syntactic, and one is not; and third, that both channels are meaningful and syntactic. Further, using the two-channel method, I argue for parallels found in all three possibilities between whales and humans. My specific objectives are outlined below:

- To discuss the current understanding and development of syntactic theory and acknowledge debates present in literature concerning the structure of whale song (Allen et al., 2019; Mercado & Perazio, 2021).
- To show how not all linguistic hierarchies are syntactic and how not all aspects of human language are compositional.
- To propose how the two-channel method can be used to analyze paralanguage and resolve issues in linguistic theory, specifically concerning syntactic amalgams and the syntax of parentheticals and modifiers.

1.4 Navigation

The contents of this thesis are far-reaching, ranging from discussions of syntactic analysis and linguistic theory, animal communication outside of whale song, human language emergence, and whale physiology.

In Chapter 2, I will first lay down a foundation for basic human language syntax (syntax tree building, structural ambiguity, the hierarchical structure of language, etc.) and then discuss theories surrounding the emergence of human language compositionality through the lens of two animal communication systems: birdsongs and honey bee waggle dances. Finally, I will discuss contemporary Chomskyan theories and biological explanations for human language emergence. Chapter 2 is helpful for readers interested in basic syntax and language evolution.

In Chapter 3, I introduce whale song specifically, discussing its structure and debates within whale song literature concerning song structure and whales' capacity for cultural transmission. Further, I discuss whale physiology as a basis for explaining the relevance of acoustic analysis and introducing the idea of two-channel communication. Chapter 3 is beneficial for readers without much knowledge of whales or their song structures.

In Chapter 4, I apply my theory of two-channel communication to human language and explore the possibilities of whale song compositionality. While making parallels to human sound production and language, I first reveal the ways in which humans could also be processing language on two or more channels, and then I attempt to provide solutions for current gaps in linguistic theory related to modifiers, parentheticals, and syntactic amalgams. Chapter 4 contains my main contribution to the discussions surrounding whale song analysis and communication.

In Chapter 5, I summarize my conclusions and discuss possibilities for future research and development of syntactic theory.

Chapter 2

Language Structure and Animal Communication

2.1 A Basis for Understanding Language Structure

Before much can be said about how the conception of human language can function in ways beyond what is currently addressed in syntactic theory, it is important to establish a foundational understanding of how language is presently perceived in a structural sense. In this section of my thesis, I will:

- lay down a basic knowledge of human language structure.
- assert preliminary distinctions between human and non-human communication that will guide discussions in whale song significance.
- establish an awareness of current developments in theoretical linguistics that will grant better insight into human language evolution and provide an understanding for how this thesis can be helpful in advancing an understanding of human language structure.

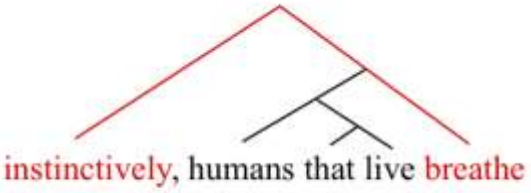
To begin this discussion, I find it necessary to establish the widely accepted ideas that human language is (a) hierarchically structured and (b) comprised of compositional syntax (Carnie, 2006).

These two ideas are what academics have assumed to be the distinguishing characteristics of human language from all other non-human communication systems (Chomsky & Berwick, 2016).

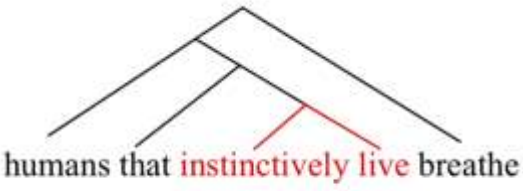
For (a), most linguists agree, often implicitly, that language is hierarchically organized. To demonstrate this phenomenon, consider the two examples below:

1) **Instinctively**, humans that live **breathe**.
2) Humans that **instinctively live** breathe.

Interestingly, the difference in these two sentences rests in the ability for the adverb *instinctively* to modify different verbs depending on its location. *Instinctively* modifies the verb furthest away from it linearly (*breathe*) in (1), but the one closest to it (*live*) in (2). Consider below the syntactic organization for (1) and (2):



Tree A. Instinctively, humans that live breathe



Tree B. Humans that instinctively live breathe

These two structures above, known as syntax trees, depict a sort of hierarchical organization to human language. While the structure of syntax trees will be further defined in a future discussion about (b), it can be noted how in tree (A), *instinctively* is structurally further removed from *live*, which is 'buried' further in the syntax, allowing for it to modify the structurally closest atomic element, *breathe*. Conversely, in tree (B), *instinctively* is structurally removed from *breathe* and closest to *live*, allowing it to modify *live* instead. There exists a developed collection of literature that hypothesizes how humans can make these sorts of

semantic computations, some of which will be explored in the following subsection. For now, it is only necessary to recognize how language meaning is not contingent on the chronological order in which words are uttered or processed, but instead that it is based on some sort of internal structure and organization – based on syntax.

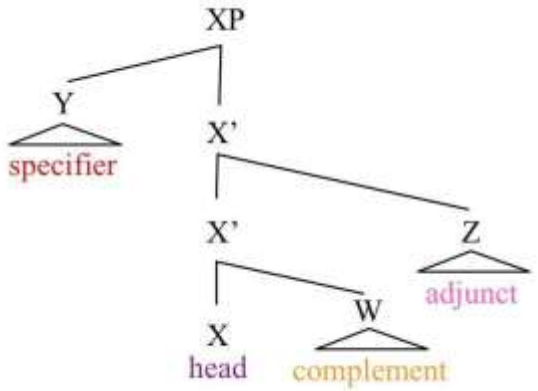
Keeping in mind the idea of hierarchical language structure, I will now discuss the concepts of syntax and compositionality pertaining to (b). The Principle of Compositionality arose from Gottlob Frege's discussions of productivity, where he asserted that ([c. 1914] 1980):

> The possibility of our understanding sentences which we have never heard before rests evidently on this, that we can construct the sense of a sentence out of parts that correspond words (p. 79).

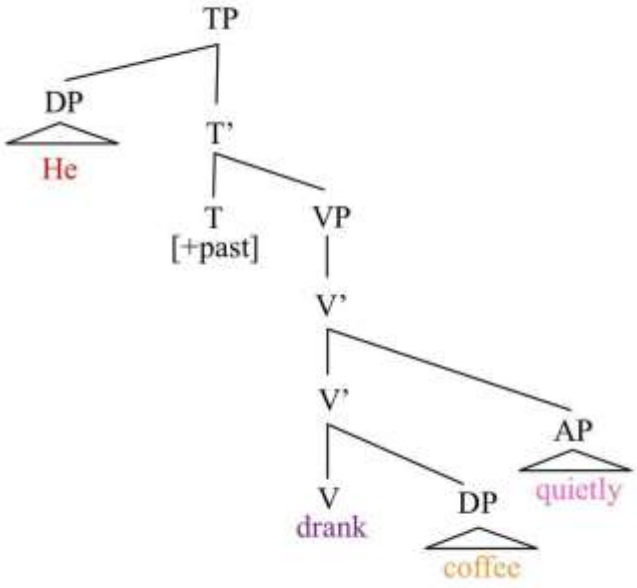
As a German philosopher and logician who employed a mathematical understanding of language, Frege never explicitly discussed the modern Principle of Compositionality, but it was later developed from his arguments on productivity (Aronoff, 2007; Pelletier, 2001). Under the Principle of Compositionality, the meaning of compound expressions found in language is a function of the expression's individual lexical items and the organization by which they are syntactically combined. Most modern linguistic theories ascribe to this principle, where meaning is assigned to words in isolation and then — through a system of algebraic operations — are combined to yield the formation of a sentence and eventually obtain the meaning of a compound (Janssen, 2001). To put this principle in practice, consider (1) and (2), which are built up of the same atomic elements, or words, with individual meanings that English speakers recognize. However, the composite meaning of each phrase changes drastically based on the syntactic constraints placed on the utterance. To summarize, the meaning of a sentence under The

Principle of Compositionality is based not only on individual word meanings but also on how words are combined.

As stated before, the compositional nature of language is often modeled through syntax trees to show the hierarchical organization of a sentence, which will be important for analysis in this thesis. Consider syntax tree (C) below, accompanied by the example *He drank coffee quietly* in tree (D):



Tree C. The structure of a syntax tree using X-bar theory.



Tree D. *He drank coffee quietly*, modeled using X-bar theory.

I have constructed all examples in this thesis using X-bar theory as structured above. While the purpose of this thesis is not to provide a deep dive into the intricacies of this theory, I have provided a brief overview to understand how the trees in this thesis will be structured:

In X-bar theory, it is claimed that every sentence, regardless of language, has the same core organization (Carnie, 2006; Chomsky, 1970). Each phrase (e.g., **V**(erb)**P**(hrase)) has a binary daughter node (Such as V') where two branches lead to either another XP or to a head at

the terminal node. The category of the head determines the category of the phrase (e.g., if the head is a verb like *drank*, it will be nested within a verb phrase). Specifiers often act as the subjects of the phrase (e.g., *He*), and complements are often used to represent situations where a verb or preposition is combined with an object (e.g., *drank coffee*). And finally, adjuncts are classified as optional or structurally dispensable parts of a phrase that, if removed, will not structurally interfere with the rest of the sentence (e.g., a modifier like *quietly*) (Chomsky, 1970). Furthermore, each tree must obey the constituent organization of a sentence and be built in such a way to where all lexical items are attached, each node has exactly one parent node, lines do not cross, and that all branches are correlated with a part of speech label (Carnie, 2006). However, some of these syntax tree characteristics will later be challenged in this thesis as a new perspective for understanding human language structure emerges from analyzing whale song.

To further stress the relevance of The Principle of Compositionality, I want to highlight two other phenomena of human language: (c) structural ambiguity and (d) recursion.

For (c), consider the following sentence:

3) John sees the professor with glasses

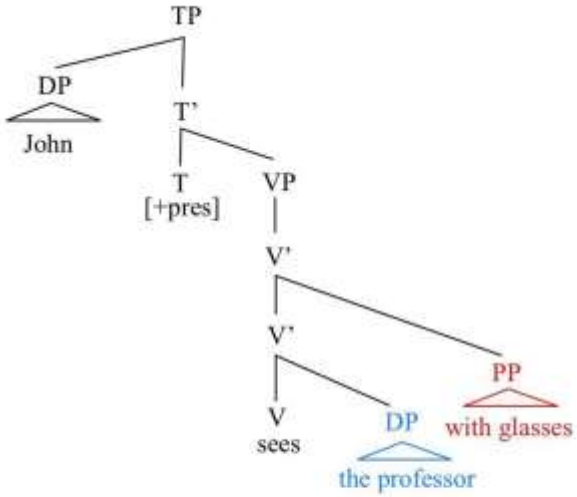
Under The Principle of Compositionality, sentence (3) can be understood to contain six lexical items, each possessing its own meaning. For example, An English speaker can understand the individual meaning of *glasses* and *professor*. Still, words like *with* have semantic flexibility depending on the syntactic rules they are governed by. Namely, sentence (3) can be interpreted in two different ways:

i) John, <u>using glasses</u>, sees the professor

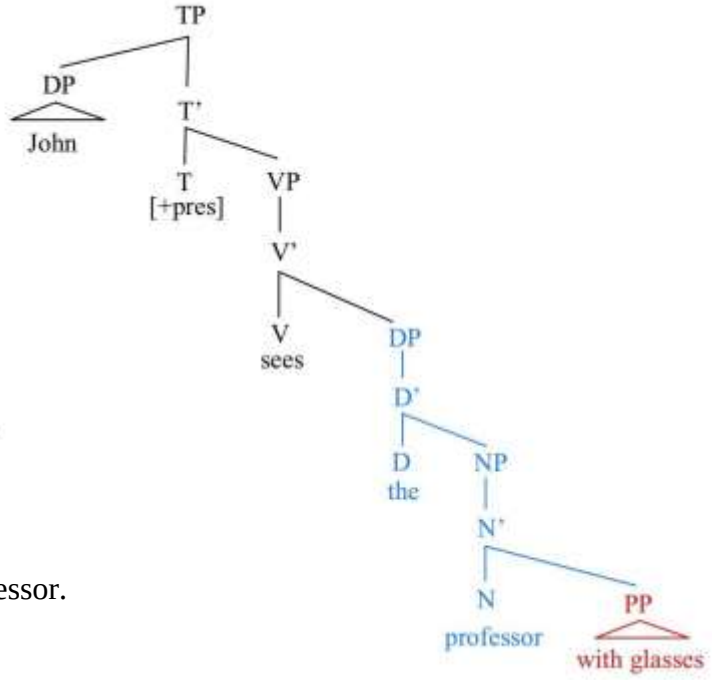
and

ii) John sees the professor <u>who possesses glasses</u>

The Principle of Compositionality seeks to explain how humans have the cognitive ability to parse together different interpretations of what are called structurally ambiguous sentences. (c) is explicitly represented by the possible syntactic constructions for (3), modeled below in trees (E) and (F) to yield both meanings (i) and (ii) respectively:



Tree E. John, using glasses, sees the professor.



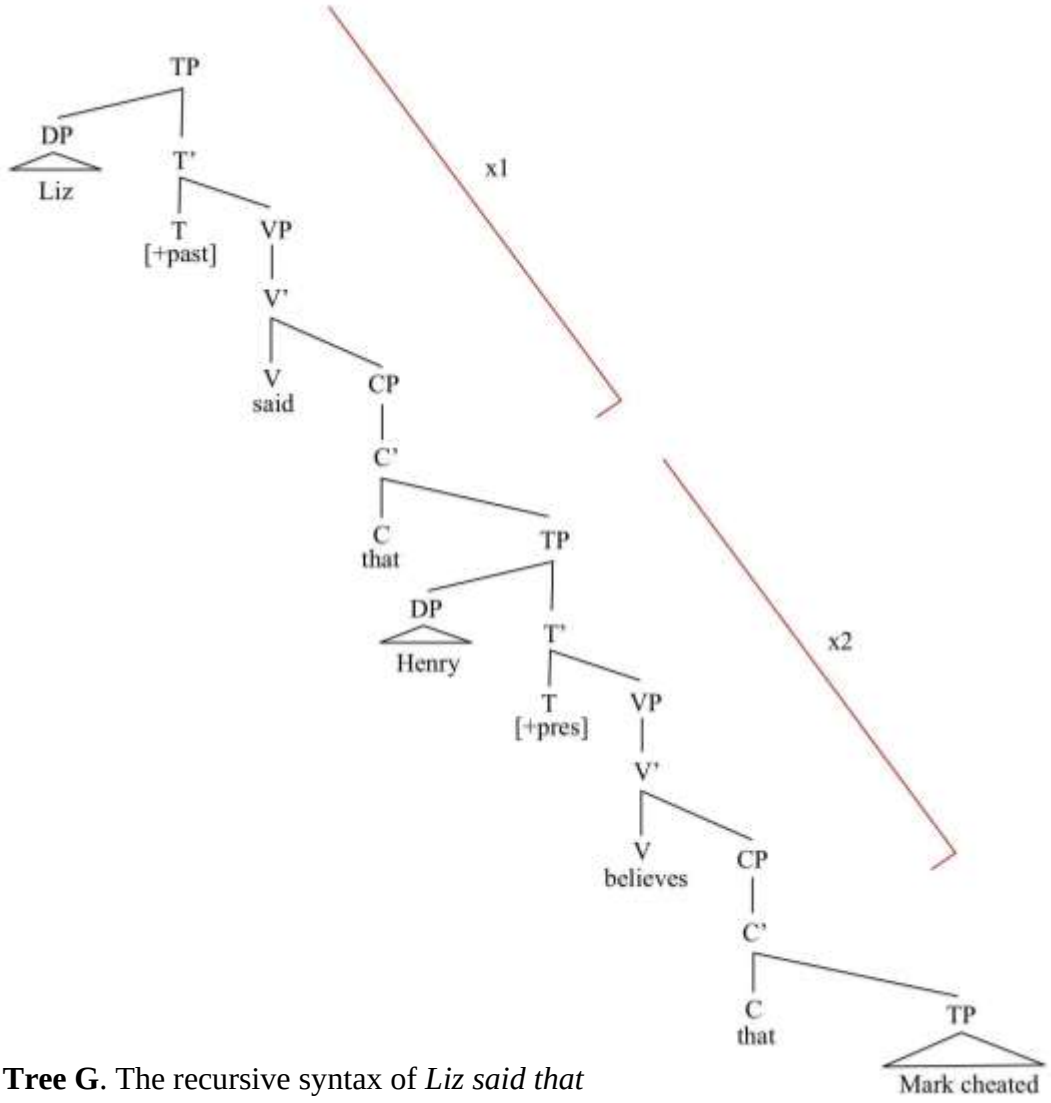
Tree F. John sees the professor who possesses glasses

With the DP in blue and the PP in red, tree (E) shows how the PP is not nested within the DP but within the VP. Thus, *with glasses* is not part of the same constituent as *the professor* and instead modifies the V, *sees*, as an adjunct. Conversely, tree (F) shows how the PP is instead nested with the DP and is thus of the same constituent. In tree (F), *with glasses* assumes the complement position to *professor* to show that the PP is in association with the object instead of

the subject. Then, it is noticed how sentence meaning is reliant both on word meaning and how they are hierarchically and compositionally organized cognitively.

For (d), note how in trees (E) and (G), a TP can have a VP nested within it; and according to the VP rule, a VP can take a CP which can then take another TP and create a possibly infinite loop of the same phrase structure embedded within itself. This phenomenon, in syntactic theory, is known as recursion (Carnie, 2006). Consider (4) and tree (G) below:

4) Liz said that Henry believes that Mark cheated.



Tree G. The recursive syntax of *Liz said that Henry believes that Mark cheated*.

