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Keara Harris April 13, 2021

Visualising Merge as a Three-Dimensional Constructed Language

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An abstract of
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Abstract

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Language as we know it is bound in time; in both spoken and signed varieties, we experience language in a linear form. However, linguists such as Noam Chomsky suggest that language is not linear at all. Rather, the rules and meanings of language are bound by hierarchical structures. This paper aims to explore the idea of hierarchical structure in language by taking Chomsky's hypothesis of Merge seriously and using it to create a constructed language in three-dimensional space. The model will be able to represent an unlimited array of hierarchical structures of language. I will additionally explore the implications of such a structure on language acquisition. This paper represents an in-depth, theoretical thought experiment into Chomsky's Merge and the idea of universal grammar.

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1 Introduction

Language, as we experience it in its spoken and signed forms, is bound by temporal linearity. When we speak out loud, we can only make one sound at a time, forming into one word at a time, then one sentence, and so on. Signing provides more flexibility – allowing for the possibility of multiple signs at once in a more three-dimensional space – but is still ultimately bound by time itself.

Despite this inevitable limitation of how we use language, there are many theories that language itself is not linear. The rules of language are not bound by time but rather structure, not by moving forward but by building upon itself. As we explore in the paper, meaning itself seems to be strongly influenced by and dependent on the internal structure of an utterance. It's difficult to even imagine a language that expresses meaning based specifically and only on linear order. American linguist Noam Chomsky is one of the biggest defenders of hierarchical structure in language. He proposes an internal structure he calls Merge, something he claims is universal to all human language.

This paper will explore this structural importance in language through a new, experimental lens. This project is not a traditional research paper, but rather a theoretical delve into a current theory through a creative thought experiment. I will be taking Chomsky's hypothesis of Merge and universal grammar seriously and investigating it through a constructed language. This language will use Merge as its fundamental basis of its structure and appearance and will exist entirely in three-dimensional space. If humans were able to produce such a structure, would we be able to acquire such a language? Can such a structure even be created in a

way that somehow resembles our own language? This thesis aims to propose answers to those questions through a theoretical experiment and a constructed visualisation.

2 Background

2.1 Chomsky and Universal Grammar

When you, the reader, look at this sentence, you see it one word after another. If you were to read it out loud, you'd have to read it one word at a time, in a linear order. It's the nature of these modalities. Written language is two-dimensional and must go in an order, right to left, left to right, top to bottom, or bottom to top – ultimately linear. Spoken language is limited by the fact that we can only articulate one sound at a time, so it, too, ends up inescapably linear. Signed languages are bound by the fact that, despite the ability to make some aspects non-linear, we are still limited in space and articulators available. Thus, it seems inevitable that language be linear.

However, according to some linguists, including Noam Chomsky, that's not the case. Human language, by the time it reaches our eyes or ears, is linear due to the limitations of the modalities we use – but it does not rely on that linearity for its meaning. Take, for example, the following English sentences adapted from Chomsky's article, "What is Language?" (12):

1) Birds that fly instinctively swim.
    a. If birds fly instinctively then they also swim.
    b. If birds fly then they also instinctively swim.
2) Instinctively, birds that fly swim.

Sentence (1) can be interpreted two ways, meanings (a) and (b) listed above. In meaning (a), *fly* is the verb that is being modified by *instinctively*. In meaning (b), however, *swim* is the verb that

is being modified by *instinctively*. There is no clear answer as to which meaning the speaker intends based on the linear order of sentence (1), but in sentence (2) the meaning becomes evident. Now, the sentence clearly refers to meaning (b): if birds fly they also instinctively swim. Linearly, this doesn't make sense. Why doesn't *instinctively* modify the closest verb *fly*? Would that not make it easier to parse for the listener? After all, this is the first verb you hear, linearly closest, with only two words between it and *instinctively* as opposed to the three between *instinctively* and *swim*. So why does *instinctively* have to modify *swim* in sentence (2)?

The answer could come from the fact that what we hear and see is not the end-all, be-all of language. According to linguist Noam Chomsky, language has a so-called Basic Property which allows for the "generation of an unbounded array of hierarchically structured expressions mapping to the conceptual-intentional interface, providing a kind of "**language of thought**"" ("What Is Language?" 13). In other words, the Basic Property allows for an unlimited array of expressions that are hierarchically structured, not linearly, and that then are connected to meanings that provide a language of though. In his article "The Galilean Challenge", Chomsky states that "production accesses an **internal language**, but cannot be identified with it". This means that what we see and hear – production – is based on the internal language our brain produces, but is not the exact same thing. In fact, Chomsky argues it is perhaps peripheral at best. This internal language, Chomsky says, has no need for linear order. It is **structure dependent**. The meaning of phrases, sentences, and even what we perceive as words are based on their structure, which **constituents** they belong to. A constituent is a node and everything contained under it. If we look at the two trees for sentence (1) we can see both possible meanings depending on how the constituents are set up.

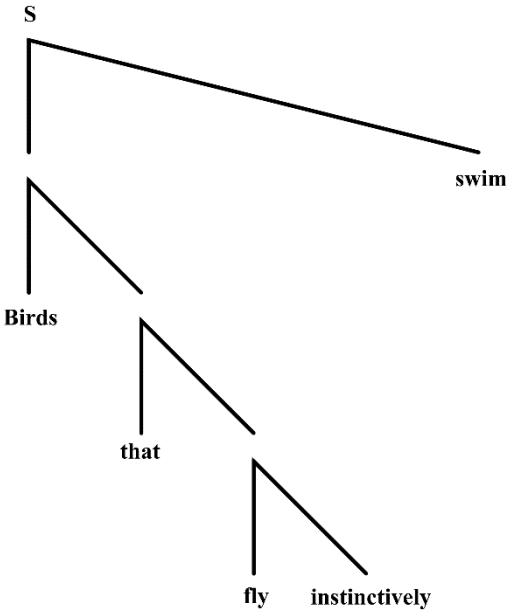

Figure 1: Sentence (1), Meaning 1

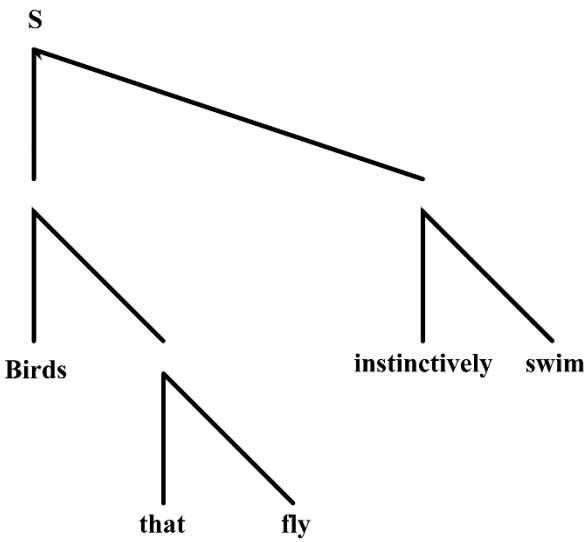

Figure 2: Sentence (1), Meaning 2

The trees above demonstrate a principle Chomsky calls **Merge**: "The simplest computational operation … takes objects **X** and **Y** already constructed and forms a new object **Z**" ("What Is Language?" 16). All nodes on the tree may only have *two* separate child nodes branching off of them, objects X and Y. In other words, Merge is a binary operation: it can only put together two child nodes at a time, never more. These two child nodes form a constituent and can influence the meaning of a phrase. When *instinctively* is part of the same constituent as *fly* – making them structurally closest – then the phrase suggests meaning (a). When *instinctively* is part of the same constituent as *swim*, then the phrase instead suggests meaning (b). Thus, the meaning of the sentence is structure dependent. I will come back to this example later on in the paper to demonstrate its structure with my proposed model.