In tree (G), recursion shows through a repeated [TP[VP[CP]]] cluster. Instead of a ‘loop’ comprised of multiple phase categories, recursion can also arise from a singular phrase recursively embedding into a phrase of its same type, like in (5), where *really*, an adverb [within an AdvP] acting as an intensifier, can embed within another AdvP and be interpreted to amplify the meaning of *liked* after each use:

5) Jane really really really really liked the spaghetti.

Recursion and The Principle of Compositionality have then demonstrated how lexical meaning and syntactic structure are independent, but both affect and contribute to overall sentence semantics. Furthermore, these two language characteristics have shown how humans can produce infinitely recursive utterances never produced or heard before. In the following section, I will contextualize these aspects of human language into the communication systems of the animal kingdom. In doing so, this thesis will begin to set up how human and non-human communication can be compared.

2.2 Aspects of Language in Animal Communication

In a reiteration of the introduction, this thesis aims to provide a new perspective for understanding and modeling human language structure using whale song. Now that a foundation for the syntactic organization of human language has been established, I will utilize this section to begin the discussion of non-human communication systems and whether they align with the Principle of Compositionality.

As previously established, human language is computed not only by semantics but also by structure. To say that a communication system is semantic is to say that is uses signals or words to represent actions or objects (Beecher, 2021). In his research, Beecher (2021) argues and concludes that, because animal communication systems contain a small repertoire of

vocalizations to represent objects (≤ 25), the semanticity of animal communication is limited. He notes, however, that these vocalizations are limited simply by nature and not by constraints in cognition or capacity for production. Further, Beecher (2021) addresses the Principle of Compositionality and asserts that semanticity and productivity are "probably the two central features of human language: by combining basic phonemic units into larger meaningful units, and combining these units further via syntactic rules, [humans] can say as almost anything." Advancing on his claims that animal communication systems are semantically limited, he states that animal communication systems are also not productive in the same way human language is.

In the following two subsections, I will expound on the idea of semanticity within the context of birdsong and then contextualize productivity (or the lack thereof) in the context of the honey bee waggle dance. By first understanding the components of 'language' found in non-human animals, it can be easier to understand the theories surrounding language evolution.

2.2.1 Phonological Structure without Meaning

Birdsongs are often used as a point of argument when discussing whether animals possess language in the same way humans do. This is because it has been noted how, unlike many other animals, oscine passerines (songbirds) represent a rare animal taxon where individuals *learn* vocalizations (Beecher et al., 2021). In other animal species, vocalizations are a product of instinct, development, or genetic disposition that arises regardless of exposure (Caruso-Peck & Goldstein, 2019). Songbirds, moreover, exhibit vocal learning similarly to how humans learn language — specifically, in six ways (Beecher et al., 2021; Bolhuis et al., 2010; Caruso-Peck & Goldstein, 2019):

- Young birds, like toddlers, necessarily require exposure to normal species vocalizations to have capacity for reproducing them as adults.

- Auditory feedback is required for memorized sensory input to be translated into motor production.
- Sensory learning proceeds motor production.
- Vocal learning is most efficient and sometimes restricted to a sensitive critical period early in life.
- There are areas of the brain primarily responsible for vocal learning and processing.

With these similarities in place, it is reasonable to contemplate how birdsong, then, could resemble a type of simple language. In conjunction with concluding that songbirds exhibit vocal learning and cultural transmission, researchers argue that songbirds contain a repertoire of songs and can produce up to ten different constructions (Beecher, 2021; Janik, 2014). Yet, despite having vocal learning and a complex vocal repertoire of song syllables, songbirds do not rearrange these syllables into different songs to signal different things. As a result, birdsong is not classified as a simple language, but many argue for its structural significance. Figure (1) outlines the structure of birdsong (Beecher, 2021):

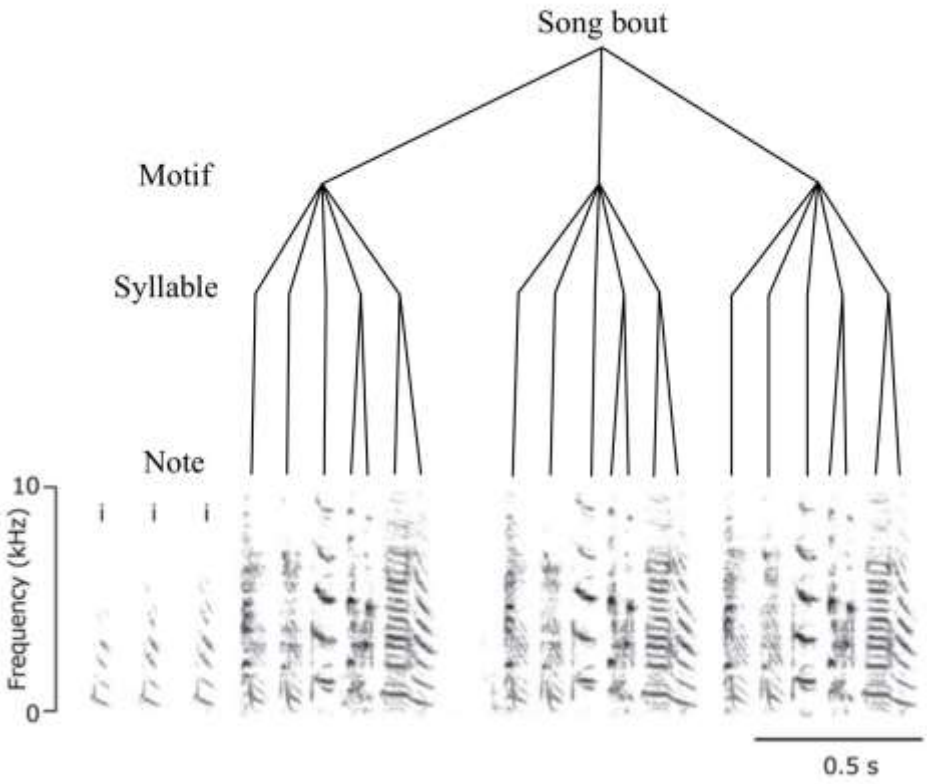


Figure 1. The structure of birdsong

Figure (1) includes a spectrogram of a typical Zebra finch song and a depiction of its organizational structure (Berwick et al., 2011). Zebra finch songs often start with three introductory notes, denoted by *i* in the figure, followed by a series of *motifs* comprising a *song bout*. Each motif consists of a set of *syllables* that are made up of *notes*. There is an important similarity between birdsong and whale song structure, which will be explored later in this thesis, but first observe how the hierarchical organization of birdsong resembles the hierarchical structure of syntax trees. This resemblance has been the root of many arguments in favor of birdsong as a form of simple language (Berwick et al., 2011).

Again, while the structure above may resemble those seen when analyzing human language syntax, it is argued that although songbirds may possess the cognitive capacity to understand hierarchical renderings in vocal signals, they do not use these capacities to represent

different objects in space (Gentner et al., 2006; van Heijningen et al., 2009). In contrast to the human capacity for language, where words are combined into sentences, songbirds do not use their songs to communicate combinatory propositional meanings, and the output of songbird recombination does not change its meaning (Beecher, 2021). More specifically, all birdsongs are described as a particular constrained type of finite-state automation, where birdsongs lack lexical items, or "words," that can be labeled (i.e., categorized as a verb, determiner, etc.) and hierarchically combined [infinitely] to yield new meanings like they are in Chapter 1. Thus, birdsong can be structurally complex and possess what is best characterized as phonological syntax, but it is not productive and does not seem to uphold the Principle of Compositionality (Berwick et al., 2001; Janssen, 2001).

2.2.2 Meaning without Phonological Structure

As established with birdsong, there exists communication systems within the animal kingdom that present phonological organization but not meaning contingent on syntactic constraints. However, there has been a development of literature and evidence supporting honey bees' ability to communicate via a waggle dance 'language' (Figure 2). Called "one of the seven wonders of animal behavior," (Gould & Gould, [c. 1988] 1995, p. 69), many arguments have been proposed to classify bee communication as a language (Alcock, 2013; Crist, 2004). In fact, earlier research in cognitive science challenges the anthropocentric view of language in favor of bees (Gould, 1975):

> Some of the resistance to the idea that [honey bees] possess a symbolic language seems to have arisen from a conviction that 'lower' animals, and insects in particular, are too small and phylogenetically remote to be capable of 'complex' behavior. There is perhaps a feeling of incongruity in that the [honey bee] language is symbolic and abstract, and, in

terms of information capacity at least, second only to human language. Despite expectations, however, animals continue to be more complex than had been thought, or that experimenters may have been prepared to discover. Especially in ethology, it is difficult to avoid the unprofitable extremes of blinding skepticism and crippling romanticism (p. 692).

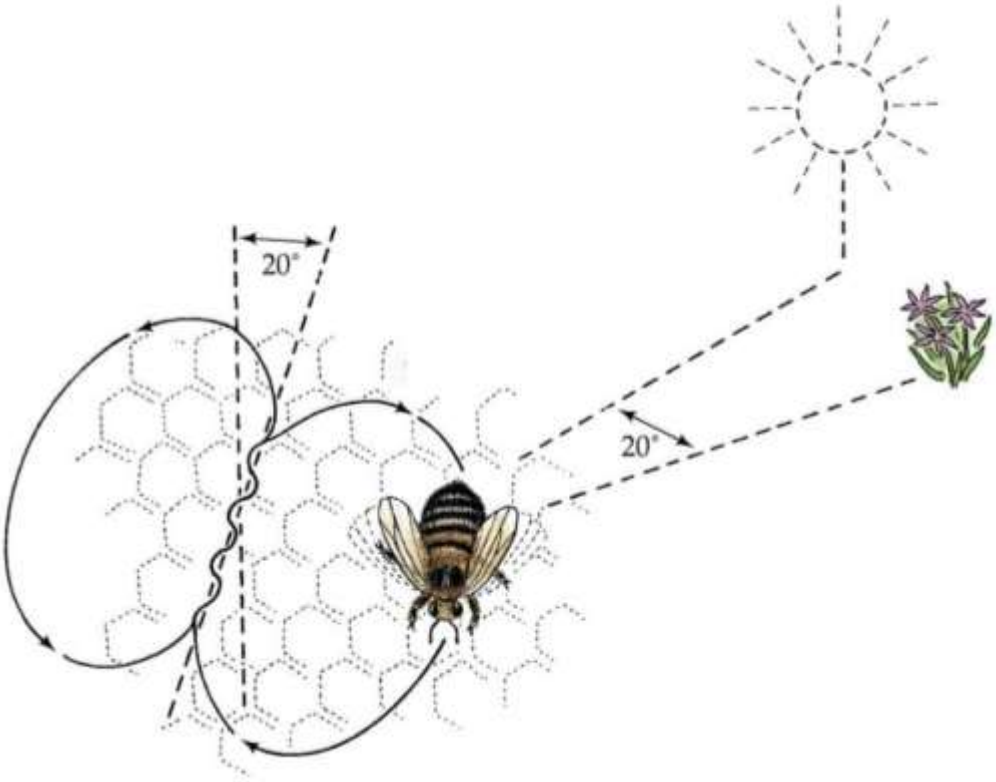


Figure 2. The honey bee waggle dance (Alcock, 2013).

Honey bee dances are overwhelmingly used to communicate about flower patches (Crist, 2004). When a honey bee becomes aware of a rich flower patch that would serve as a prosperous food source, the bee will return to the hive where she assumes a location near the entrance, called the dance floor, and performs the dance. The orientation of the dance in relation to the perpendicular of the comb creates an angle with the vertical of gravity. This angle is equal to the angle the bee has flown, with respect to the sun, from the hive to the food source, and charts the

direction that observing bees can follow (Crist, 2004; Riley et al., 2005). Further, the dance speed indicates food source distance (where speed has an inverse relationship), and 'enthusiasm' indicates desirability, where energy is positively correlated (Lindauer, 1971). It is thus apparent that bees, as opposed to birds, are arbitrarily communicating meaning with their dances. In fact, Gould estimates that the honey bee waggle dance can produce at least 40 million unique messages, which is more than ten-fold the amount of any other animal save for man, but the purpose of this thesis is not to argue whether the honey bee waggle dance classifies as language but to instead highlight on its relevance to the discussion of human language structure and emergence from non-human animal communication systems (1975).

Eileen Crist, a professor of Science, Technology, and Society, presents a compelling argument for how the honey bee dance 'language' represents many of the characteristics of human language, asserting that the waggle dance is: rule-governed, complex, stable and dynamic, symbolic, and performative (2004). For honey bees can group two or three elements together (e.g., orientation, speed, and enthusiasm) without syntax to arrive at an amalgamated meaning (Riley et al., 2005). Yet, while these characteristics are known and admired, the honey bee waggle dance, unlike birdsong, is argued to be genetically fixed rather than learned and, unlike human language, lacks semanticity in the way that dances are without syntactic constraints of lexical items that determine and influence meaning (Anderson, 2004). The bee dance 'language,' then, with its structure absent of phonology, is argued to still lack the complexity that human language has (Chomsky & Berwick, 2016; Hale & Keyser, 1993).

The case of the honey bee dance 'language,' however, brings about an interesting question concerning the emergence of human language: how did it happen? In the next section, I will provide an introduction for human language evolution and modern syntactic theory.

2.3 Human Language Uniqueness

While the question "what is language?" has had many different answers to account for the complexity in which humans communicate, there have been few theories widely adopted by linguists. Noam Chomsky, commonly regarded as the father of modern linguistic thought, suggests that the faculty of human language is a biological phenomenon specific to human beings (Chomsky, 2015). Namely, he suggests that human language exists in the brain and possesses a Basic Property, or a generative procedure that results in an infinite set of hierarchically structured expressions with unique semantic interpretations. In his book *Why only us?*, where he explains the exclusivity of human language, Chomsky and Berwick (2016) propose three key properties of human language syntactic structure, outlined below:

- Human language syntax is hierarchical and is blind to considerations of linear order, which is a peripheral part of language reserved for externalization.
- The hierarchical structures associated with sentences affect their interpretation.
- No upper bound exists on the depth of hierarchal structure, which implies that human expression is potentially infinite.

These points align with previous discussions of language and the Principle of Compositionality in Chapter 1, but it is now important to distinguish language from speech. As proposed by Chomsky, language exists in the brain, and speech is simply the byproduct of such cognitive activities. In fact, Chomsky argues that language is used for thought instead of communication (Chomsky, 2015). He asserts that humans possess what he calls I-language, or internal language separate from what we externalize as E-language, further arguing that "externalization is rarely used [and] [m]ost use of language use [sic] by far is never externalized" (Chomsky, 2015, p. 14). Under this belief that communication and vocalizations do not imply

existence of I-language, Chomskyan ideologists would be hesitant to classify any non-human animal that performs vocalizations as possessing language. However, primates have shown an extensive capacity for communication. For instance:

- Vervet monkeys use distinct predator-specific alarm calls (e.g., one for leopards, one for pythons, etc.) that elicit predator-specific responses from perceiving monkeys (Seyfarth et al., 1980).
- Campbell's monkeys combine their alarm calls with a preceding boom-call to symbolize less dangerous situations, such as a falling tree instead of an approaching predator (Zuberbühler, 2002).
- Bonobos, during feeding, will combine acoustically distinct food-associated calls into larger sequences to communicate food quality, where barks and peeps are reserved for highly preferred food, and peep-yelp and yelps are used to designate food of lower preference (Clay & Zuberbühler, 2009).

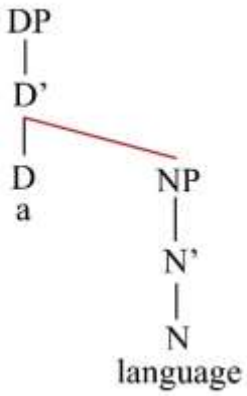
Yet, despite impressive displays of vocalization and communication, Chomsky denies monkeys and apes status of having language (Chomsky, 2015; Dunbar, 1998; Tomasello, 2008). He asserts that while non-human primates may be well adapted to process hierarchical vocalizations and even human speech, they fail in the realm of language acquisition (Chomsky, 2015). Further, research has suggested that monkeys can create language sequences consisting of two units, but that they "cannot be the result of a combinatorial operation [as seen] in human language, where the recursive operation of Merge allows for a potentially infinite array of structures" (Miyagawa & Clarke, 2019).

Chompskyan linguists have relied on the idea of Merge to explain the structural formation of language. Merge, as the name suggests, is set formation that allows for a given

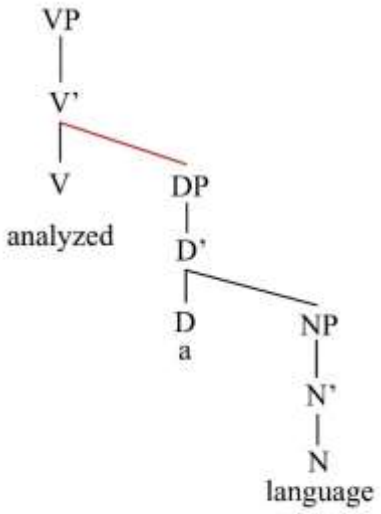
syntactic object X (which can be either an atomic element of language or a product of Merge) to *merge* with another syntactic object Y. Merge then forms a new, hierarchically structured product or set {X, Y} that has the recursive ability to apply to its own output without limit. To demonstrate Merge and how it relates to The Principle of Compositionality, consider the verb phrase and following computation below, which will reinforce understanding of the preceding syntax trees and the more complex trees to come later in Chapter 4:

6) analyzed a language.

    a. MERGE (a, language) = {a, language}



b. MERGE (analyzed, {a, language}) = {analyzed, {a, language}}



In (6a), *a* must combine with *language* (represented by the red branch) to show that *language* is the word it was modifying. Further, (6b) shows how, in order to understand the meaning of an uttered sentence, the verb *analyzed* has to combine with the set {a, language} semantically. While the purpose of this thesis is not to delve deeply into the intricacies of Merge, it is important to grasp an understanding for how linguists currently model and assess the phenomenon of human language.