2.2 Alternative Theory: Usage-Based Grammar

Although this paper will be taking Chomsky's theories as true, not all linguists agree with Chomsky and his theory of universal grammar. In fact, the idea that there is some internal system like Merge that we all share is a highly contested one. One of the main competitors to this theory is *usage-based grammar*, in which "all things flow from the actual usage events in which people communicate linguistically with one another" (Tomasello 61).

Usage-based grammar is language specific, as it deals almost exclusively with the input to build up a grammar during language acquisition. In a way, this is another version of the ancient nature versus nurture debate. Where universal grammar claims that there is something innate about language – indeed, for Chomsky, this innate construct is Merge – usage-based grammar believes that everything about language is acquired along the way. According to Tomasello, "it is not at all clear that children are actually operating with adult-like categories" (Tomasello 67). Instead, it may be that rather than understand grammatical constructs, they understand fixed constructs based on previous input data. A child saying "Wanna go outside!" may not actually understand the infinitival clause but rather that "wanna" pairs with "go" fairly often, and "go" pairs with "outside". Thus in usage-based grammar, linear order ends up being very important; when the linear order is by necessity the input, of course that is what language is built on.

There are potential issues with this theory of language, but perhaps the most glaring is the fact that children do not hear every possible utterance they will ever produce. In fact, the input that children receive is minimal compared to their rapid development of language; chances are we are not exposed in childhood to every grammatical structure we will ever use, let alone the correct linear order for every structure. It relies on children's ability to "infer how to generalize

appropriately and display the kind of category-based productivity that characterizes adult speech" (Bannard et al. 17289). But with so much input missing, it cannot be easy to make such inferences.

Nevertheless, missing stimuli aside, usage-based grammar and Merge are not fully incompatible. Chomsky's Merge as a Universal Grammar does not claim to explain language-specific grammatical concepts *or* lexicon. An argument could be made combining the two, suggesting the underlying structure of Merge facilitates the usage-based acquisition of language-specific grammar. In other words, while Merge provides the foundations for language, the rest of the house still needs to be built and usage-based theories could easily be the tools needed to build it. I will return to this idea and examine what language acquisition would be like with a three-dimensional, Merge-based model. Would the structure allow for easy acquisition thanks to universal grammar's innate Merge? Or would the lack of linear order prove difficult for usage-based acquisition? I will examine this more closely later in the paper.

2.3 Potential Arguments for Linearity

The fact that sentence (1) can lead to misinterpretation and confusion in the listener speaks to our use of linear order to understand sentences, at the very least in English. And if linear order is important in one language, then its unimportance cannot be a factor of universal grammar – right? When we cannot tell based on linear order what the sentence means, we experience confusion and have to guess based on context. When we don't have context, this can become next to impossible.

In this section, I will be addressing three phenomena that make it seem at first glance that linear order is fundamental to understanding language. However, as I will discuss, all three of these examples can be explained by Merge or ultimately do not need to be.

2.3.1 Garden Path Sentences

Another example of linear order leading to confusion is the concept of *garden path sentences*. These are complete, interpretable sentences that at first glance or listen can seem incomplete or even nonsensical. Take sentence (3) below:

3) The horse raced past the barn fell. (“What is Language?” 22)

A first glance seems to suggest that there’s information missing – my own first glance made me wonder what on earth a “barn fell” was. What this sentence means to say is that there is a horse that was raced past the barn, and this horse fell. However, because this is a reduced relative clause, as we hear and interpret this sentence in its linear order, we get confused. We don’t see the hierarchy that makes a constituent out of “the horse raced past the barn”, and it makes sense from prior experience that a horse would be racing. It isn’t until we hit “fell” that it all falls apart, and the fact that it does shows the way linearity does affect our understanding of language.

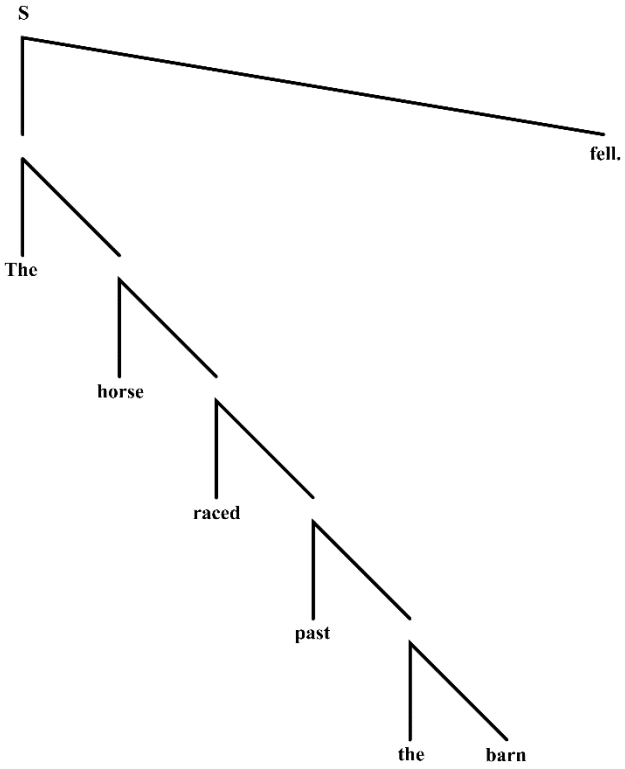

Figure 3: "The horse raced past the barn fell."

However, the underlying structure of the sentence makes it much clearer. As we can see in the tree in figure (3) on the following page, “fell” is the main verb of the sentence. Something must be falling, and that something is the constituent combining with “fell” through Merge. Thus, “the horse raced past the barn” is the thing that fell. With the structure clear, the meaning is clear, without the confusion that comes with linear order. In my proposed model, this structure would be clear from the beginning, and therefore, as I will later show, garden-path sentences would never occur.

2.3.2 Centre-Embedding

Yet another example includes centre-embedding. These sentences have clauses embedded in the linear centre of the phrase, which can lead to some confusion. For example, take sentence (4):

4) The boy the dog chased fell.

In this case of centre-embedding, linearly we end up with two noun phrases directly next to each other and two verb phrases directly next to each other. Hearing this linearly might take a moment to re-evaluate. However, as with the previous examples, the underlying hierarchical structure makes the meanings of these sentences very clear, similarly isolating *fell* as the main verb in the sentence combining with the thing falling, the constituent *the boy the dog chased.*

However, while embedding “refers to all types of clauses occurring as subordinate parts of their superordinate clauses” (Karlsson 4), only some forms allow for multiple centre-embedding in English. For sentence (4), multiple centre-embedding is not allowed, such as in the ungrammatical example (5).

5) *The dog the boy the cat hated chased fell.

Even though this structure is completely allowed under Merge, it is ungrammatical in English and, besides which, incredibly difficult to parse. Nevertheless, as I discussed in an earlier section, Merge was not meant to account for language-specific grammatical rules. While structure would make the meaning of this sentence clear, the same kind of rules that dictate English's word order dictates the fact that this sentence is ungrammatical.