According to Chomsky, the Basic Property of human language, its application through Merge, and the hierarchical structures produced from it are the distinguishing factors of human language that separate it from all other forms of non-human communication systems (2015). The question, however, remains as to how or why humans developed the capacity for language. This is an important question to mention within this thesis, as animal communication is often regarded as a precursor for the complexity of human language.

Notably, the complex capacity of human language seems to be a recent evolutionary phenomenon. Believed to have suddenly arisen within the last 100,000 years, the faculty of language has not undergone any significant evolutionary changes since our early human

ancestors parted from Africa around 50,000-80,000 years ago (Tattersall, 2009). Evolutionary biolinguistics, as a result, has become a popular topic of study as it attempts to explain the evolutionary aspect of language and how humans developed such a unique, species-specific capability. With interest in the emergence of the hierarchical structure of human language, linguists have turned to non-human animal communication systems in search for an evolutionary explanation for how human language came to utilize hierarchical structures.

While it is widely agreed among the linguistic community that Merge evolved exclusively in human lineage, little discussion has been had about *why* and *how*. While Chomsky and Berwick (2016) admit that "we don't understand the genomic or neural basis for the Basic Property" (p. 50), it is speculated that the emergence of Merge and the capacity for syntactic computation came after a *single* [macro-]mutation that led to small genomic change in a growth factor for a neuronal circuit fiber (Chomsky & Berwick, 2016; Ramus & Fisher, 2009). Yet, it is criticized that such a mutation would be sufficient for justifying the extent to which humans can generate grammar (de Boer et al., 2020).

2.3.1 Evolution of Human Syntax and Communication in the Animal Kingdom

In consideration of evolution, diverging from the uncertainty revolving around genetics, some propose that human language emerged from an amalgamation of two pre-existing simpler systems – the expressive system (Type E) and the lexical system (Type L) (Fujita & Fujita, 2021; Miyagawa et al., 2013). Respectively, a system comprising categories (e.g., tense, the state of being a question, etc.) and a system comprising component parts containing meaning (e.g., words). To recontextualize the discussion of birdsong, where songs are used to mark territory, attract a mate, or perform other "expressive" actions without syntactic structure, birdsong can represent a sort of Type E structure (Berwick et al., 2011). Type L structures, on the other hand,

are found in communication systems like honey bees, where predicates are demarcated with one or more “arguments” (like speed and direction) as they are in the honey bee waggle dance (Riley et al., 2005). Type E and L structures, when considered separately, are meaningful (L) and complex (E), but — in contrast to human language — they are not capable of producing recursively infinite structures (Berwick et al., 2011).

In terms of human language, Type E structures represent a limited amount of functional elements that lack independent status (e.g., -ed or question markers). In contrast, Type L structures represent elements that occur independently (e.g., words) without immediate functional connections to one another (Hale & Keyser, 1993). When computed from these two systems, human language suggests a *duality of semantics* (Miyagawa et al., 2013). Consider the following:

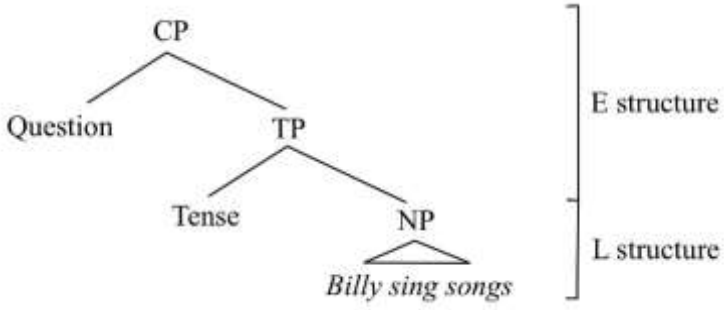
7) Type L: *Billy*, sing, *songs*

Type E: *did*

Did Billy sing songs

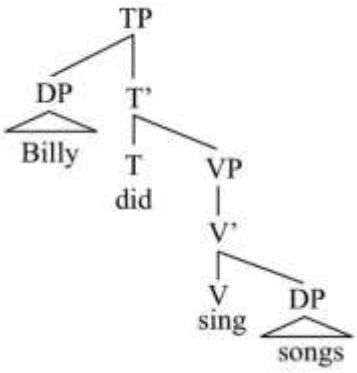
Billy **did** sing songs

In (7), *did* can serve two functions, as question formation or tense establishment, both characterized as expressive components of language (Miyagawa et al., 2013). Tree (H) demonstrates the duality of semantics mentioned above (Miyagawa et al., 2013).

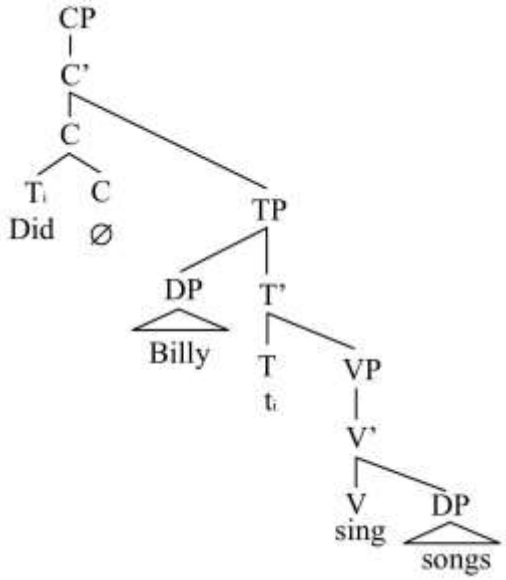


Tree H. The possible positions of *did* in syntax to show duality in semantics.

Further, trees (I) and (J) show the different semantic computations depending on the placement of *did*:



Tree I. Tense position (T head) of *did* for *Billy **did** sing songs.*

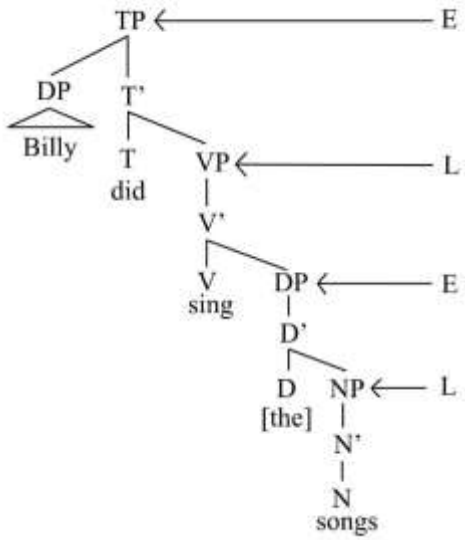


Tree J. Question position (C head) of *did* for ***Did*** Billy sing songs?

To refocus: the discussion of E/L structures – and how they relate to both non-human and human communication – is important to this thesis because they help to:

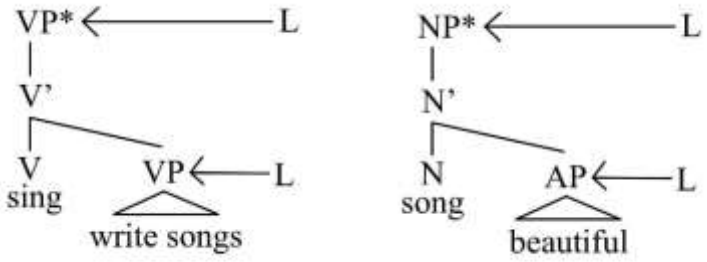
- Establish preliminary parallels between human and non-human communication that will continue to develop as this thesis progresses.
- Establish a possibility for how [syntactic] hierarchical structure and the Principle of Compositionality emerged.

Consider the figure below, based on the sentence *Billy did sing [the] songs*:



Tree K. E/L hierarchy for *Billy did sing [the]songs.*

It is hard to assign a definition to words like *did* (tense-marker) and *the* (determiner) in the same way as words like *sing* and *songs*, implying that they are members of the expression structure (Miyagawa et al., 2013). This phenomenon suggests that E/L hierarchies, like tree (K), make up human language by combining Type E and Type L structures. The ungrammaticality of combining purely lexical elements into L hierarchies, like trees (L) and (M), further supports the presence of E/L hierarchies in human language:



Trees L & M. Ungrammatical L hierarchies absent of expression structures.

Trees (L) and (M) show how the absence of E structure items (*and* and *is*, respectively) makes them ungrammatical. Thus, Miyagawa (et al., 2013) argues that hierarchical structures in the context of human language evolved from the stand-alone structures that exist in non-human animal communication systems, such as those discussed previously. The E/L theory of evolutionary linguistics attempts to explain how human language is different from the rest – how the Principle of Compositionality emerged. The question, however, still stands: do non-human communication systems contain structural organizations that could reveal new ways of better understanding human language? Perhaps answers lie underneath the water.

Chapter 3

The Anomaly of Whale Song

Now that the previous sections have established awareness of the big questions surrounding human language evolution, structure, and non-human animal communication, the discussion of whale song becomes especially relevant. Because – while the bee waggle dance, songbird songs, and non-human primates have been the focus of an extensive amount of literature, dating back to the 1940s and 50s – there are still many questions surrounding the function and structure of humpback whale (*Megaptera novaeangliae*) song, which has only recently been analyzed from a syntactic standpoint. According to research over the last 50 years, it has been concluded that humpback whale song is produced exclusively by males, but females and juveniles still produce sounds (Janik, 2009; Videsen et al., 2017). However, the songs have shown to have both inter- and intrasexual implications. Humpback whales are among the few mammals that sing, but the role of sexual selection via song in whales is not well understood (Cholewiak et al., 2018). While it is not uncommon to assume that humpback whale song is exclusively meant for attracting females for reproductive purposes, it has been found that whale song mediates male-male interactions, manifested by the formation of two-singer dyads, presentation alteration, song evenness, the rate by which phrase type changes (Cholewiak et al.,

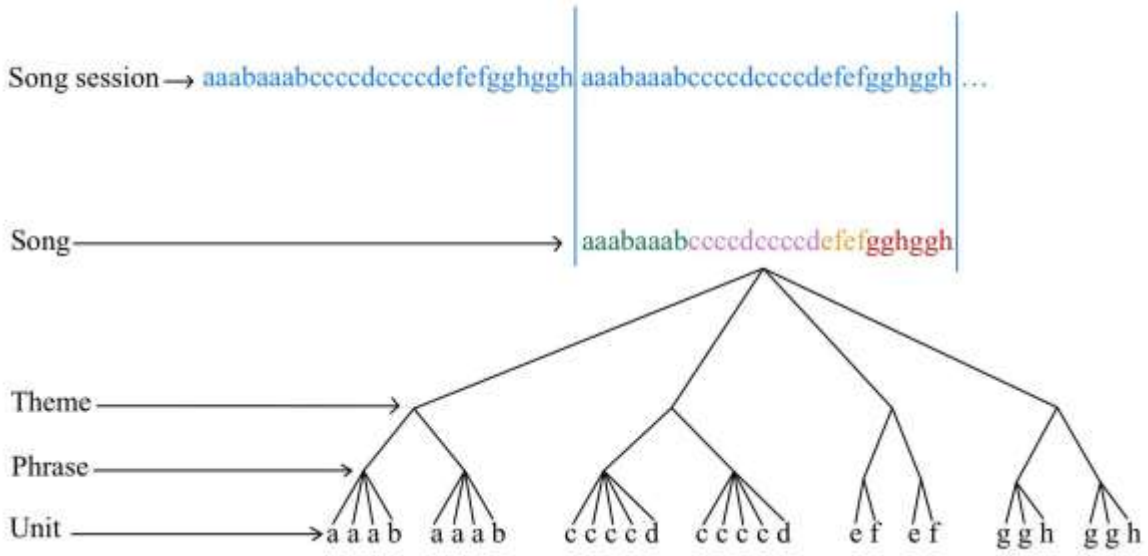
2018; Darling & Bérubé, 2006). These intersexual interactions call to attention the possibility of communication outside of the realm of reproduction. The big question, then, is what could whale song mean? Could their songs in fact be more than simple learned phonological syntax (like bird song), or innate genetic wiring (like bee dances), existing outside of the assumptions around mate attraction?

To reiterate, the world may never know, and the purpose of this thesis is not to argue that whales have language (or don't). Rather, the following sections will further introduce the mystery of whale song by analyzing previous literature. In doing so, I will be equipped to offer new ways of approaching human language syntactic analysis.

3.1 Structure of Whale Song

Roughly 50 years ago, Payne and McVay (1971) first described the acoustic performances of whales as "songs," aligned with the definition presented by Broughton (1963): "a series of notes, generally of more than one type, uttered in succession and so related as to form a recognizable sequence or pattern in time" (p. 54). This definition resonates with the previous acknowledgment of birdsong. Yet, Payne and McVay (1971) admits that the function of whale song is unknown, and I would argue that not much more has been determined regarding function. However, the *structure* of whale song is familiar. Whales, because they repeat songs without any notable pause in between them, have been observed to sing for 20+ hours at a time, with some singing for as long as 70 hours (Payne & McVay, 1971). These song sessions, however, have recently been analyzed for underlying syntax, attempting to expand the possibility for mammalian language outside of human language.

A research group based in Australia, led by Dr. Jenny Allen, argues that little is known about rules governing non-human mammalian vocalizations and that humpback whale song can provide a model for a better understanding of such phenomena (Allen et al., 2019). Further, Allen (et al., 2019) argues that whales produce songs in a stereotyped, nested multi-level hierarchy where *units* (or individual sounds) are arranged in a stereotyped pattern to comprise a *phrase* (a collection of units), where phrases then repeat to make a *theme*, and a string of four to seven themes make up a *song* (Catchpole & Slater, 2008; Payne & McVay, 1971). Yet, this argument is not entirely foreign. Comparing the below figure to the information presented in section 2.2.1, humpback whale songs share a phonological structure resemblant of birdsong:



Tree N. ‘Hierarchical’ structure of whale song.

In tree (N), I adapt the methodology commonly found in the literature by representing *units* as letters and construct a hierarchical depiction of the proposed structure of whale song. Like Allen (et al., 2019) and many others propose, the ‘nesting’ of units into phrases, phrases into themes, themes into songs, and songs into sessions has caused for many researchers to

compare this organization to human syntax, crafting parallels between how words fit into phrases and phrases fit into sentences (Cholewiak et al., 2013; Payne & McVay, 1971). Allen (et al., 2019) argues that due to the nature of whale song construction – which is similar to human language syntactic modeling – whale songs can be regarded as hierarchical in structure.

3.2 Culture of Whale Song

As discussed with birdsong, phonological organization is not a sufficient condition for classifying a communication system with having hierarchical structure or syntax in the same way that human language does. However, it is noted that whales – unlike birds – do not use a fixed repertoire of sounds (Cholewiak et al., 2013; Mercado & Handel, 2012). In a whale pod, all male whales will typically adopt one song pattern, but it is not uncommon for the song to vary in structure over a same-year period. These variations are argued to be adopted through horizontal social learning, supported by observing whales within the West and South Pacific, where over the span of 11 years, multiple song types were transmitted eastwardly (Garland et al., 2011). Song types were grouped together into song lineages, where songs were shown to evolve through changes at the unit level or with the addition or deletion of themes (Garland et al., 2011). The question of *why* then becomes relevant, as this suggests that song production is in fact a conscious phenomenon that occurs outside of simple reflex. Namely, I suggest that whale song communication exists with a complexity outside of what is observed in birds or bees. Whales actively engage with song variations – they don't simply listen to the overarching song patterns but instead recognize and pay attention to individual unit shifts enough to adopt the shifts themselves.

Allen (et al., 2019) further explains that recent investigations have analyzed the connectivity of structural features among whale populations. Namely, if a sequence AB occurs

frequently, then it suggests that A and B are highly connected and that A transitions to B. For more complex sequences, like ABCDEF, A and C are better connected than A and F. Network modeling of such connections proposes an underlying syntax or organization of whale song, presenting small-world networks of connected elements and transitional motifs that are either deterministic or non-deterministic. Deterministic motifs occur when a particular sound type is followed by a restricted variety of other sound types (a sort of predictability), while non-deterministic motifs consist of sound types that a large range of sounds can follow. Research showed that whale song – while utilizing a large amount of redundancy – was mainly composed of deterministic motifs, indicating a level of stability and order important for efficient communication (Allen et al., 2019). Figure (3) demonstrates a small-world network for the song sequences within an Australian whale population in 2002 (Allen et al., 2019):

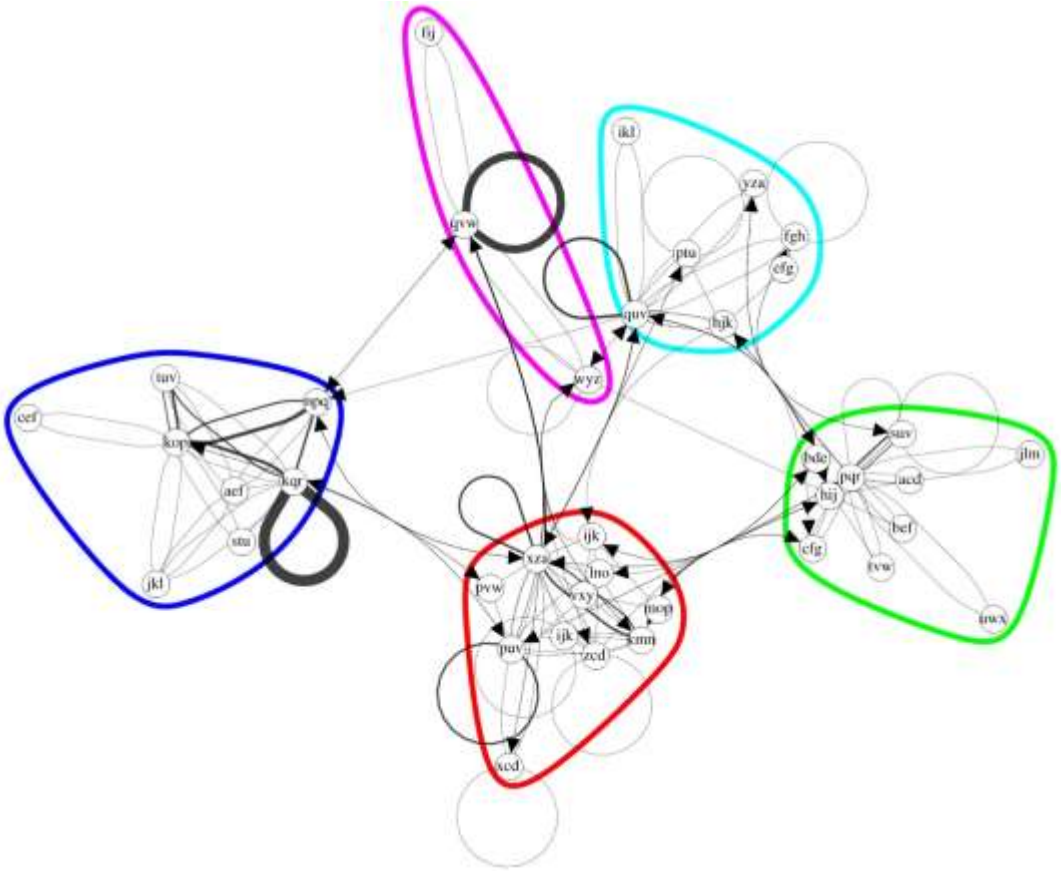


Figure 3. Small-world network of singing whale population.