2.3.3 Pragmatic Arguments

However, are these instances of confusion just an unfortunate consequence of the linear nature of externalised language? What about cases where it seems that linearity is intrinsic to the meaning, not to the confusion of meaning? It can be argued, especially from a pragmatic standpoint, that linearity actually matters quite a lot for the meaning of a sentence. Take, for instance, the following examples:

6) He did not like Susie.

7) Susie, he did not like.

The first sentence is straightforward, its basic meaning easy to grasp in and out of context. The second sentence, however, is in need of context. This syntactic form can only exist in English with a comparison, such as example (7):

8) Cait, he liked. Susie, he did not like.

There is a pragmatic change in the meaning due to the fronting of the object. At first sight, the linear order of the sentence has changed and added new implications that make it so the sentence cannot easily stand on its own. Does this mean linear order is important to our understanding of language?

In actuality, even this still fits within Merge. First of all, Merge is not concerned with pragmatic meaning, which is language-specific, but rather with the syntactic structures underlying a sentence. Movement, which I will discuss in the next section in further detail, allows for the external linear order, and can even allow for some of the pragmatic meaning through the change in the underlying structure of the sentence.

2.4 Internal and External Merge

So how does movement work? How does it relate to Merge? Before I present my model, I want to take a moment to explain this concept, which I will return to later on in the paper. Take sentence (2), for example. If linear order doesn't matter, why is it that this order of words clarifies the meaning of sentence (1)? How does *instinctively* even get to the beginning of the sentence? And if it's there, would it not be under a different node, and thus structurally very far from both verbs? For each of these questions, the answer can be explained with structural movement that I will further elaborate on now.

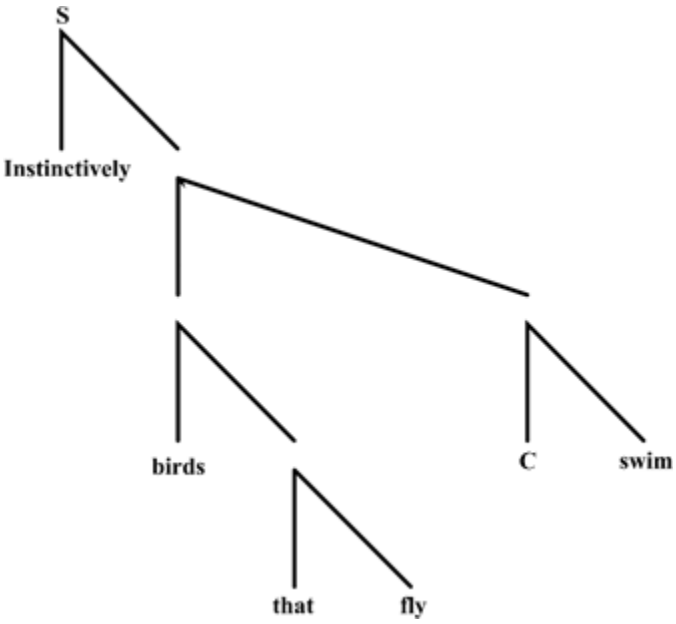

Figure 4: Sentence (2)

Figure (4) shows the sentence tree for sentence (2), which demonstrates another fundamental aspect of Chomsky's hypothesis: Internal Merge and External Merge. **External Merge** is the version of Merge I have already covered, the simple process of combining X and Y into Z, where X and Y are two distinct lexical items or an already-formed constituent.

Internal Merge seems different at first glance, but it is still fundamentally the same process; it takes something already formed inside the phrase and moves it to Merge somewhere else in the structure. You can see it in the tree to the side, with something I have marked as a **copy** using the letter *c*. According to Chomsky, the brain processes *instinctively* in both spots, so the sentence is processed as "instinctively birds that fly instinctively swim". Object X, *instinctively*, has been combined with object Y, *birds that fly instinctively swim,* to make our new object Z. Because object X is found inside object Y, this is called Internal Merge. The instinctively in object Y is not externalised, but it is crucial to the internal language understanding of the sentence.

This kind of movement can also be seen in questions in English. Take, for example, the question sentence (9) below.

9) What did Steve read?

Object X will be *what* and object Y will be *Steve read what*. This gets processed in the internal language as "what Steve read what", which gets externalised as "What did Steve read?" through other processes that are not important for the purposes of this paper. The tree on the right demonstrates the internal representation using a copy again.

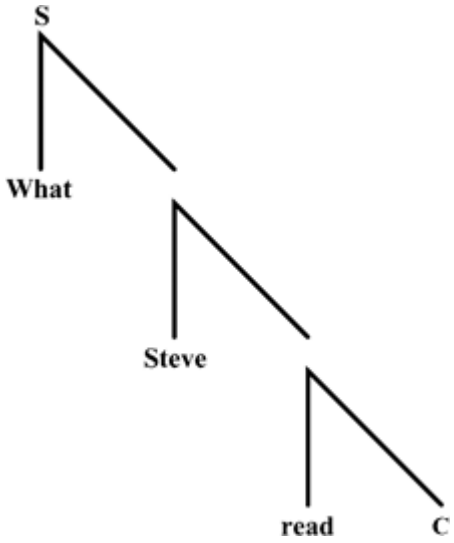

Figure 5: Internal Merge for Questions

With Internal Merge, many of the examples of linear order seemingly mattering can be explained and fit into Merge as a whole. Structure is still the key principle in the understanding of the sentence, and according to Chomsky's theories, the linear order is simply a consequence of the structure. My model will have ways to account for the examples I have just demonstrated in this section through the use of Merge.

2.5 Constructed Languages and Structural Dependence

Later in this paper I will be exploring a constructed language model based entirely in Merge. It follows, then, that it would make sense to look at a constructed language that does not follow in line with Merge and structural dependence, and instead relies on linearity for some of its grammatical structures.

In their book *The Mind of a Savant*, Neil Smith and Ianthi-Maria Tsimpli followed a case-study of a linguistic savant, Christopher. As part of their tests of his linguistic capabilities, they attempted to teach him an invented language known as Epun. This language includes both structure-dependent operations and structure-independent operations. Structure-dependent operations are the same kind of operations natural human language uses, basing the phrases and processes on structure rather than something else like linearity. The structure-independent operations are in direct conflict with Chomsky's idea of language and its inherent hierarchy.

One example of these forms, and perhaps the one most relevant to my paper, is the syntax of emphasis. In Epun, emphatic sentences are marked with an "emphatic marker … suffixed to the third orthographic word of the sentence – matrix or embedded – of which it is part" (Smith and Tsimpli 140-141). In other words, emphasis is always marked grammatically with a suffix after the third linear word, as seen in examples (10) and (11).

10) Fa zaddil-in ha-bol-u-nog guv.
The man-NOM PAST-go-3MS-EMPH yesterday.
"The man didn't go yesterday."

11) Lodon-in ha-bol-u guv-nog.
Lodon-NOM PAST-go-3MS yesterday-EMPH
"Lodon did go yesterday." (Smith and Tsimpli 140)

This is similar to imagining a language where negation is indicated with a morpheme after the third linear word. This can be seen in example (12). Instead, negation is indicated structurally; in English, the negation would be combined in Merge with the verb phrase being negated, such as in example (13).