In figure (3), vertices represent units, and the connections between vertices represent the transitions between units. The arrows represent the direction of transition between units, and the thickness of the line represents the frequency of transition. The colored rings represent network communities, or the clustering between a particular group of units. Notice how units within network communities have more transitions between them than those outside of network communities. The loops in the figure show the presence of repeating patterns across song types (Allen et al., 2019).

Small-world structures are also found in human language, seeming to stem from a need for language to have optimal navigation, in which word arrangement can efficiently express an intended message while using the smallest number of steps (Capitán et al., 2012). Furthermore, small-world structure in whale song likely increases learning efficiency, which may explain why song variation adoption is such a rapid process, allowing songs to spread through an entire whale population or geographical region in under a single year (Garland et al., 2011; Garland & McGregor, 2020). Again, this suggests that song acquisition among whales is a cognitive, creative process that creates and adopts variation through cultural transmission, meaning that whales may possess a potentially productive communication system that is more sophisticated than other communication systems (Janik & Slater, 2000).

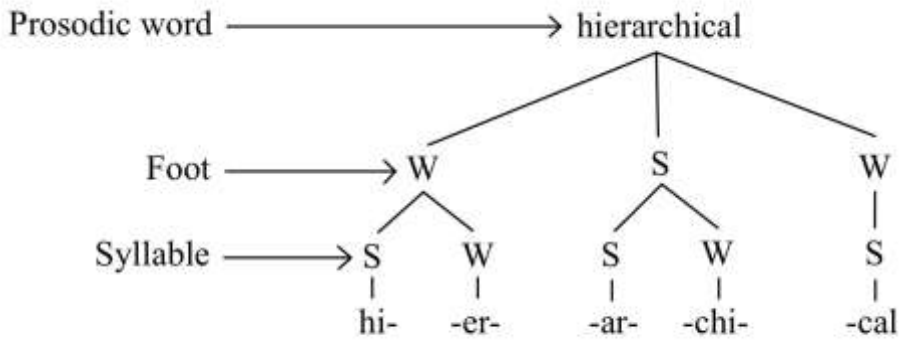
3.3 An Argument from the Unconvinced

While whale song has previously been described by several in the field in terms of a tree-like hierarchy, it is argued that whale song hierarchy is not in fact hierarchical in the same way that human language is (Allen et al., 2019; Mercado & Handel, 2012; Payne & McVay, 1971). According to linguistic theory, the hierarchal representation of language structure is meant to demonstrate the cognitive capacity for language processing — in other words, to model how the

mind works to combine elements of language together to compute the composite semantics of an utterance (Chomsky, 2015). Mercado and Handel (2012) argue, however, that whale song does not meet this condition, stating:

> Whale researchers describe humpback whale songs as hierarchical because the regular patterns within songs are generally consistent with the hierarchical framework proposed by Payne and McVay. However, the fact that hierarchical descriptors can be useful for analyzing variations in humpback whale songs provides no evidence that the sound sequences being analyzed are hierarchical in either production or perception. Watches provide a simple way of hierarchically classifying time, but this does not provide evidence that time itself is hierarchically structured.

To Mercado and Handel's point that hierarchical syntax is meant as a tool for understanding production or perception, I argue that it is necessary to be aware of a 'speaker's' cognition before a sort of hierarchical organization can be extrapolated from their communication system. Thus, because there is no evidence to support a knowledge of whale cognition, I do not believe it is possible to understand whale song to the same extent that we understand (through experience) the human process of thought and language. Further, Mercado and Perazio (2021) argue that even if whale songs were hierarchically structured in the ways proposed by others in the field, this wouldn't entail that whale song is compositionally meaningful. While whale song does — with the evidence that we *do* have — differ from human language in the sense that it is not *compositionally* organized, I propose that there are parallels to be made on how human language also contains non-compositional hierarchal organization. Consider tree (O).



Tree O. Prosodic structure of *hierarchical*.

As a prosodic structure – or a structure that models how an utterance is prosodically or phonologically organized – tree (O) demonstrates that a word's phonological production can be hierarchically structured (adapted from Heffner & Slevc, 2015, Fig. 1). Namely, that a *prosodic word* is pronounced by one or more weakly (W) or strongly (S) pronounced *feet* comprised of weakly or strongly pronounced *syllables*. As with the case above, the pronunciation of *hierarchical* can be modeled to show that, for example, *hi-* and *-er-* are nested within one of the three prosodic feet that make up the word. Yet, when contrasted with a syntax tree that *is* hierarchical *and* has compositionality, it is noted that an individual syllable such as *-chi-* does not hold meaning in the same way that a lexeme does. Further, words such as *Mississippi* cannot be broken down into roots and affixes, suggesting that a word, despite having prosodic complexity, can sometimes act as a singular morpheme. This is important because it shows that while a word may hierarchically contain entities such as syllables, the prosodic construction of a word does not entail compositionality nor recursion in the same way as human language syntax.

Thus, prosodic structures show how even human language can be modeled in ways similar to bird and whale song, but that the focus is on phonological organization as opposed to syntactic structure. In fact, Mercado and Handel (2012), knowing that evidence does not exist given current technologies but that it may come in the future, do not argue that whales cannot

produce compositionally hierarchical structures. Yet, seeming to dismiss debates surrounding hierarchical organization (for now), they do say that whale song productions can be organized and analyzed acoustically:

> More generally, evidence of higher order structure in sound sequences does not provide evidence of hierarchical organization. Consequently, the recent information theoretic analyses of songs by Suzuki and colleagues also provide no evidence that songs are hierarchical. In the case of birdsong, bioacousticians generally focus less on theoretical definitions and instead use behavioral, physiological, or acoustic data to support claims that birdsong is hierarchical. None of these approaches can be applied to singing whales, leaving acoustic analyses as the only viable approach to clarifying how whale songs are structured (Glaze & Troyer, 2006; Mercado & Handel, 2012).

With the focus shifting away from hierarchical organization and more towards acoustics, I close this section with this: linguistic theory may not support the notion that whales are conveying syntax in the same way as humans, but it does support the existence of non-syntactic hierarchies in human language. Therefore, there is the possibility of interesting parallels to explore between the realms of whale song and human language. Because Mercado and Handel (2012) suggest acoustic analysis to be the most viable option, the next section establishes a foundation for such exploration by first providing an acoustic perspective for whale song.

3.4 A Debate for Song Analysis

While there is controversy surrounding the hierarchical structuring of whale song, it is unanimously agreed that, as opposed to most birdsong, humpback whales do not use a fixed repertoire of sounds, phrases, themes, or songs to construct their song sessions (Mercado & Perazio, 2021). Instead, the song constructions are more fluid and vary over the span of a year.

This differentiation opens the possibility for more complex mechanisms of communication. However, as Mercado and Handel (2012) specified, humpback whale song differs from birdsong and human language in that it is subjectively characterized, making it harder to analyze. For example, whale songs have no clear beginning, as stated before, and there are not predictably longer duration pauses between phrases, themes, or songs that may serve as objective determiners of initiator or terminator units (Mercado & Perazio, 2021). Thus, the human analyzer must arbitrarily pick a starting point at the 'first' theme of the song sequence. This arbitrariness – paired with the hierarchical approach of asserting uniformity within thematic variation, prevalence, and order – diverts from a focus on possibly significant aspects of the acoustic character of whale song. Among these features is the consistency in pattern timing despite constituent composition and the consistency of spectral shifts despite the considerable differences in the structure of individual units (Mercado & Handel, 2012). Figure (4) shows a spectrogram that demonstrates such properties, where spectral energy peaks near two frequencies, 90 and 180 Hz, alternate throughout the recording, and their stereotypy between spectral shift timing reveals a gradual modulation across song cycle (adapted from Mercado and Handel, 2012, Fig. 1).

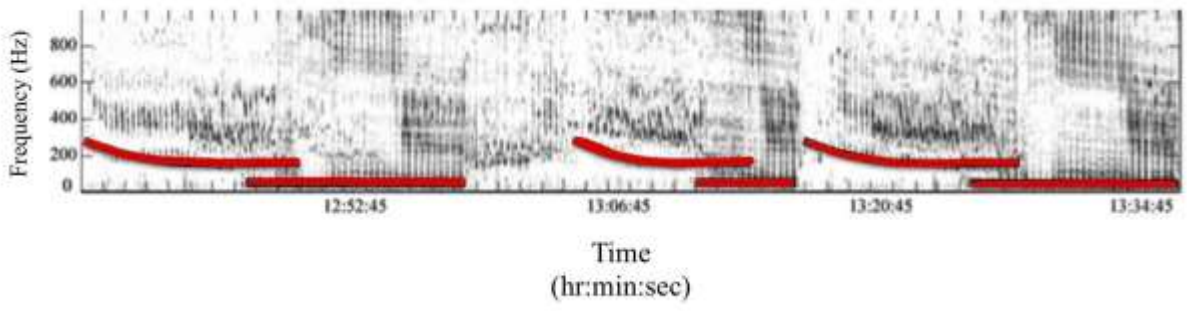


Figure 4. Spectrogram of whale song highlighting acoustic properties.

These acoustic modulations may occur independently of the types of units being produced. Further, it is pointed out in the research that symbolic modeling of whale song omits important acoustic regularities that may be important for understanding how Humpback whales process, produce, and modify song structures (Allen et al., 2019; Green et al., 2011; Mercado and Handel, 2012; Mercado and Perazio, 2021).

3.4.1 Hierarchy or Heterarchy?

Suppose the phenomenon of whale song is best approached acoustically. In that case, the mystery resides in whether whale song structure and variation are due to physiological and environmental constraints or syntactic ones. Mercado and Handel (2012) argue that song variation is due to two things – the dive cycle and internal recirculation of air – rather than conscious syntactic computation. Namely, the position of the whale in the ocean – and thus the pressures it is subject to – and the state of its air circulation are primarily responsible for song structure, which will be explored in section 3.4.2. However, it is admitted that the proposed hierarchical structure of whale song has never been empirically tested and that it is unsure how it would be. I have argued throughout this thesis in alignment with this conclusion, as it is hard to imagine a way in which such evidence could be attained. Instead, Mercado and Handel (2012) propose that whale song is *heterarchically* structured in the sense that two (or more) physiological cycles are interacting to generate the structured acoustic qualities of song patterns, instead of them being organized into discrete categories of nested levels that progress in a fixed order (Bruni & Giorgi, 2015). With focus on the argument that structure comes from a combinatorial interaction of acoustics, not much emphasis is given to the possibility of hierarchical structure.

While the rest of the discussion regarding whale song will adopt the heterarchical theory proposed by Mercado and Handel (2021), I would like to note that this argument does not mean that hierarchical structure within whale songs doesn't exist, but that its simply undeterminable given our current technologies and capabilities. It is also possible that perhaps whale song is simply conducted and perceived in ways unconsidered by humans. Perhaps whales are using depth to modulate songs rather than modulation due to depth being a mindless consequence; perhaps the use of air recirculation is also a conscious tactic of modulation. Building off the proposals offered by Mercado and Handel (2012), I take particular interest in the idea of air recirculation and will explore this phenomenon and its possible implications.

3.4.2 The Physiology of Whale Song Production

To build off of a statement made in the beginning of this chapter, it is worth noting while adult male whales are the only ones recorded to sing, females and juveniles produce sounds that are more social – such as mother-calf calls or feeding calls – but involve the same anatomy used in whale songs (Damien et al., 2019; Videsen et al., 2017). Yet, while 'speech' physiology remains constant despite sexually dimorphic behavior, it is important to establish a physiological differentiation between whale and human respiratory systems and resultant sound production.

In human speech, sound waves are generated in air by vocal cord vibrations, which are impossible to form underwater, where humpback whales spend their time (Zhang, 2016). Or, perhaps these waves exist, but in a form that is impossible for the human ear to perceive in water. On the other hand, whales are the only mammalian species to have ears fully adapted for underwater hearing that allow for deep diving and long submission; among these adaptations include broad-bore Eustachian tubes, no air-filled external canals, and no pinnae (Ketten, 2012).

During human speech production, air escapes from the lungs most of the time. However,

contrary to what one may assume, air doesn't escape from the whale's body during sound production (Mercado & Perazio, 2021). Instead, whales have developed unique anatomy in which U-shaped vocal cords can transfer sound energy to water and permit air recirculation during song sessions (Damien et al., 2019). The vibrations yielded from air passing from the lungs through the vocal cords cause vibrations within the tissues of the laryngeal sac; these vibrations transfer through the overlying blubber and skin and eventually into the water, experiencing minimal transmission loss due to the density similarity of tissue and water (Damien et al., 2019). The air residing in the laryngeal sac then recirculates back into the lungs, and different sounds are produced depending on the path of direction. More specifically, the transfer of air from lung to laryngeal sac yields *egressive* sounds, while air that reverberates back into the lungs from the laryngeal sac produces *ingressive* sounds. This production of both egressive and ingressive sound is referenced by what Mercado and Handel (2012) call "bidirectional sound production" and "internal recirculation of air." While humans can produce ingressive sounds (e.g., whistling via inhalation), egressive sounds mainly make up human language.

Furthermore, Humpback whales appear to be capable of confining air into various chambers of the respiratory system because of the multiple valve sites present along the respiratory tract. Given that the volume of least one of these chambers – the laryngeal sac – is controlled by voluntary muscle contraction, this gives reason to believe that whales are capable of controlling their buoyancy independently of, or in addition to, the effects of ambient air pressure exerted in that chamber (Damien et al., 2019). This conscious control could relate to the whales' use of depth as a measure of sound production. However, this possibility is wildly speculative and not extensively researched, especially in the specific context of song production. Most research concerning dive cycle centers around behavioral questions as opposed to those

related to the physiology of sound production – this provides another avenue of rich research yet to be explored. Still, because this thesis does not provide empirical data, my purpose will not be to argue the specifics related to the relationship of dive depth to phonological impact (Derville et al., 2020). Instead, I will be developing an argument pertaining specifically to the use of bidirectional sound production in whales.

3.4.3 Importance of Ingressive and Egressive Sounds in Whale Song

Figure (5) below, adapted from Mercado and Handel's research (2012, Fig. 2), shows the spectrogram of a singing humpback, where the ingressive (red) and egressive (blue) sound distributions are outlined.

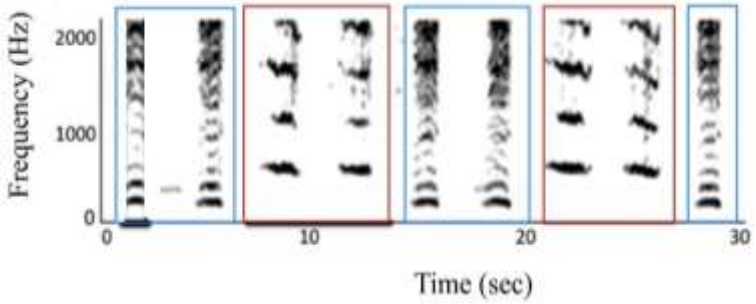


Figure 5. Spectrogram of humpback whale song, outlining egressive (blue) and ingressive (red) sounds.

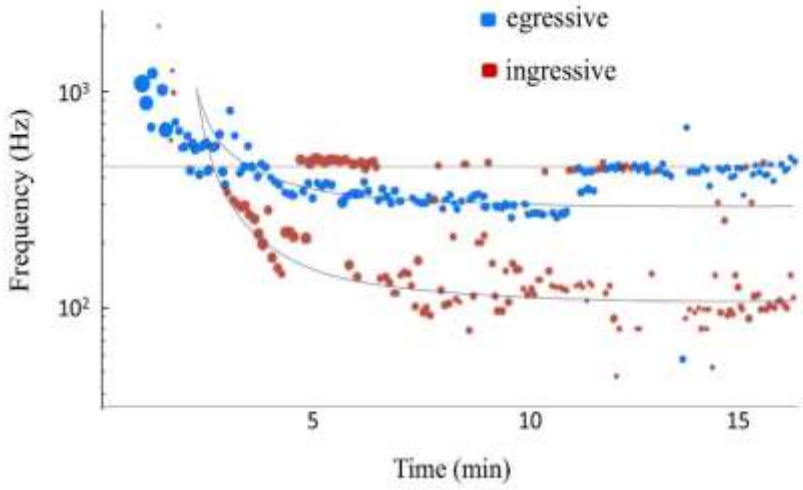


Figure 6. Frequency distribution of egressive and ingressive sound productions in whale song.