12) He likes cherry not cheesecake.

13) He doesn't like cherry cheesecake.

If Chomsky is correct in his hypothesis that language is fundamentally structure-dependent, a construct such as emphasis in Epun or the made-up negation system in (12) should be impossible to acquire. Interestingly, the case study corroborated this hypothesis: "Christopher had no idea what to do with [the emphatic marker]" (Smith and Tsimpli 141). This was in contrast to the control, where Christopher was given the chance to acquire an existing human language, Berber, that he had no previous experience with; he was able to partially acquire the language and "the structural properties of the language led him to correct conclusions even in the absence of overt evidence" (Smith and Tsimpli 136). This provides extra evidence for structure-dependence in language.

In this paper, however, I will be examining a constructed language based exclusively in Merge. I will be imagining the feasibility of acquiring such a language. Will it be far easier than acquiring the constructed Epun, which at times ignores structure-dependence in its entirety? Or will it be of equal difficulty? This paper seeks to proposes potential answers to these questions.

3 Concept

The idea behind this project is to take Chomsky's theory of Merge and visualise it in all its non-linearity. To do this, I am crafting a constructed language that exists fully in three-

dimensional space. I am taking the ideas described by Chomsky and finding a way to imagine them without linear order getting in the way, so to speak. Basically, I am testing Chomsky's hypothesis. It is important to note that this is theoretical, and additionally makes no claim to state what language *exactly* looks like in our minds. Aspects of the visualisation are chosen for a variety of reasons, but ultimately it boils down to the judgement of myself and my committee. Nonetheless, this project is an exciting thought experiment and a glance into what it might mean when Chomsky discusses non-linear language.

3.1 Design Process

3.1.1 Blender

For some concepts as well as the final visualisation of my models, I used the open-source 3D creation software Blender. Blender has all the tools needed to create, rig, animate, and render 3D models, as well as various other functions needed for complete 3D animation. It is customisable with an API for Python scripting, although no customisations were made for this project. As an open-source, community-driven program, Blender is free to use for any purpose, including academic work.

3.1.2 Clip Studio Paint

For some concepts as well as surface rendering for my models, I used the digital art software Clip Studio Paint. Clip Studio Paint is a programme designed for drawing and painting as well as comic creation. I used the fill tool and the pencil tool in order to create the surfaces for the heads of my models.

3.1.3 Modelling Process

To build the final model, I worked primarily in Blenders Edit Mode in the Layout tab. This mode allowed me to use the loop cut tool to divide cubes into smaller faces, then use the extrude tool on the faces to create the arms seen in the model. Rather than eye the measurements, I directly imputed the same numbers each time. For aesthetic reasons only, I chose to subdivide the node to give it a smoother appearance. Once a single node was complete, I copy and pasted it and used the move tool to move it into place.

Again for aesthetic purposes, I worked in the Shading tab in order to colour each node. I colour-coded based on the type of head each node represented, going by grammatical category. I used blue for nouns, red for verbs, teal for determiners, gold for adverbs, purple for prepositions, and green for complementisers. I created the surfaces in Clip Studio Paint and handwrote the word in question on each face of the cube for ease of understanding. From there, I set these surfaces for rendering on my model.

In order to get images for this paper, I used screenshotting and cropping in Clip Studio Paint. I manoeuvred the model each time in such a way all the words were visible, once again for ease of understanding in this paper.

4 The Model

4.1 The Building Blocks

There are two building blocks for my visualisation of Merge: the heads and the Merger. Figure (6) below is a **head**. It is a simple block that can be modified to represent a morpheme. Figure (7) beside the head is the **Merger**. It has two structures for latching onto other structures,

either another Merger or a head. These structures, labelled in figure (7) below, are known as the **arms**. The Merger also has a **nucleus**, labelled below, consisting of one flat side and one extended side. Each Merger can only be latched onto by an arm on the extended side, as they cannot be a part of two constituents at once.

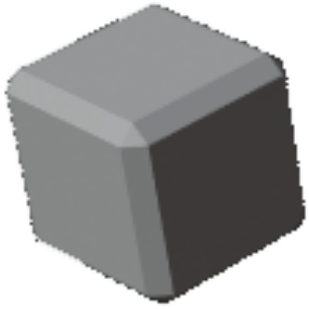

Figure 6: Head

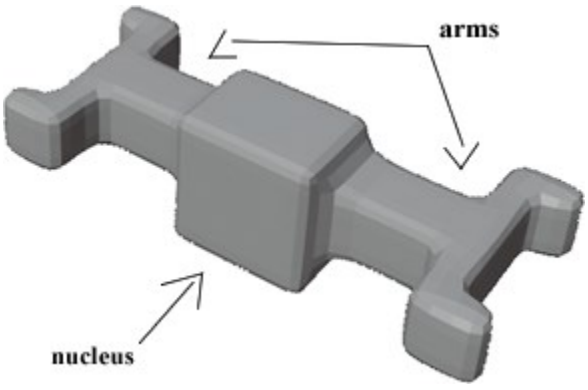

Figure 7: Merger

4.2 Basic Model

Now I will walk through a couple of example sentences. In each sentence, there is an arrow pointing to the top-most node, or the **root**, of the sentence. As mentioned before, they are colour-coded by for convenience, with blue representing nouns, red verbs, teal determiners, and so on.

14) The dog chased the cat.

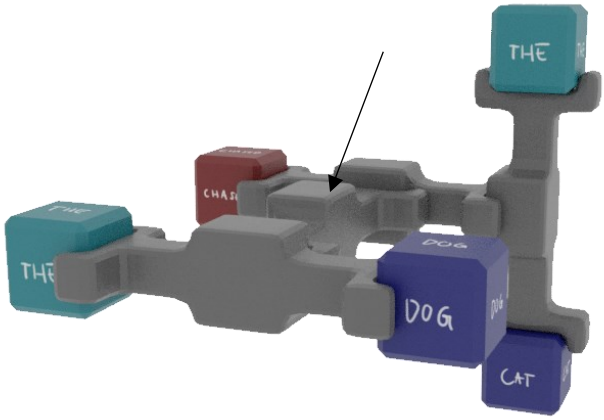

Figure 8: "The dog chased the cat."

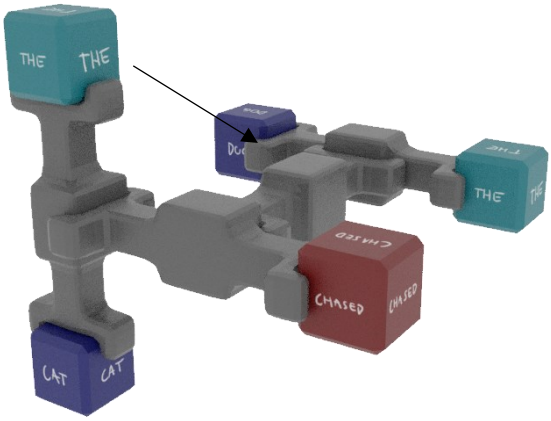

Figure 9: Alternate View One

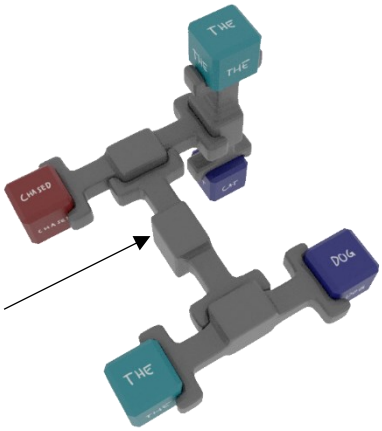

Figure 10: Alternate View Two

Above, we can see each of the combinations through Merge. *The* and *dog* combine to form *the dog*. *The* and *cat* combine to form *the cat*, which then combines with *chased* to become *chased the cat*. Then, we can see where the sentence "begins" with the only Merger that has not been latched onto by any other mergers. Mergers, again, are the grey objects with two arms; we can identify the root of the sentence by finding the Merger that is not "grabbed" by any other Mergers. This is the top of the sentence which connects the rest together. This Merger connects *the dog* and *chased the cat*. To latch onto these constituents, which each have their own parts, the head Merger grabs onto the highest Merger in each constituent. As you can see, each of these

structures I have outlined breaks into two separate parts and never more. *The* and *cat* must combine into *the cat* before they can be combined with *chased*. These, in turn, must be combined before they can Merge with the already merged *the dog*.

This form of representing Merge is not bound by one view, and can be seen from multiple angles and still understood. We can see examples of this in figures (9) and (10) above. All of these angles still represent the exact same sentence and structure.

4.3 Clarity in Structure

Now, I will demonstrate how the structural nature of these models is able to clear up confusion in meaning that occur in spoken language. Many ambiguities of spoken language occur because we cannot inherently know the underlying structure of a sentence from the beginning, which can lead to uncertainty and processing errors. I will refer back to examples used in earlier sections, specifically sentences (1), (2), and (3) and explain their models. For reference, the sentences are listed below:

1) Birds that fly instinctively swim.
2) Instinctively, birds that fly swim.
3) The horse raced past the barn fell.

4.3.1 Ambiguity in Meaning

Sentence (1) is based on the example that Chomsky uses to demonstrate why meaning cannot come from linear order, as sentence (1) has two different meanings. The first, meaning (a) is that if birds fly instinctively then they also swim, and the second, meaning (b), is that if birds fly they also instinctively swim. Note that the order of these meanings is at random, and the

"first" is not necessarily the default understanding. Just as sentence trees are able to distinguish the two meanings, my models below are able to show the same thing.

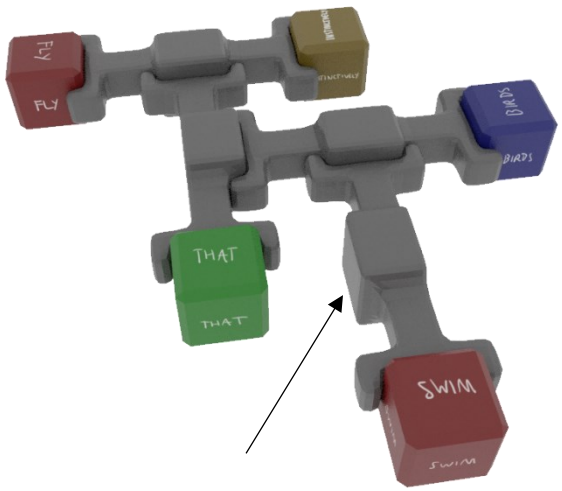

Figure 11: Meaning One

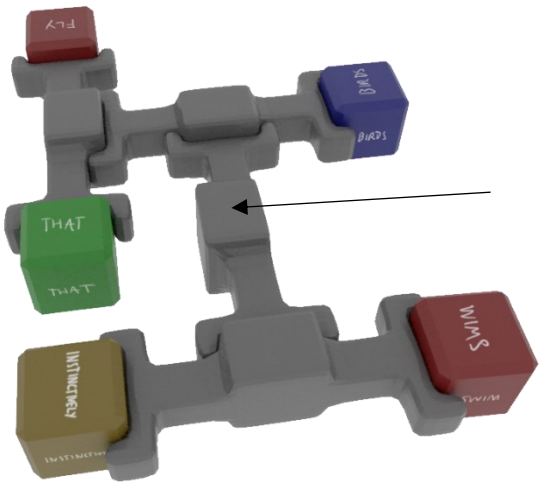

Figure 12: Meaning Two

The meaning is made clear by the position of *instinctively*. In Figure (11), it combines with *fly* to become *fly instinctively*, which then connects with *that* to become *that fly instinctively*, which then combines with *birds* to be *birds that fly instinctively*. Thus, it is clear that the thing that is instinctive is the verb *fly*. *Birds that fly instinctively* then combines with *swim* to form the whole sentence. However, in Figure (12), it is only *fly* that combines with *that*, and *that fly* that combines with *birds* to become *birds that fly*. Meanwhile, *instinctively* combines with *swim* to become *instinctively swim*. When these two elements combine, we have the whole sentence again, but this time the thing that is instinctive is the verb *swim*. It is important to note that the above configurations are not the only ones possible, and are in fact somewhat flattened and simplified.

As I discussed in an earlier section, the meaning of sentence (1) becomes clear in sentence (2) with the fronting of *instinctively*. Once this is fronted, only one interpretation is

available. Thus, there's only one possible option for where *instinctively* moved from in order to be fronted. It has to have been moved from a position where it was modifying *swim* rather than *fly*. If we look at the models to follow, we can see why that might be.

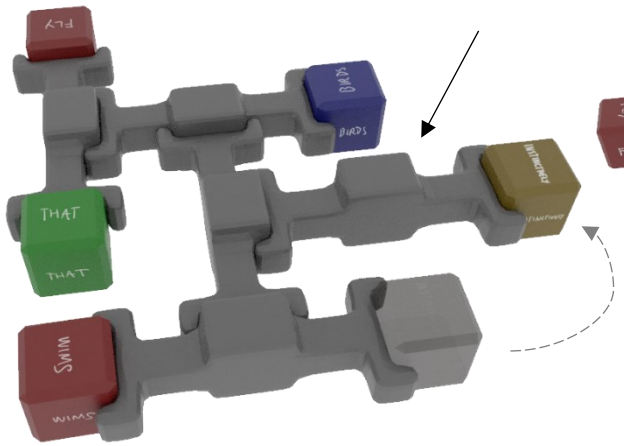

Figure 13: Correct Model for Sentence (2)

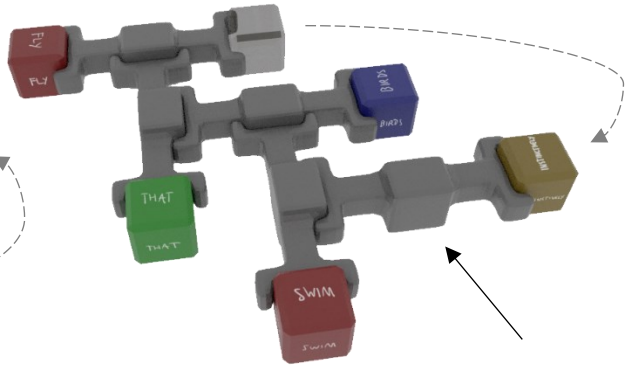

Figure 14: Incorrect Model for Sentence (2)

Figure (13) shows the grammatical representation of sentence (2). The dotted line shows the movement that has occurred. *Instinctively* has been moved out of the structurally closest constituent where it modifies *swim*. The transparent block in its original place is what is known as a copy, and it shows the other place *instinctively* is interpreted in the sentence. This is an example of Internal Merge.