Figure (5), in contrast to song analysis under the traditional hierarchical approach where phrase descriptions rely on symbolically notated unit types, focuses on acoustic properties that demonstrate possible similarity despite a difference in number and type of units. Research shows that, regardless of song representation, timing is maintained, but differences can appear depending on analysis type, especially during ingressive sound productions that would not otherwise be noted. Further, there is evidence of regularity with timing and stable relative changes in frequency despite a difference in constituent units (Mercado & Handel, 2012). Though the acoustic properties of whale song have been determined as the essential aspects of whale song analysis, the pressing questions still preside: why does this matter? What could be so significant about bidirectional sound production or acoustic complexity within whale song?

Well, if whale song [has] demonstrated complexity extending past birdsong through song variation and the use of egressive *and* ingressive sounds, what could this mean for the study of other animal communication systems and human language? Could it provide insight into the origins of language in an evolutionary sense? Could a developed familiarity with non-primate mammalian communication provide a platform by which mysteries of human syntax can be analyzed from a different viewpoint, allowing for a better understanding of human language? These are important questions to consider, instead of adopting a view that whale song is unuseful to study linguistically. Because ingressive and egressive sounds are produced unpredictably in whale song sessions, it is possible that sound type could serve as a determiner of its function, similar to how different phonological categories in human language serve various functions in human speech (e.g., vowel classification).

Further, I propose the possibility that whales utilize two channels of communication, similar to humans, which will be further explored in the next section. One suggestion is that

ingressive and egressive sounds provide different information synthesized to yield a composite meaning for immediate whale communities. Alternatively, egressive and ingressive sounds may be utilized to communicate with different target communities – like those closer and those further away — since egressive and ingressive sounds occupy different frequencies, shown by figure (6) (adapted from Mercado & Perazio, 2021, Fig. 7).

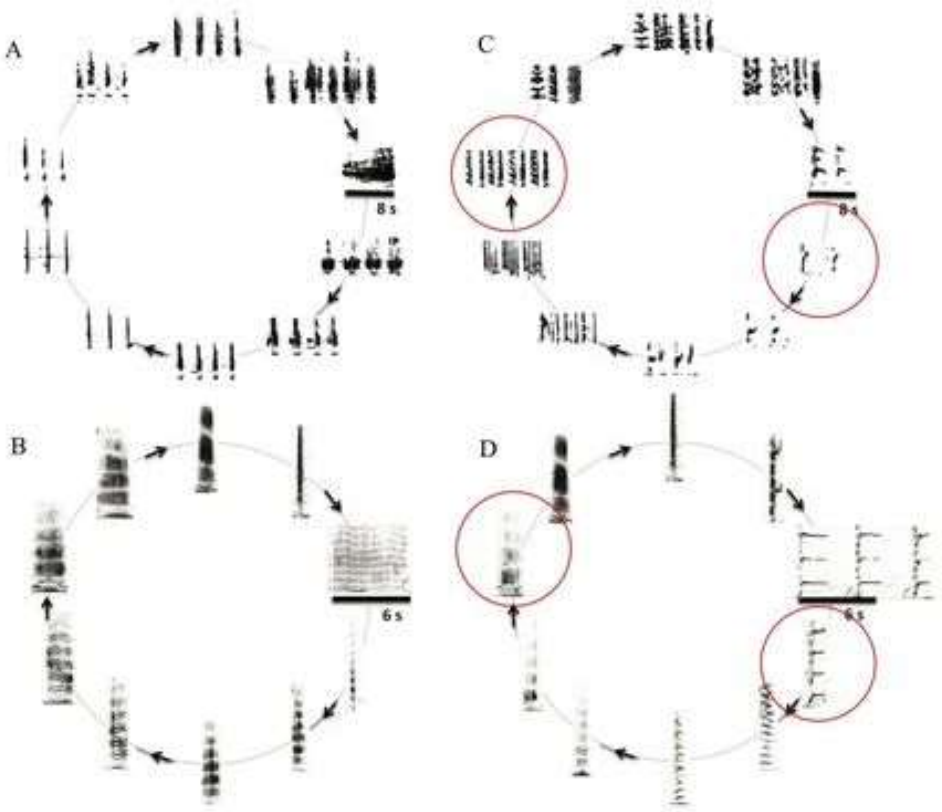


Figure 7. Heterarchical representation of whale song variation over time and space.

Further, figure (7) (from Mercado & Handel, 2012, Fig 6), demonstrates the variational patterns present in egressive and ingressive sound production among whales observed in Puerto Rico and Hawaii. The spectrograms are arranged in circles to represent the fact that the beginning phrases of songs (called *singerings*) are hard to determine, as stated at the beginning

of section 3.4. Panels A and B represent ingressive productions that are exclusively low-rate pulsed sounds that vary in duration, number, rate, and pitch. Panels C and D represent egressive productions that gradually changed in duration, number, pitch, frequency, and/or complexity. The figures show that unit and unit sequence changes were more extensive and directional for egressive sounds (note the contrast between the circled portion in panels C and D), consisting of higher-pitched productions, tonal sounds that lower in pitch, and the emergence of more complex broadband sounds. Such data reinforces the question of whether ingressive and egressive sounds, which appear to have differing characteristics and tendencies, serve different purposes. In the next subsection, I will expand on whale song structure to consider if egressive and ingressive sound production could, in some way, act along two different channels of communication.

3.4.4 Two Channels of Communication

As stated before, the claims within this thesis are not based on empirical evidence, as it is hard to imagine evidence that could account for the large-scale nature of humpback whales or the reality that they live their lives submerged in the ocean out of captivity. As opposed to studies on birds and primates, where researchers can manipulate environments and conditions to answer specific questions, the behavioral implications that whales' songs could have on their behavior are not as apparent. If further technology, however, could measure whether certain behaviors follow certain linguistic features, the meaning of whale song could be better predicted. As it stands now, though, the meaning of whale song is a mystery. It is theorized that they are responsible for the reproductive nature of whales, but it is also argued that the evidence for this is not exhaustive and that whale song may be used for other purposes. For example, a recent paper by Mercado suggests that humpback whale song, instead of for attracting a mate, is used as a sort of tool for echoically detecting and tracking other humpbacks (Mercado, 2021). Instead of

presenting empirical evidence and postulating possibilities for whale song function, I present methods for modeling whale song composition.

Consider figure (8), which depicts the symbolic rendering of a whale song (B) heard in the West Indies in 1978 based on ingressive (C) and egressive (A) sounds (adapted from Mercado & Perazio, 2021, Fig. 2; Winn & Winn, 1978).

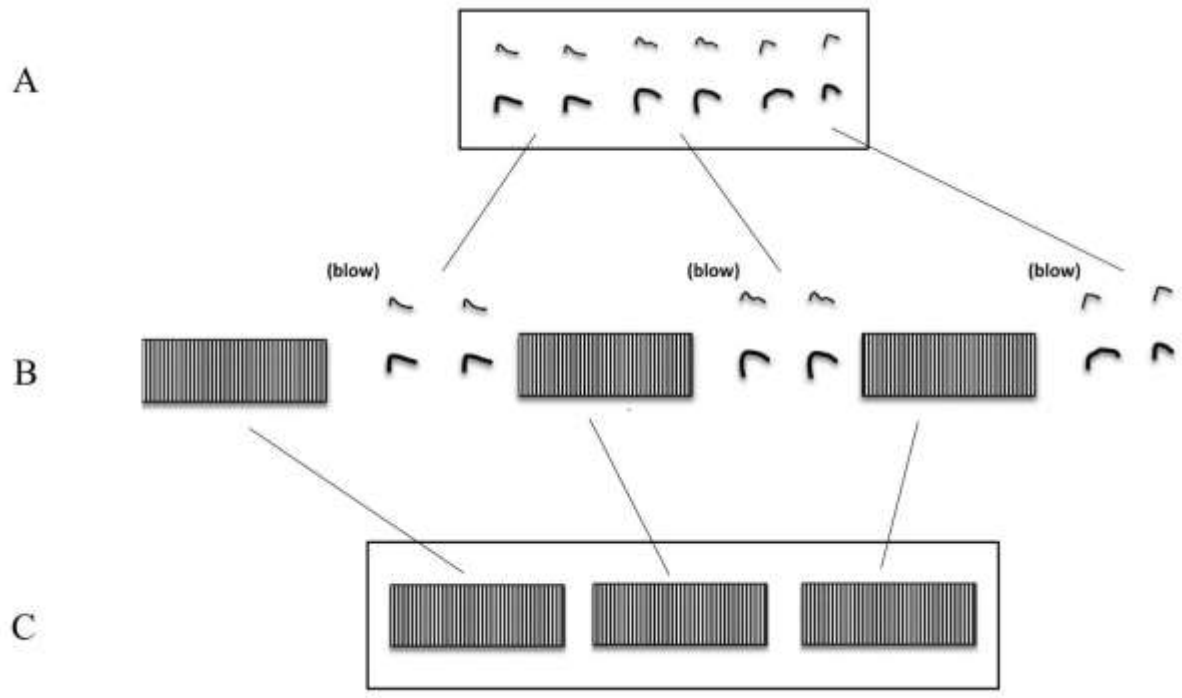


Figure 8. Symbolic representation of acoustic properties within whale song (B), composed of ingressive (C) and egressive (A) sounds.

As seen in figure (8), a whale song is composed of both egressive and ingressive sounds. Further, it has been shown that egressive and ingressive sounds change and modulate over time and through communities (Allen et al., 2019; Garland et al., 2011; Mercado & Perazio, 2021). While Mercado and Perazio (2021) argue that such variations are not a result of cultural transmission and are instead innate – supported by the findings of two populations, supposedly

never in contact with each other, that sang the same song 40 years apart with minimal variation – Allen (et al., 2019) and Garland (et al., 2011) argue that variations are due to interactions within a singing community. Despite their claims, Mercado and Perazio (2021) further assert that whales may be inserting units into predetermined "time slots" and that they likely reuse existing time slots for acoustically variable content. However, I argue that the reason for variation is not determined and that the argument of cultural transmission and socialization should not be discredited simply by seeming unrealistic. Perhaps whale song acts in such a different way from human language that we cannot appropriately comprehend how songs change and then return to having minimal variation in other locations. Yet, I argue that the same sort of phenomenon occurs in human speech. For example, consider common statements used in social settings, such as "How are you, what are you doing?" It is entirely plausible for this statement to be repeated word-for-word over time in different regions independent of direct social interactions between the two regions. Yet, does this mean that slang and other dialectical/lexical variations fail to perpetuate through human populations via cultural transmission? I suggest that both original constructions and emerged constructions could coexist. Similarly, whales could possibly share this same sort of communicative practice where some songs are fixed as commonalities while others are more freely varying and free to evolve via cultural transmission.

Again, there is no way to know at this point in time, but perhaps there is a 'catalog' of different possibilities to explore. Instead of jumping to the conclusion that whale song is obviously not a case of cultural/social transmission, I am not going to take for granted the complex structure that whale songs exhibit outside of what is seen in avian song. Based on the acoustic properties of ingressive and egressive sounds explored in section 3.4.3, as well as the mystery as to why whales utilize both in their songs, I propose that – in interest of the possibility

that whale songs are functional in some way outside of reproduction – whales may be using two channels of communication. In doing so, whales are providing and processing two separate inputs that can be interpreted together (or separately, if, say, the purpose of one is to communicate to proximal communities and the other is used to communicate to distant ones) to yield meaning. Using this possibility as a platform for analyzing whale song, I will begin to formulate an argument for how the same sort of two-channel communication may be used in human communication.

Chapter 4

Parallelisms of Song and Language Structure

Before I continue to make direct applications of the two-channel communication method in human language, I want to take a moment to bullet some of the main points that have been covered thus far:

- Human language evolved rather suddenly, and during this evolution developed the capacity for not only hierarchical syntax, but compositionality, which has not been shown [yet] to exist in non-human animals. Instead, phonological structure has been observed without meaning (e.g., in birdsong) and meaning has been observed without phonological structure (e.g., in bee dance); but human language has structure *and* meaning.
- Hierarchical organization doesn't imply compositionality or syntax, as seen with prosodic structures, bird song, and whale song, which all have certain structural parallels with one another.
- Whales, while sharing many acoustic characteristics with birds, do not have a fixed repertoire of sounds and instead are noticed to modify their songs over time across populations.

- Whale song is composed of a non-stereotyped combination of egressive and ingressive sounds, which have been used to frame the idea of two-channel communication.
- While humans too can make ingressive sounds, it is more-or-less preserved for specific pragmatic situations.
- As it stands now, there are no systems in place to account for paralinguistic and linguistic features in syntactic modeling.

Because whales are mammals and because their communication methods differ from other species studied in the animal kingdom, I argue that the parallels made between whale song and human language can be useful for a better understanding of how further research and thought can be developed regarding how human language is processed in the mind. According to contemporary syntactic theories, language is represented by one structure — one tree. What if, however, utterances can contain structures independent from one another, or only partially interacting?

In this section, after an introduction to non-animal communication, the emergence of human language, syntactic theory, and whale song, I will directly consider three scenarios for the complexity of whale song and its possibility for compositionality. In doing so, I will establish whether parallels can be found in human language and sound production, eventually addressing current gaps in syntactic theory that can be reconciled by using the theoretical mechanics of whale song. The three positions I will address are as follows.

Whale song is meaningless:

- In the first position, I will present a parallel for if whale song is not compositional, like birdsong, and is instead only phonologically structured.

Whale song is meaningful:

- In the second, I will present a parallel for if whale song is only compositional in the egressive channel, like human speech.
- In the third and arguably most exciting position, I will argue that whale song is compositional both egressively and ingressively, and that parallels can be made to human language and syntax.

4.1 Whale Song is Meaningless

As stated throughout this paper, and even by the linguists and biologists that I have cited, the function of whale song is widely unknown. There have been several hypotheses but given our current technology and the uncontrollable environments in which humpback whales live, it is hard to know whether an answer will ever be attained through empirical data and evidence. Instead, I hope this thesis establishes relevance for a similarity between whale song and human language despite the presence or absence of compositionality of whale communication.

Under this position, I side with the unoptimistic, more pragmatic speculation that whale song, like bird song, is phonologically structured but meaningless, a result of genetic predisposition and reflex, and non-compositional. However, I want to demonstrate that humans present this same phenomenon of practicing bidirectional sound production in a non-compositional manner. Recall the symbolic representation of whale song in figure (8) and then consider figure (9)(adapted from Mercado & Perazio, 2021, Fig. 2):

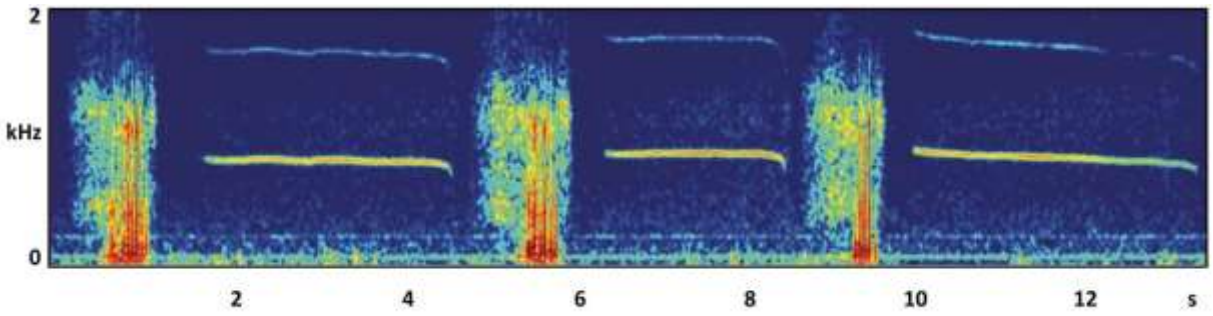


Figure 9. Spectrogram of bidirectional sound production in a snoring human.

While figure (9) shows acoustic similarity to whale song, it represents the bidirectional sound production of a snoring human that is switching between making pulsive and tonal sounds. When considering the act of snoring, it is not meaningful nor compositional, though it is rhythmic and recognizable. Despite there not being much to analyze, as the productions are meaningless, this parallelism is important because it shows that, if whale song is in fact meaningless, this same sort of bidirectional phenomenon still occurs in humans.

4.2 Whale Song is Meaningful

While the arguments to follow are based on the acoustic assessments of Mercado and Perazio (2021) and suggest that whales could be using two channels of communication for creative transmission of information, I want to note that Mercado (2021) argues against the creative processes of whales in favor of genetic predisposition and imitation. However, like Allen (et al., 2019), many researchers suggest that whale song is a phenomenon of cultural transmission and social interaction (Cerchio et al., 2001; Noad et al., 2000; Noad et al., 2004). My arguments, then, will attempt to combine the acoustic properties of whale song with the belief that they could be products of creativity and compositionality. In the following two subsections, I will assume the possibility of compositionality for first only the egressive channel

and then for both channels. I argue that both possibilities can give insight for a better understanding of human language.

4.2.1 Egressive Compositionality

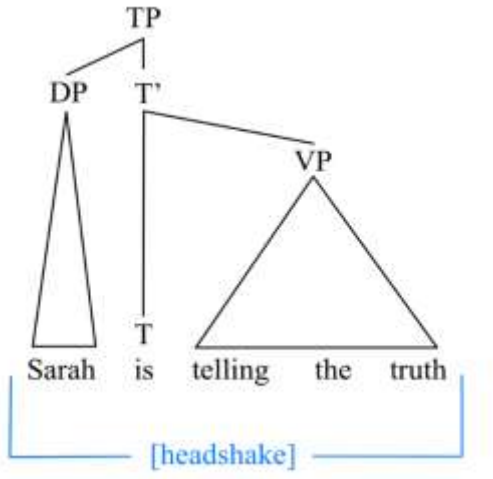
Under this first possibility of whale song being meaningful, I argue that if only the egressive channel of whale song is compositional and syntactic in the same way egressive sound can be in human speech, then this does not necessarily invalidate the importance of the ingressive channel. Imagine, for example, that while information is compositionally transmitted in the egressive channel, the sounds of the ingressive channel could mark characteristics of egressive channel contents, such as importance and context. Under this application, a connection can be made to paralinguistic communication in human language. Paralinguistic communication encapsulates many non-verbal techniques, including facial expressions, body language, tone, pitch, and even silence (Austin, 2016; DeVito, 2017; Poyatos, 1984). Naturally, it can be imagined how paralanguage has much to do with human language and communication. It gives insight into how while aspects of human communication are syntactic and compositional, non-lexical qualities are not (Mehrabian, 1972). This suggests that human language is so much more than the words used to construct it. Further, when interacting and interpreting language, humans utilize and interpret multiple channels of communication to extrapolate overall meaning.

In fact, in Chomsky Berwick's *Why only us?* (2015), it's stated that:

> Lewontin's remarks in *The Triple Helix* (2001) illustrate how difficult it can be to assign a unique function to an organ or trait, even in the case of what at first seems like a far simpler situation: bones do not have a single, unambiguous "function." While it is true that bones support the body, allowing us to stand up and walk, they are also a storehouse for calcium and bone marrow for producing new red blood cells, so they are, in a sense,

> part of the circulatory system. What is true for bones is also true for human language. Moreover, there has always been an alternative tradition, expressed by Burling (1993) and others, that humans may well possess a secondary communication system like those of other primates, namely nonverbal systems of gestures or even calls, but that this is not language, since, as Burling notes, 'our surviving primate communication system remains sharply distinct from language' (p. 63).

In these claims, it is acknowledged that communication is multifaceted and does not solely contain the words we speak, but also encompasses the gestures and intonations used to accompany them. And even with Burling's (1993) statement, I will show how application for two-channel communication resides in language, as well as in our "surviving primate communication system," such as gesture. Suppose the applications hold, and the assumption regarding whale song are correct. In that case, this could provide evidence for how our language and primal, non-human communication origins are more integrated than not. Consider the tree below:



Tree P. *Sarah is telling the truth*, with two-channel method used to account for non-verbal communication.

In tree (P), I present a two-channel representation of communication, presented by black and blue coloring. In this example, it can be seen how one channel is comprised of lexical items and is compositional; in contrast, the second channel in this example contains a paralinguistic headshake that is not lexical, syntactic, or compositional, but still affecting of meaning. Namely, if a situation were to arise where someone said “Sarah is telling the truth” while shaking their head, the perceiver would be tempted to interpret the exchange as a negation of what is said: Sarah is *NOT* telling the truth.

If only one channel of whale song is compositional while the other is not, I argue that the same phenomenon is demonstrated by these two channels depicted in tree (P) – one compositional, one not. Similarly, the same applies to instances of sarcasm and other cases of paralinguistic signaling that foundationally influence the meaning of what is actually being spoken.

Thus, I establish another possible parallel between whale song and human language with this representation, even if only one channel is compositional.

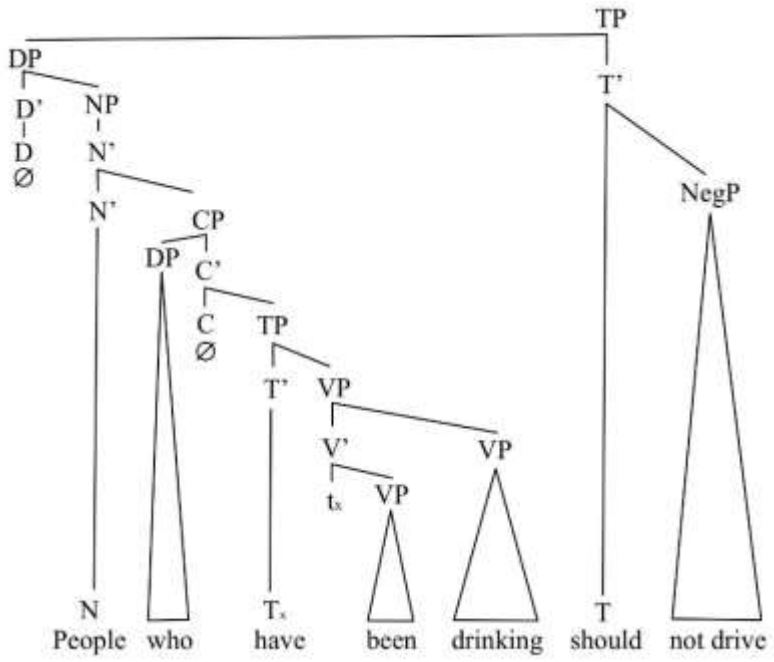
4.2.2 Egressive *and* Ingressive Compositionality

Lastly, an even more radical – but very intriguing – position considers the possibility of compositionality in *both* channels. Under this belief, I will establish below three cases in which a two-channel methodology of communication can provide explanations for other phenomena of human language. This section will address gaps in theory and offer syntactic reconfigurations to represent modifiers, parentheticals, and syntactic amalgams.

4.2.2.1 Modifiers

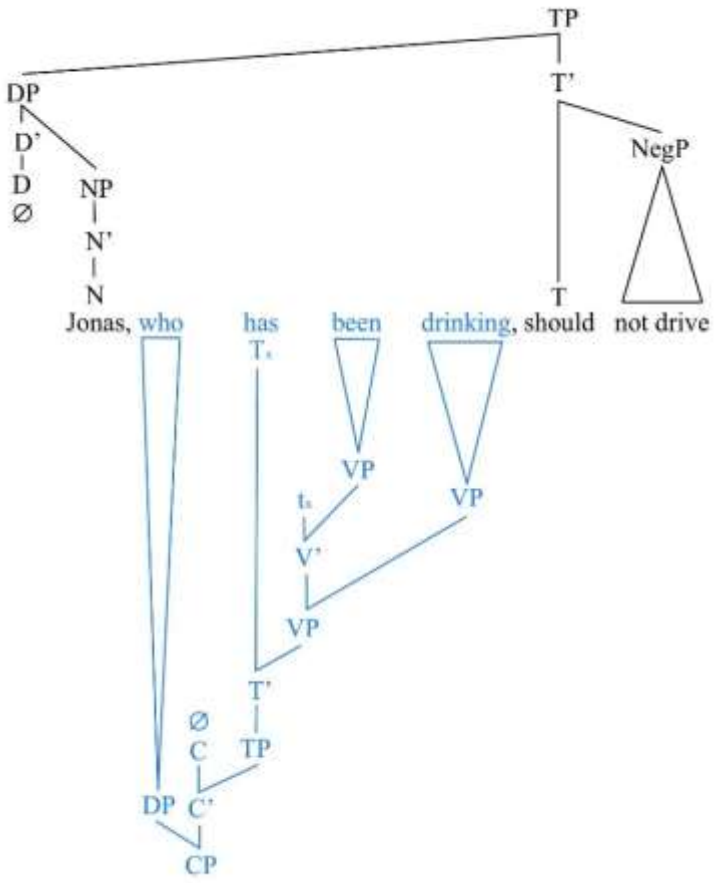
In human language grammar, modifiers are lexical words or phrases that restrict or add to the sense of head nouns or NPs. I argue, however, that restrictive and nonrestrictive modifiers have different syntactic qualities and use of a second channel. To introduce this perspective, I will analyze the points Heim and Kratzer (1998) addressed regarding these two classes of modifiers. Consider (8) and (9) below with their corresponding syntax trees (Q) and (R):

8) People who have been drinking should not drive.



Tree Q. People who have been drinking should not drive.

9) Jonas, who has been drinking, should not drive



Tree R. Jonas, who has been drinking, should not drive.

Example (8) represents a restrictive modifier, where if the modifier *who have been drinking* were to be removed to yield *people should not drive*, the semantic integrity of the sentence before and after removal is obviously not the same. Restrictive modifiers, then, restrict the N in which they are associated, "characterized by the fact that they leave the semantic type, including the adicity, of the modifier completely unchanged" (Heim & Kratzer, 1998, p. 64). Alternatively, example (9) represents a nonrestrictive modifier, where if the modifier *who has been drinking* were to be removed to yield *Jonas should not drive*, the semantic computation of the sentence before and after removal is preserved, only without supplementary information

about the subject. Nonrestrictive modifiers, then, do not limit or restrict the NP's meaning but only add information. As Heim and Krazer (1998) point out, it is reasonable to assume that at the level at which our semantic rules apply, the nonrestrictive modifier isn't part of the structure.

Because of this, I argue that the modifier is semantically unimportant and its attachment at the complement position of an NP is not obligatory. Thus, while I agree that restrictive modifiers are embedded into the primary channel as a complement of N, I argue that nonrestrictive modifiers are perceived in a second channel separate from the channel containing the main clause, as shown in tree (R). If the non-restrictive modifier were to remain attached in the NP, it would imply that it is semantically important for the meaning of the sentence to hold; this is, however, not true, and allowing for the nonrestrictive modifier to occupy a second channel would give a more precise syntactic representation for the meaning that is ultimately interpreted by the sentence.

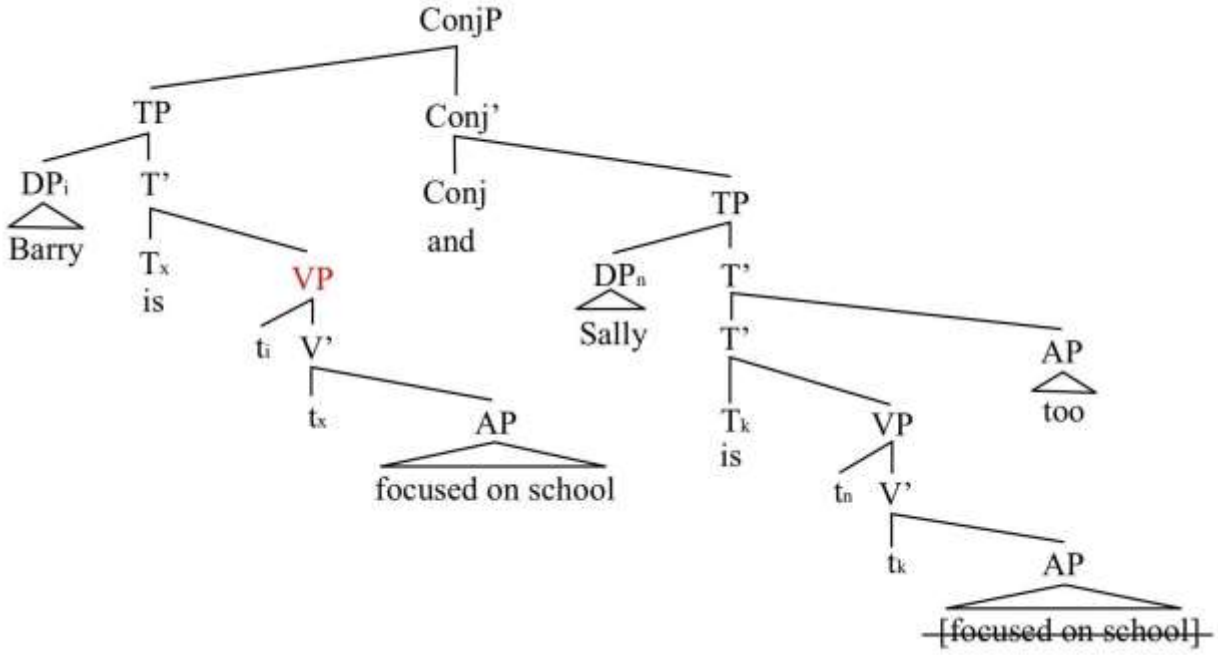
4.2.2.2 Parentheticals with VP Ellipsis

Expounding on the phenomenon of nonrestrictive modifiers, which are a subset of parenthetical, parentheticals at-large have presented an interesting phenomenon for both syntacticians and semanticists to grapple with, as it appears they function in a sometimes unpredictable manner. In Standard American English, it is not uncommon for a person to utilize parentheticals in their speech to insert an explanatory or qualifying word, clause, or sentence. This subsection will specifically address the phenomenon of VP ellipsis, the ways in which modern syntactic models fail to represent it, and how these problems can be resolved with the two-channel method.

VP ellipsis refers to a phenomenon and type of anaphora in which a verb phrase is excluded, or elided, from a syntactic construction as long as its antecedent presides within the same linguistic context.

Consider sentence (1) and subsequent tree (S) below:

10) Barry is focused on school, and Sally is too.



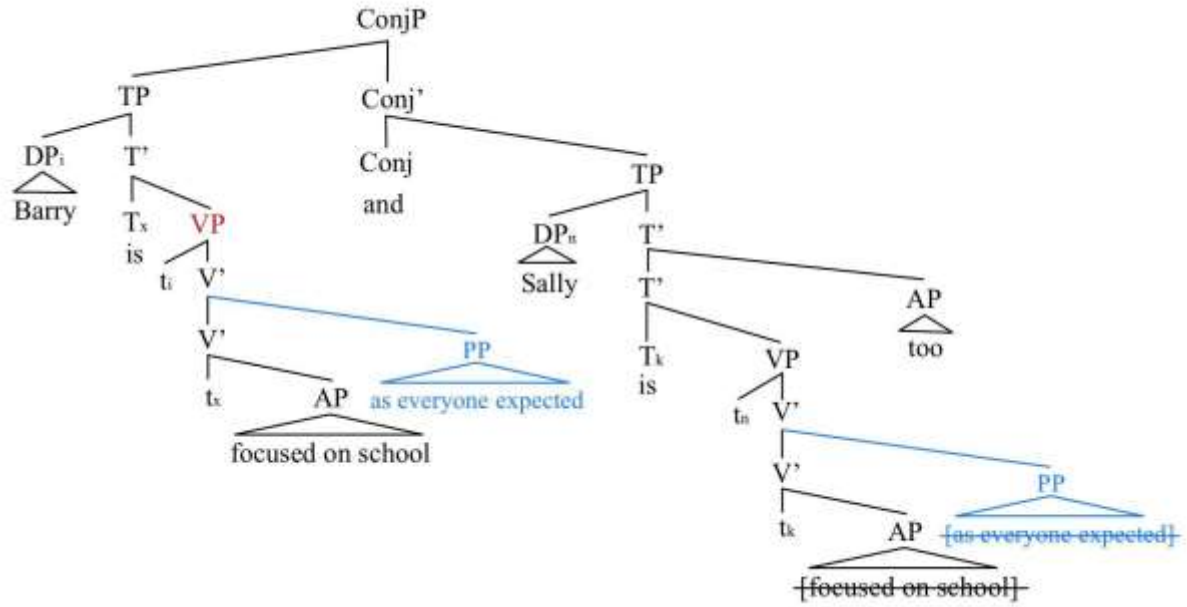
Tree S. Barry is focused on school, and Sally is ~~focused on school~~ too.

In tree (S), the VP in [Sally is [VP] too] becomes the target for the VP in the antecedent and thus is elided and interpreted without externalized repetition in speech.

VP ellipsis, however, poses a problem for parenthetical placement in the syntax, because Potts (2002) suggests that *as*-parentheticals attach where they are interpreted and pronounced.

Under this assumption, consider sentence (11) below:

11) Barry is focused on school, as everyone expected, and Sally is too.



Tree T. Barry is focused on school, as everyone expected, and Sally is ~~focused on school, as everyone expected~~, too.

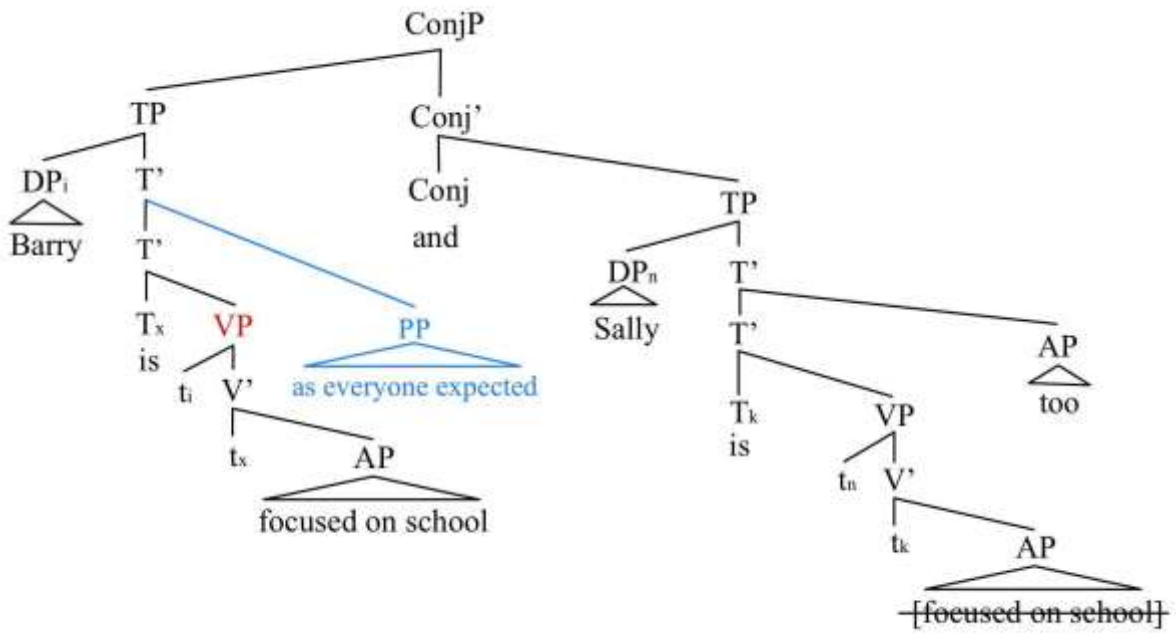
In tree (T), *as everyone expected* is a clause-internally placed parenthetical that, while seeming to have a contrastive focus on Barry's quality of being focused on school, is elided with the VP. Sentence (11) should be interpreted, according to Pott's syntax, as:

11. a) Barry is focused on school, as everyone expected, and Sally is_x too.

Where is_x = focused on school, as everyone expected

However, it is questionable whether *as everyone expected* acts as part of the antecedent for the targeted VP in [Sally is [VP] too]. It is possible in tree (T) for *as everyone expected* to instead attach at T', where it will not elide with the VP.

Consider tree (U):



Tree U. Barry is focused on school, as everyone expected, and Sally is ~~focused on school~~ too.