To rehash what this means, Internal Merge is a type of Merge that takes an object that already exists in the structure and moves it to a different place in the structure, merging with the rest. According to Chomsky, we interpret the moved item in both its new and original locations on the structure. For the purposes of my model, I turned the original *instinctively* head translucent, while the moved one is solid as that is where it is heard out loud. Figure (14), on the other side, is not the correct way of representing sentence (2). In this figure, *instinctively* is the

structurally farthest away, buried within several layers of Merge instead of just one. This can be seen as well if you write “Birds that fly instinctively instinctively swim” and then change it to “Instinctively, birds that fly instinctively swim”. Only the *instinctively* modifying *swim* moves. This can be made even more dramatic by changing it to “Birds that fly naturally instinctively swim” and “Instinctively, birds that fly naturally swim”. By changing one of the adjectives (but keeping the same structure), you can clearly see which adjective is moving. Therefore, we can see that the grammatical reading is also the simplest one, falling in line with the idea that Merge is the simplest computation.

4.3.2 Garden Path Sentences

Sentence (3) is related to a different type of confusion in linear language. Rather than the inability to tell out of context which meaning is applicable, this sentence only has one meaning that is not obvious on first glance or listen. As discussed before, since English allows for the dropping of the complementiser *that*” or “*who*” and auxiliary “*be*” that would make things clear, “*raced*” can be interpreted as the main verb of the sentence rather than part of the phrase modifying “*the horse*”. This is called a reduced relative clause, and it’s incredibly common in English. You probably use them all the time to say things like “the coffee on the table” or “the girl dressed in a yellow shirt”. Yet in sentences like sentence (3) it can also be incredibly confusing. However, if we look at the figure (15) below, the structure of the sentence becomes clear.

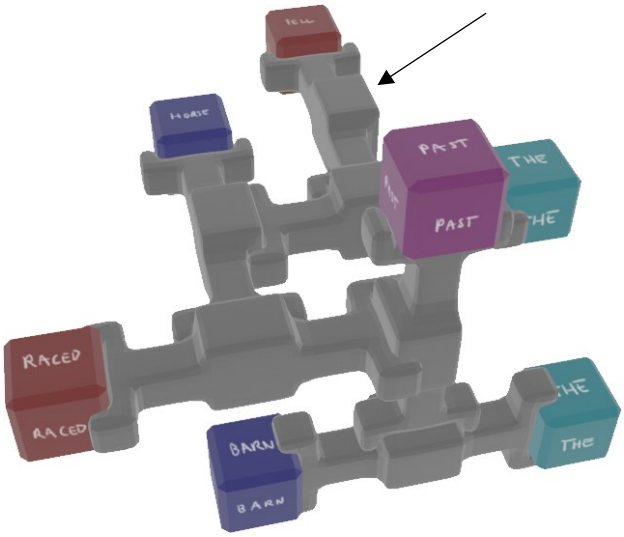

Figure 15: "The horse raced past the barn fell."

As we can see, *the horse raced past the barn* is connected by a merger to *fell*. Because this is a constituent connected to a verb, it must be a noun phrase rather than a full sentence in and of itself. As with all the others, these constituents can be broken down further as well. However, in this model, the structure is clearer, and we know from looking at it that something fell, and that something will be connected by the Merge connected to *fell*, thus making the thing that has fallen *the horse raced past the barn*.

4.4 Impossible Forms

Now that I have demonstrated the working models, I want to highlight some of the impossible forms it might look like this model can take. I will start with the form below in Figure (16).

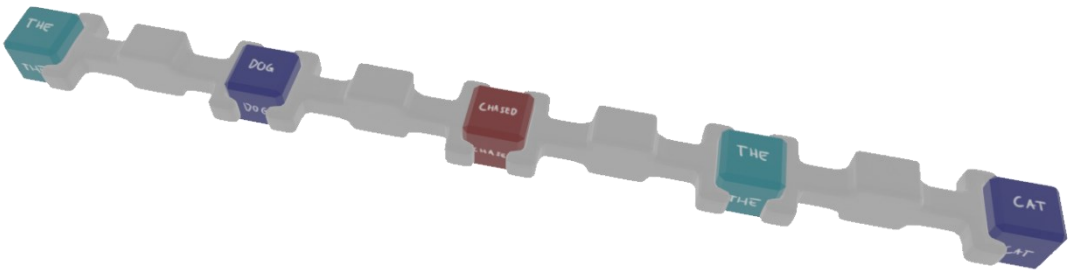

Figure 16: Error 1

This first error is fairly simple: this model has no structural form whatsoever. Yes, it uses Mergers to connect with only two things at a time. However, this is all done in linear order. Additionally, three of the five heads have been latched onto by two different Mergers, which would not be allowed in the model's accurate form. This gives these heads more than one parent, which is not at all possible, as well as erases the concept of constituents altogether. Thus, this form makes no sense.

Now, take the second error form demonstrated below in Figure (17):

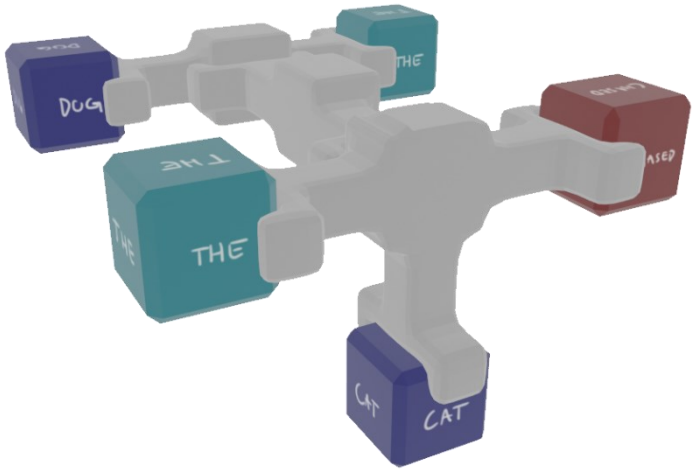

Figure 17: Error 2

In this figure, there is in fact structural integrity. However, this model breaks the rule of two, allowing three connections to a single Merger. Instead of *the cat* combining with *chased*, we have *chased* combining with both *the* and *cat* separately. This would not be possible. There is a piece of structure that doesn't exist in my model of Merge, nor would it exist in any model of Merge. Merge joins two items; this model joins three.

4.5 Possible Errors

The next error I would like to demonstrate is one a little more subtle but also very important. This is something completely possible within the form of Merge and within my model. It uses

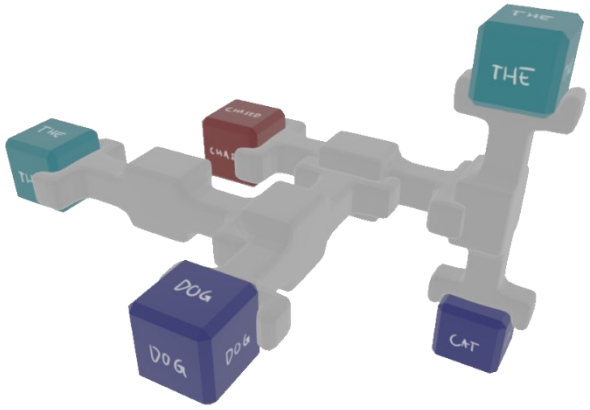

Figure 18: Error 3

the same forms, the same objects, one parent per head, two objects per Merger. However, it is ungrammatical as a full sentence in English. Figure (!8) below shows this error.