Tree (U) allows for the following interpretation:

11. b) Barry is focused on school, as everyone expected, and Sally is_x too.

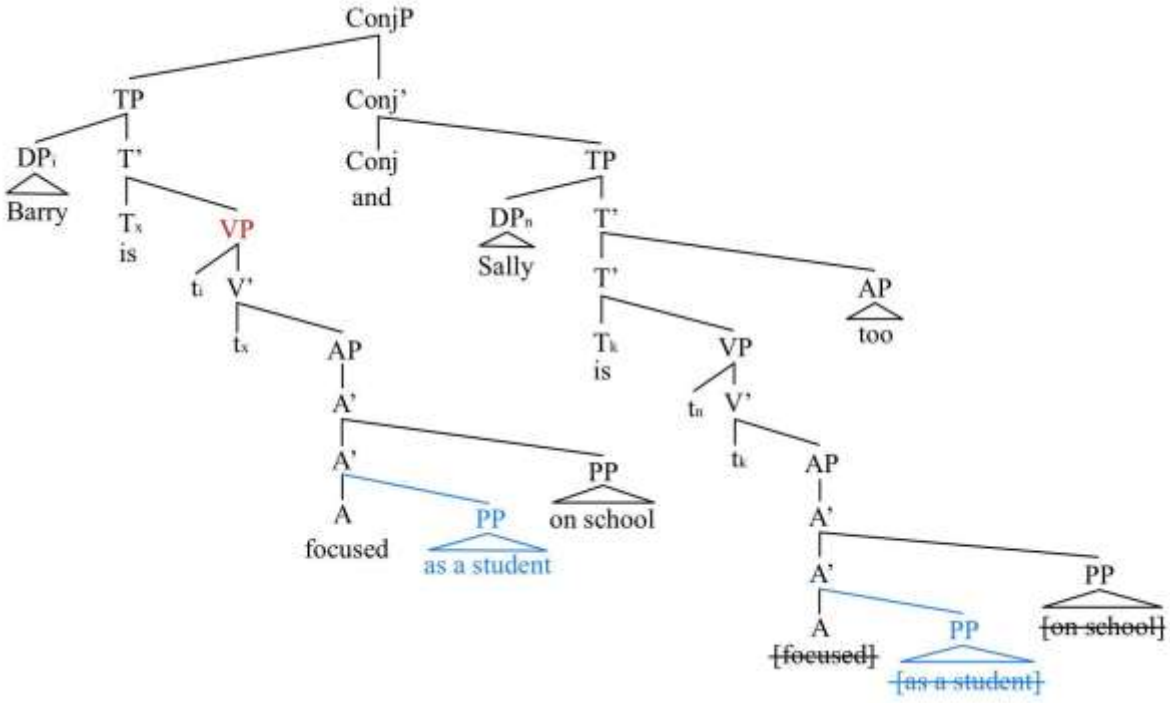
Where is_x = is focused on school

$is_x \neq$ is focused on school, as everyone expected

Potts' (2002) argument, while not explicitly addressing the T' attachment of parentheticals, does align with this method of higher attachment to account for structural ambiguity.

Arguably, a parenthetical like *of course* or *by the way* could be interpreted within the elided VP and deem structural ambiguity as unimportant for overall sentence meaning. However, consider the sentence below, adapted from (1), and imagine a world in which Barry is a student and Sally is a professor:

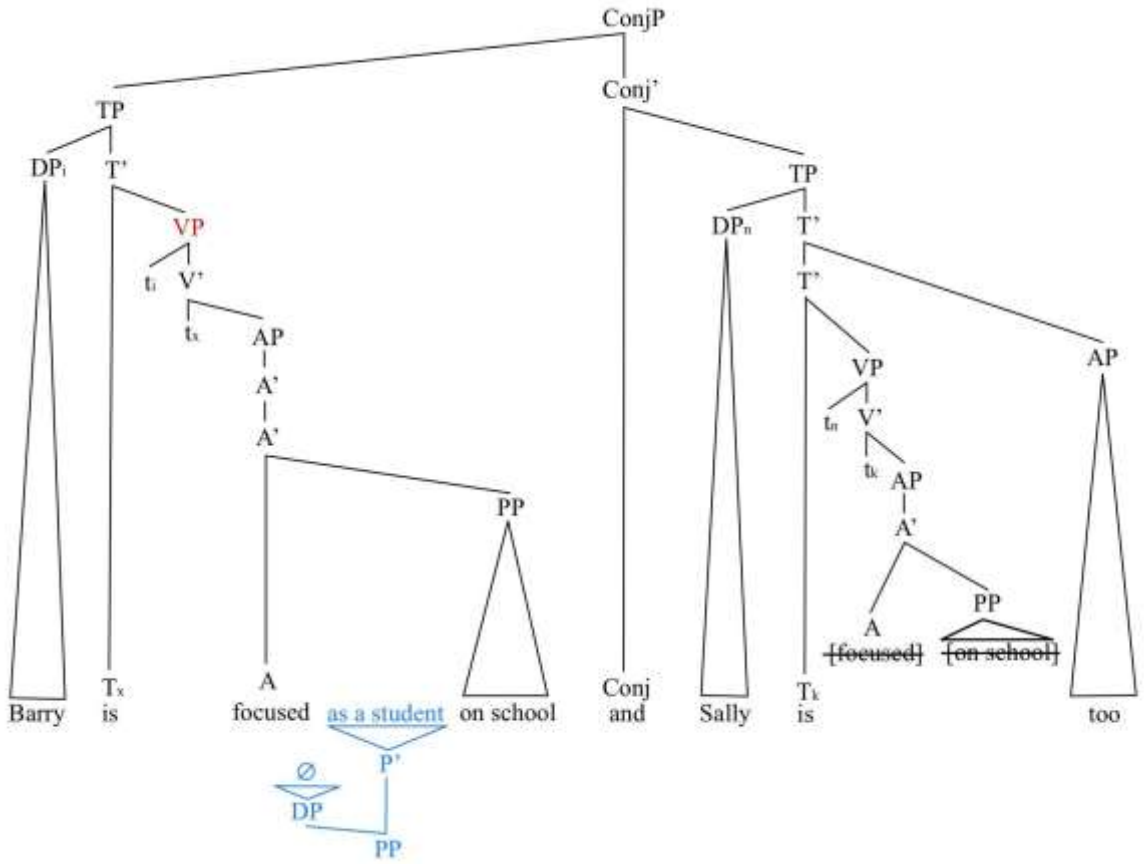
12) Barry is focused, as a student, on school, and Sally is too.



Tree V. Barry is focused, as a student, on school, and Sally is ~~focused, as a student, on school~~ too.

In tree (V), the parenthetical is nested within the VP with no other possibilities of higher attachment (such as T') while still maintaining word order. Additionally, the tree contains an elided VP, which makes the syntax problematic considering the proposed world where Sally is a professor, not a student, and the fact that a parenthetical separates a head from its complement. This problem, unreconcilable using modern syntactic analysis, can be rectified if assessed through the two-channel method.

Consider tree (W) below:



Tree W. Barry is focused, as a student, on school, and Sally is ~~focused on school~~ too.

First, as context for tree (V), I argue that there are characteristics to support that parentheticals are processed differently – on a different channel – than the rest of the sentence that contains them. This is because research supports that parentheticals occur between prosodic gaps, occupy different speech rates, do not carry primary stress, and have low pitch range in comparison to the main clause in which the parenthetical is inserted (Bing, 1980; Dehé & Wichmann, 2010; Dickerson, 1999; Levis et al., 2015). Thus, I conclude that it is not completely unreasonable to model syntax in the way I have done in tree (W).

Specifically, tree (W) is comprised of DP that is containing of the parenthetical but separate from the main ConjP, *Barry is focused on school and Sally is too.* The DP in the second channel is occupied by a ∅ to show that it will refer to some DP, such a *Barry*, to show contrastive focus depending on discourse rules. The most important property of this construction, however, is related to the elided VP. Previously, in tree (V), the parenthetical that separated the head from its complement was forced to elide, yielding a semantically incorrect interpretation given the conditions of the world previously established. In the new construction, however, the parenthetical is no longer nested within the VP, allowing for it to elide freely without the consequence of incorrectly interpreting it within the elided VP of the conjoined TP, *Sally is too*.

4.2.2.3 Syntactic Amalgams

First documented and discovered by Lakoff (1974), syntactic amalgams are sentences that have within them "chunks of lexical material that do not correspond to anything in the logical structure of the sentence[s]." In other words, syntactic amalgams are nonstandard grammatical patterns that contain two or more contiguous or overlapping syntactic sequences that cannot otherwise be combined, allowing for multiple propositions to be presented in a singular sentence with parenthetic-like constructions (Brenier & Michaelis, 2005; Miranda, 2004). Miranda (2004) classifies these parenthetic-like constructions as 'invasive' clauses (indicated by bold lettering in 13-15) within an 'invaded' sentence. Consider the following:

13) She made **how could anyone forget how many** millions of dollars.

14) Mark is going on a date with **guess who**.

15) Ivan has gone **who knows where** to get into **you can only imagine what** kinds of trouble.

16) I ate **I don't even know how many** cookies at the event.

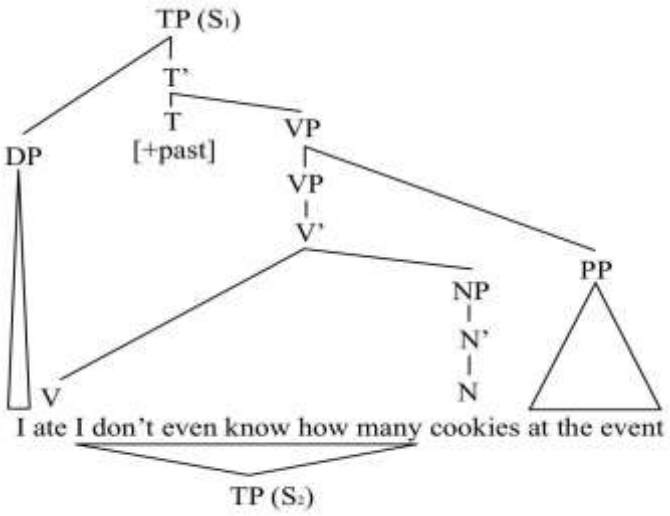
It can be imagined and recalled how these sorts of constructions could be used and are not foreign to normal conversation. However, because syntactic amalgams are produced by an unusual merging of propositions, modern syntactic theories do not currently propose adequate methods for modeling these sorts of constructions. I will construct my analysis around (16) similar to Miranda (2004) for this thesis.

To begin this discussion, consider two possible input sentences that merged to create the syntactic amalgam seen in (16).

17) S_1 = I ate cookies at the event.

18) S_2 = I don't even know how many.

19) Product = I ate I don't even know how many cookies at the event.



Tree X. *I ate I don't even know how many cookies at the event*.

Sentences (17-19) can be further represented by (20) and (21), where the crossed-out words represent the unpronounced clause that is interpreted with that sentence:

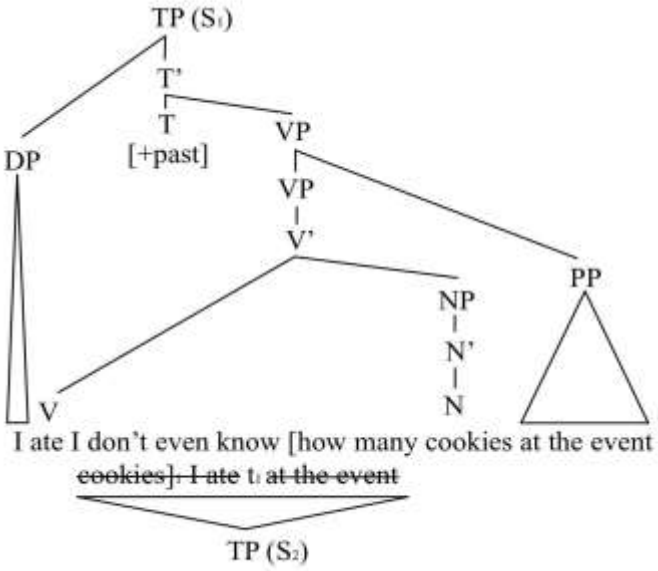
20) S_1 = I ate cookies at the event

21) S_2 = I don't even know how many ~~cookies I ate at the event~~

Further, since *cookies* is the complement of the transitive verb *ate*, another construction could be like (22) if taking into consideration the combination of sluicing and parentheticalization that syntactic amalgams are said to reduce to (Merchant, 2001).

22) Product = I ate cookies at the event, but I don't even know [how many ~~cookies]$_1$ I ate t$_1$ at the event.~~

Consider tree (Y) below for (22) (Miranda, 2004):



Tree Y. *I ate I don't even know how many cookies at the event*.

While understanding *cookies* as a complement of *ate*, Miranda offers a more controversial interpretation of the sentences, where *ate* acts as an intransitive verb like in (23):

23) I ate **I don't even know how many cookies** at the event.

Miranda would argue that the invasive clause is not complete because *know* selects an entire clause, *how many cookies*, instead of an NP. Under this realization, a sentence like (26) is proposed to be a reconstruction of (23), despite different informational structures if the invasive clause contains elliptical material that replicates the structure of the invaded clause (Miranda, 2004).

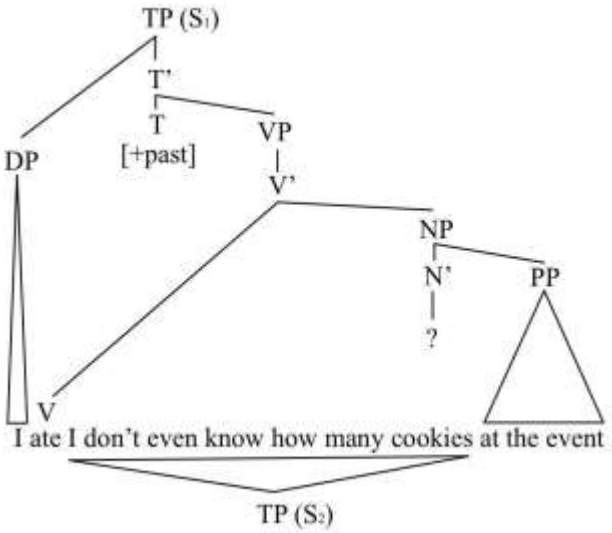
Consider sentences (24-26):

24) S_1 = I ate at the event

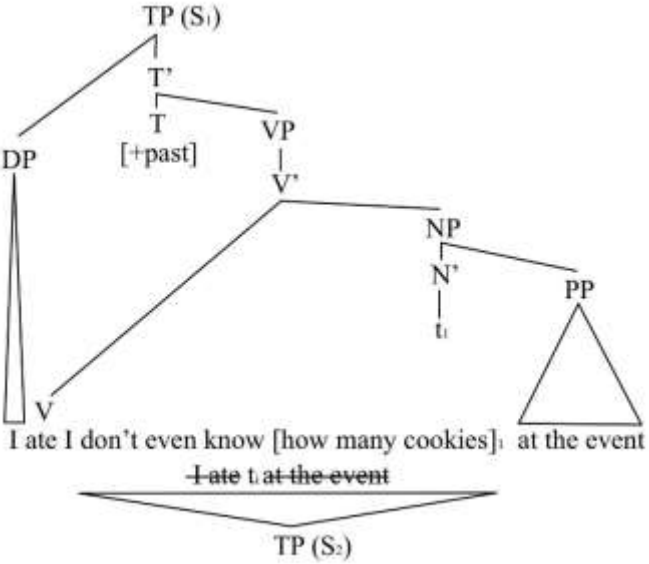
25) S_2 = I don't even know how many cookies ~~I ate at the event~~

26) Product = I don't even know [how many cookies]$_1$ I ate t_1 at the event.

Under this assessment, consider trees (Z) and (α) below:

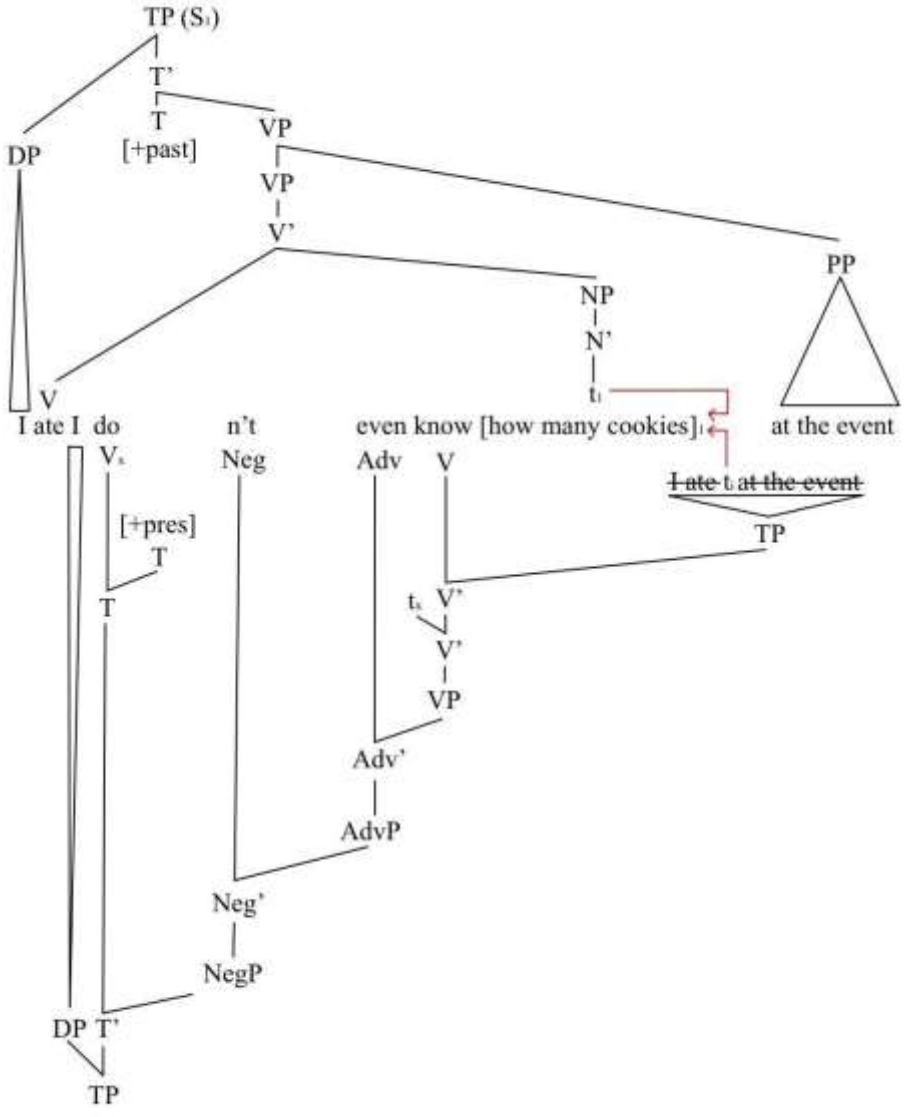


Tree Z. *I ate I don't even know how many cookies at the event*.



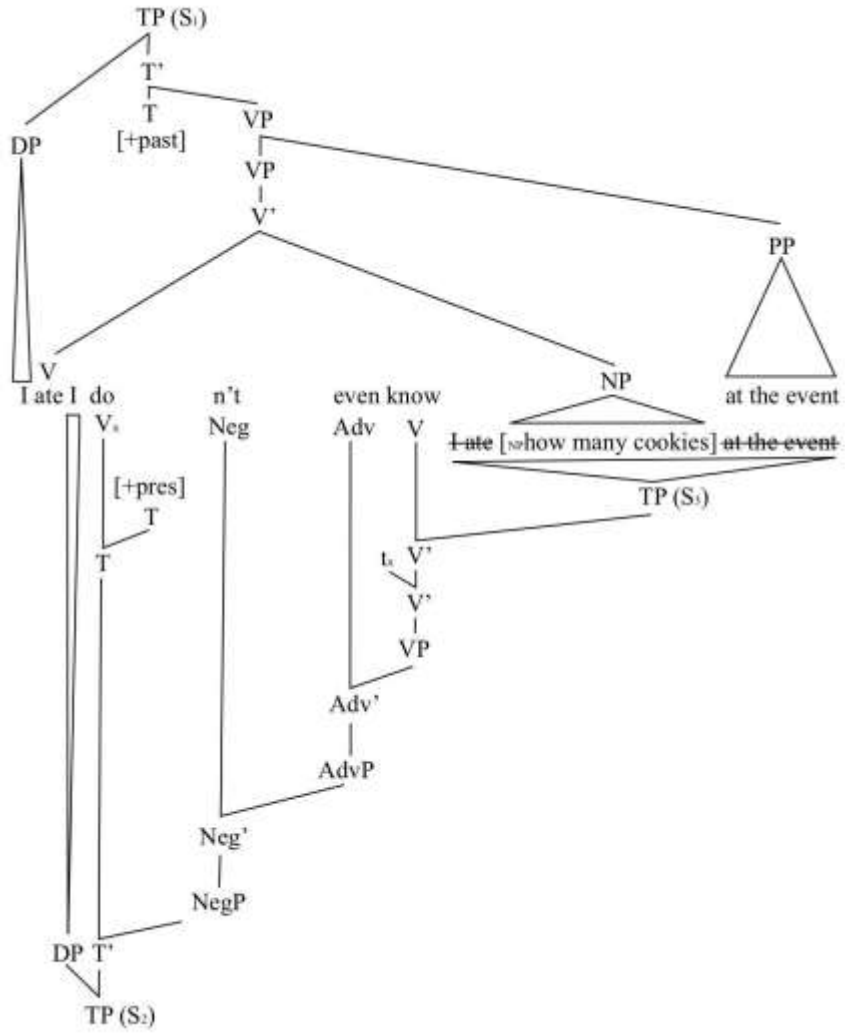
Tree α. *I ate I don't even know how many cookies at the event*.

In tree (Z), an empty N category is included in reference to Miranda's (2004) note on the incompleteness of the invasive clause. Tree (α), completed with a t_1, shows S_2 with its unpronounced components, allowing for a better understanding of how it interacts with syntax. Modeling this interaction, consider tree (β) below:

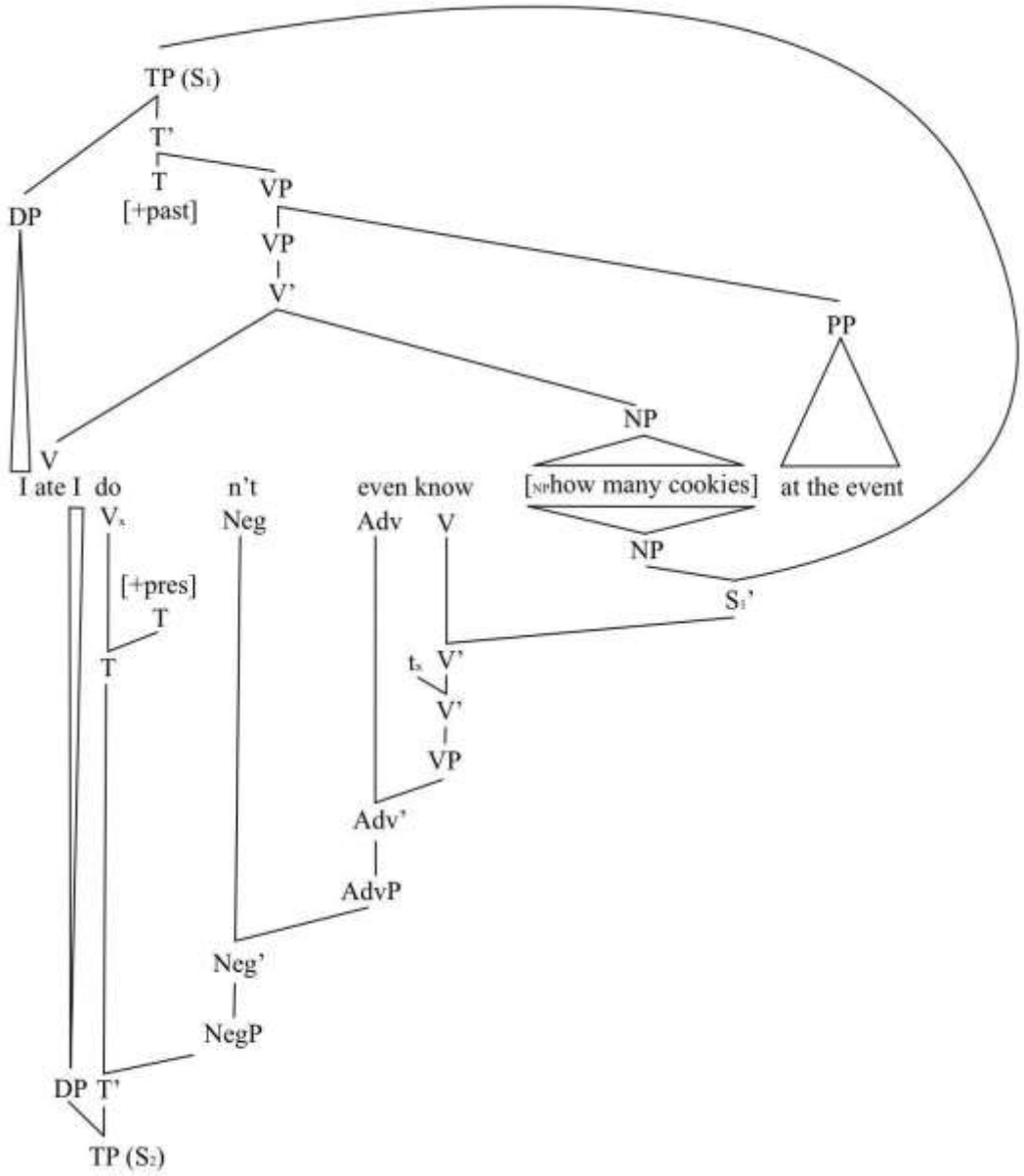


Tree β. *I ate I don't even know how many cookies at the event*.

Tree (β) represents where syntactic amalgams become problematic. Miranda admits that this 'chain-collapsing mechanism' (shown by the red arrows), in which t_1 from both sentences combine with the NP *how many cookies*, "does not fit into the standard definition of chain and its trace is not c-commanded by the corresponding moved phrase" (Miranda, 2004, p. 25). Nonetheless, this mechanism yields tree (γ) where the NP *how many cookies* combines with both the invasive and invaded clauses to create a syntactic connection between the two. The final construction is shown in tree (δ) where the syntactic constituent is shared between *two* parents:



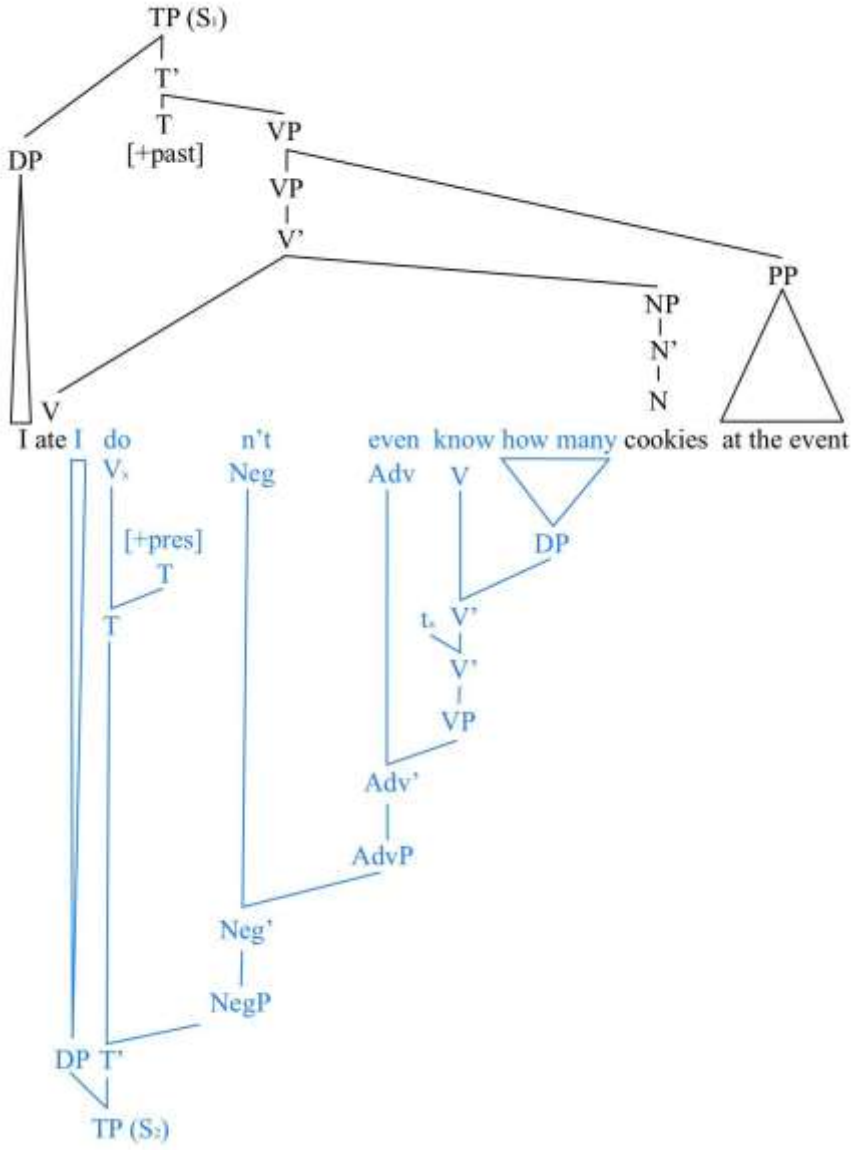
Tree γ. *I ate I don't even know how many cookies at the event*.



Tree δ. *I ate I don't even know how many cookies at the event*.

However, the sharing of a constituent between two parents in the same channel is not supported by standard assumption.

Instead, using the two-channel mechanism – where syntactic amalgams may be separated since they are made up of two distinct propositions – I offer tree (θ) to show a way that allows for a constituent to not be shared by two parents in the same channel.

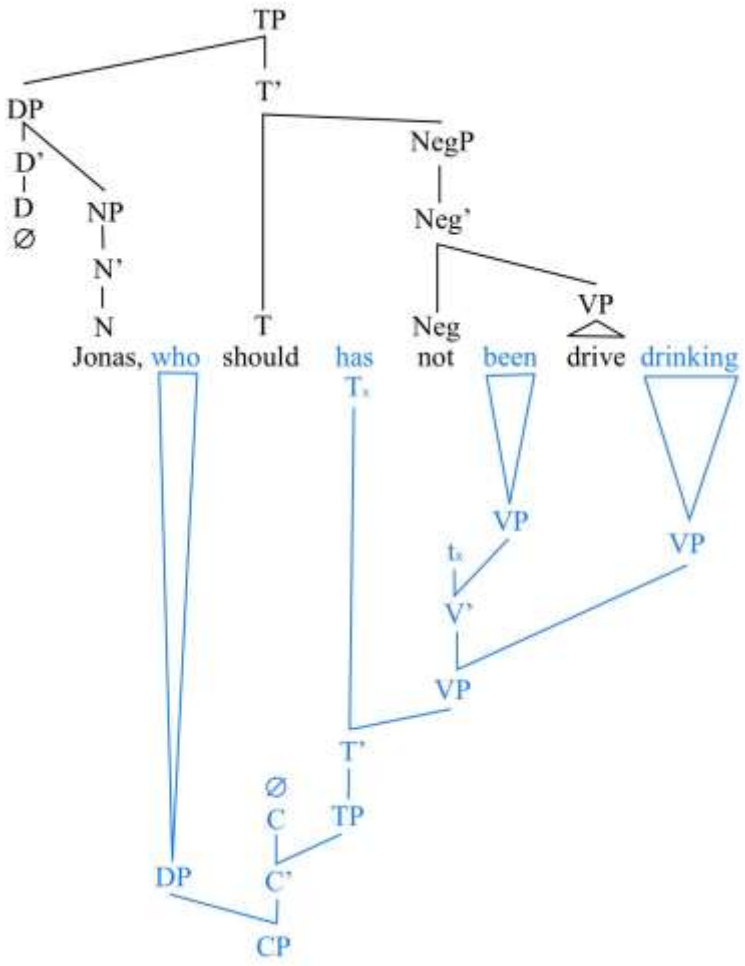


Tree θ. *I ate I don't even know how many cookies at the event*.

Suppose whale song is compositional and meaningful both ingressively and egressively, which would mean that they are able transmit different information along each channel. In that case, I thus offer a possibility for how human language can be analyzed in a similar way. If parentheticals were processed in a different channel, this would explain their prosodic differences (when considering how whales are using two different sound types) and also allow for current insufficiencies in syntactic modeling to be solved. While parentheticals are still grossly understudied, and many questions still exist regarding the neurolinguistic processing of language, future studies could be conducted to determine whether parentheticals activate different areas of the brain when being processed or uttered. If so, such a discovery would support how humans utilize different cognitive pathways for parsing together meanings of different semantic and prosodic categories.

4.3 Limits of Human Language

While I have shown how human language can utilize multiple channels for communication, I do want to take a moment to note that this capacity for multiple-channel information processing is not limitless. For example, recall the sentence (9), *Jonas, who has been drinking, should not drive*. In 4.2.2.1, I argued that this sentence is processed using two channels because it contains a non-restrictive modifier. While maintaining its two channels modeled in tree (R), consider tree (λ).



Tree λ. **Jonas who should has not been drive drinking*.

When considering the construction *Jonas who should has not been drive drinking*, it is evident how the original sentences' semantic integrity has been lost. Therefore, even if the two-channel processing of humans is present, it is nonetheless limited.

Chapter 5

Conclusion

5.1 A Summary of Remarks

In this thesis, I first acknowledged the debate surrounding human language uniqueness, discussing the components of compositionality through the lens of non-human communication systems and calling to attention the question of human language emergence. I noted the non-syntactic structure of phonological syntax and further pointed out that human language structures are not always compositional. In doing so, upon the introduction of whale song, I asserted that other parallels could be made between human language and animal communication.

Because of the unique acoustic properties of whale song, containing remarkable use of egressive and ingressive sounds, I have used this thesis to present a two-channel mechanism that may exist in human cognition to parse together [or apart] semantic products from both linguistic and non-linguistic inputs. By applying this two-channel method to human communication, I was successfully able to discuss paralinguistic processing and propose possible solutions to current problems in modern syntactic theory concerning the modeling of parentheticals and syntactic amalgams.

While further work must be done to better understand the biological relevance of two-channel communication, and how such a theory could be more formally and widely introduced into the study of syntax, this thesis serves as a steppingstone towards better conceptualizing how animal communication may provide tools for analyzing human language structure.

5.2 Future Directions

Despite its influence on my modeling of human language, the meaning of whale song may never be known. But perhaps in the future, technology will be discovered to have the same impact that the microscope had, allowing us to see an aspect of animal communication that had not before been considered or believed to exist.

Without said technology, however, future studies may seek to establish evidence for behavioral responses to song production, or how song structures change – if at all – in different environmental or social conditions. Further, as postulated by Mercado, Handel, and Perazio (2012, 2021), observational research can be collected to determine how dive cycle and buoyancy affect the acoustic properties of whale song.

Ultimately, advancement in understanding whale communication may be the product of long-term studies that seek to see how song patterns influence behaviors related to buoyancy control, direction, or some other characteristic of whale behavior that we have not yet been able to isolate. However, on the flip-side, I hope this thesis has provided a new perspective on human language so that future neurolinguistic research can explore how exactly humans may be engaging with multiple channels of communication.

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The ocean is a mystery, and many things are yet to be discovered.

Perhaps a better understanding of language will be one of them.

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