In this model, *the* connects to *dog chased the cat* rather than connecting to *the dog* and then connecting to *chased the cat*. However, this ends up implying that *dog chased the cat* is a constituent. As we saw with sentence (3), this is a possibility – just not as a full sentence. Pairing it with a determiner like "the", as well, implies that this constituent is a noun phrase. Ultimately it is important to recognise that neither Merge nor my model can be the end-all-be-all of any language – only a starting point from which to build.

5 Discussion

5.1 Relation to the Field

In a paper like this one, it can be difficult to relate it to the field. Primarily, this experiment serves as a potential three-dimensional representation of Chomsky's Merge. The fact that it is possible to construct something like this in a way that makes sense certainly suggests

something in support of Chomsky's ideas. However, there is nothing that can be said concretely either way using this model. However, the model is able to highlight aspects of Chomsky's theory that aren't well recognised, as well as make the proposal clearer for readers who cannot quite grasp it.

Overall, however, this project serves as a different kind of approach to a research paper. It takes a well-known idea and provides an exercise in imagining what the theoretical would look like if we could actually see it. It is something not done often in the field, and hopefully provides a fresh perspective to the theory of Merge.

5.2 Feasibility Based on Current Theories

Theoretical exercise or not, how feasible would a three-dimensional, purely hierarchy-based language be for language acquisition based on the current theories we have today? Ultimately, the answer would depend heavily on which theory we look at.

For Chomskian universal grammar theories, specifically the one we based this on which states that Merge is a fundamental building block of language, this language should be as easy to acquire as any human language that exists, if not easier. Without obscuring Merge behind the linear order and structures of spoken and signed language, theoretically, this language would be simple to understand and perhaps even quicker to acquire.

However, in usage-based grammar theories, the water is muddier. At first glance, it seems this language would be acquirable in these theories through ample input and exposure. But things aren't so simple with a non-linear, hierarchical language like this. First of all, children acquiring language would have to process a configuration from several angles as the same syntactic structure. In spoken or signed language, the words and phrases and structures are heard

or seen the same every time, although with varying prosodies and whatnot. However, not only would they have to deal with seeing the configuration from different angles, the configuration itself can change and mean the same thing. As I discuss in earlier sections, there's no reason for the layout to be exactly the same every time, as long as things are lined up in the correct hierarchy. In figure (8), there's no reason *the* should be visually above *cat* and not vice versa, as long as they are connected by a Merger. This would make it significantly more difficult to acquire. Would it be *impossible*? I don't necessarily think so. But the difficulty makes it less feasible under usage-based theories.

To imagine this in action, I want to refer back to Smith and Tsimpli's case study on the savant Christopher. Would he be able to acquire a language based in my model? While the new modality may prove somewhat difficult, I believe Christopher would be able to acquire such a language because it is based in structure-dependence as "the structural properties of the language led him to correct conclusions even in the absence of overt evidence" (Smith and Tsimpli 136). If this were the case and Christopher or someone like him could acquire a language based in my model, it would provide further evidence towards the importance of structure-dependence.

5.3 Accounting for the Combinatorial Property of Language

Merge, as a concept, is almost completely unbounded. There are no restraints on what X and Y can be, only that only two things can combine at any given time. Therefore Merge and my model of it would completely allow for sentences like sentence (8):

15) *I sleep the baby.

This sentence in English is entirely ungrammatical. Yes, "sleep" is a verb, but it is an intransitive verb now being used in a transitive environment. A listener could likely glean approximately the

meaning of this sentence – something along the lines of "I put the baby to sleep." – but they'd also likely conclude that perhaps they need to "sleep" the speaker. But Merge fully allows for this ungrammatical sentence. If Merge will allow for it, how can we account for the grammaticality – or lack thereof – of statements like this?

Ultimately the explanation for this lies outside of Merge and further into specific languages' grammars. In English, an intransitive verb cannot be followed by an object. Therefore, sentence (8) is ungrammatical. One can think of such things as *conventions* of a language, where Merge can be a rule. Though conventions vary by language, Merge is followed by all languages. However the conventions are also needed for a full-fledged languages, and thus, as I mentioned before, Merge and my model are not and should not be considered the only grammar of a language.

5.4 Future Directions

In terms of future directions this research can be taken, it is important to note once more that this concept is highly theoretical. However, it can be further developed by collaboration and getting judgements from more people. While I was able to formally discuss my model with my advisor and informally discuss my model with friends and family, this small sample of informal judgements is not enough to determine anything. Allowing the concept to expand and gain suggestions from multiple pairs of eyes will allow it to take on a potentially more natural form.

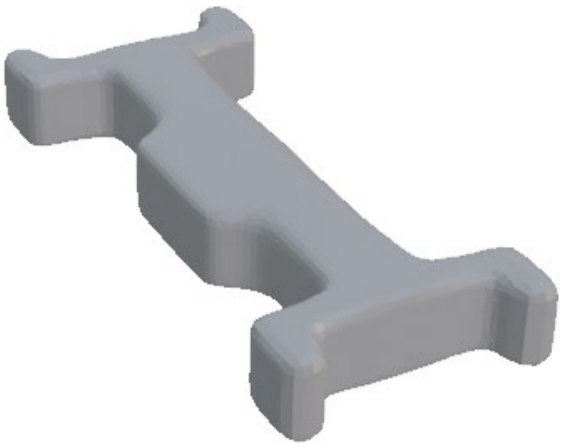

Figure 19: Revised Merger

Additionally, further revising of the model is necessary as it is not as fully refined as it can be, especially with additional judgements. For example, the model currently allows for Mergers to be latched onto in multiple places rather than just one, as the top and bottom of the model extends as well as the side. Figure (19) to the left is a better example, as the top and bottom are now flattened while the side is extended to be latched onto. As we can see, there is now only one spot where the Merger can be latched onto by another Merger, rather than the three that existed before.

On a longer term and more hopeful track, if this were to become something that starts to veer out of the theoretical and into the feasible, it might be interesting to work with brain scans in order to see how people might process this model. Would it be processed more as a puzzle? Or could it be processed as a language? Would that depend on the exposure to it? Could children process it better than adults? If it could indeed be processed as a language, then perhaps it could show us a lot about what can and cannot *be* Language and how language is processed in the brain.

6 Conclusion

Throughout this paper I have looked at the proposed hierarchical structure of language, examining the evidence for structural dependence and arguments to the contrary. My paper takes a highly theoretical approach to looking into this topic using Noam Chomsky's hypotheses about the internal structure of language, Merge, and unbounded system which combines two and only

two objects together to form a new object, which can then go on to combine with another object and so on. I devised a constructed language that exists in three-dimensional space in order to further explore Merge and its place within human language.

Language and its inner workings are still something that mystify linguists. While this model is not perfect and certainly does not claim to be the perfect grammar system for all languages, it is a glimpse into the internal structure of language that Chomsky proposes underlies every human language we know.

7 References

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8 Appendix

8.1 Creative Work: Theoretical Plan

As an extra way of theoretically testing the hypothesis, I have additionally devised a potential play that could explore the process of learning a language based in this model. If humans were faced with acquiring this language, would they be able to? By all rights they should be able to, if Chomsky is correct. This play would look at the difficulties faced learning it as an adult – and the theoretical ease of learning it as a child.

This creative work draws inspiration from the structure of a section of a play called *Fefu and Her Friends*. The idea of structuring my play relative to the language itself led me to the structure used in this section, where the audience travels between scenes in no specific order, split into parts. Therefore, to highlight the way my model can be understood starting from any point, I set up the creative work in this way as well.

While for now this remains the plan of a play and not yet a play itself, further directions could include fully fleshing out the play itself.

1. All scenes should be occurring at once on different stages connected by walkways, perhaps even in the shape of the Merge language.
2. Scene A
    a. We're on a ship bound for a planet far away, but not too far - five to ten light years, a long but reasonable journey. Our main character is a young linguist, with her partner and a infant-to-toddler daughter.
        i. The team is going to make first contact with an alien civilisation on this other planet. They have been tasked with learning their language before they arrive, since the aliens went out of their way to learn Earth languages.

ii. They were even given plenty of samples!!

1. The problem: the samples are these weird 3d structures. MC cannot parse them.

a. But the child is immediately intrigued by them. MC brushes it off as baby saw a new thing

3. Scene B

a. We're on a ship bound for a planet far away, but not too far. The child is older now, well into language learning, fluent in her mother tongue.

i. MC is working with the language again. She's starting to figure out the lexicon, but the syntax is still baffling her. Every time she thinks she's found a word order, two more "sentences" prove that wrong. Maybe it doesn't have a super solid word order? There are languages on Earth like that.

1. But the child is curiouser and curiouser by the day. Her building blocks are starting to take familiar shapes.

4. Scene C

a. We're on a ship bound for a planet far away, but not too far. The child is old enough now, maybe 6 or 7. No one really knows they're bilingual.

i. MC is still working with the language. She has the lexicon and she's starting to get the structure. It seems familiar. It's hierarchically structured as if should be.

1. The child has been drawing the structures but she finds the tech that was provided in order for the humans to produce the structures.
2. Get to watch the child start to learn this technology.

ii. MC discovers the child's proficiency and starts working with her.

1. Discovery: this is literally Merge. It's the same as the theory for human language.

5. Scene D

a. We're on a ship almost to a planet far away, but not too far. The child is gaining on ten now. They arrive and greet the aliens.

i. MC is able to use the tech haltingly to produce the structures. But, as she tells them, they have a young one who can produce them perfectly.

1. The child gets to show off their skill! The mundane but miraculous human language acquisition - UG given strong evidence in this child who so easily picked up this explicitly Merge-based language.

a. The aliens are rightfully pleased by this and welcome the humans.

8.2 Concept Sketches and Sculptures

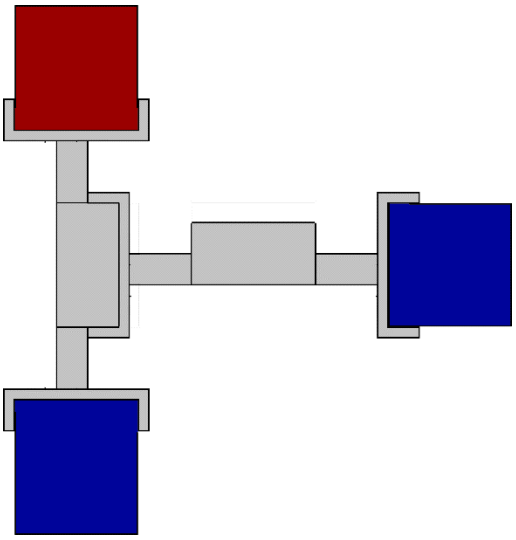

Figure 20: Final Concept

This concept is visually interesting and unique. It allows for us to distinguish heads through the lack of "arms" branching out, and with these two arms it allows us to demonstrate that Merge only allows for two elements branching off. It is the clearest to follow, and is able to show movement fairly well. Ultimately, this is the concept chosen for the modelling process, and will be explained in more detail later in the paper.

Figure 21: First Concept

This concept, one of many made with Play-Doh, has the benefit of being visually recognisable when compared to the traditional X-bar syntax trees. It is clear where things branch off and connect. However, it has the disadvantage that it is difficult-to-impossible to distinguish heads. It may be too much like a tree, and has no real way to show movement. Most importantly, it cannot demonstrate that Merge consists of two elements only, and so was set aside.

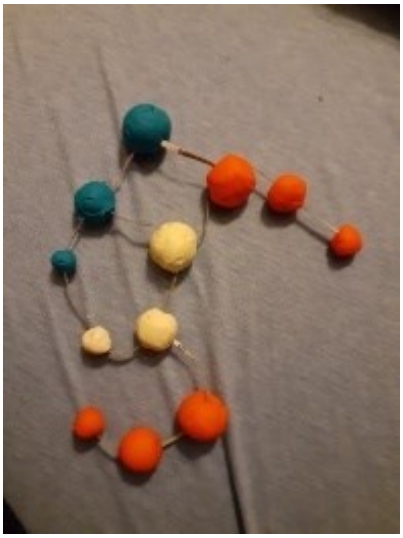

Figure 22: Second Concept

Much like its above cousin, this concept is visually recognisable compared to trees, somewhat clear where things branch off, and has the advantage of trying to show movement. However, this movement is extremely unclear. Like its cousin, it is hard to distinguish heads and maybe too much like a tree.

Figure 23: Third Concept

Finally, and once more most importantly, it can't show that Merge uses two elements.

This next concept has the advantage of having some distinguishing of heads through their size. It is fairly clear where things are connected, and it is visually interesting and distinct. However, it is difficult to clearly show movement, and heads are still a bit difficult to see.

Additionally, heads are in different sizes. Once again, in this form, this concept still cannot show that Merge uses two elements.

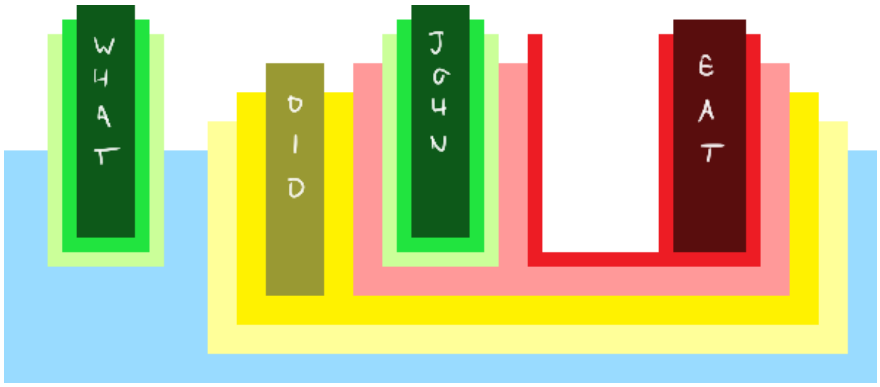

Figure 24: Fourth Concept

This concept was one of the few done in 2D first. Like concept three, it has some distinguishing of heads. It is clear where things are connected, and it is visually interesting and distinct. It even has the ability to show movement. However, heads are still a bit difficult to see, and as in concept three, elements are not all the same size, leading to confusion and difficulty processing. Finally, and again most importantly, this concept cannot show that Merge uses two elements only.