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# Three-Dimensional Constraints on Human Cognition as Expressed in Human Language

Christopher Adam

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**THREE-DIMENSIONAL CONSTRAINTS ON HUMAN  
COGNITION AS EXPRESSED IN HUMAN LANGUAGE**

**by**

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**DISSERTATION**

Submitted in Partial Fulfillment of the  
Requirements for the Degree of  
**Doctor of Philosophy  
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## ACKNOWLEDGEMENTS

بسم الله الرحمن الرحيم

This dissertation represents the culmination of a decade of work, combining research of phenomena from linguistic typology, cognitive psychology, and biology, and using calculus to unite them under a single principle.

Three systems previously in place have made possible the observation of the phenomena in question. The first and most important of which is the natural array of observable facts in the world's languages that I lived in the midst of and performed daily tasks in while spending time either in the continents where they are spoken or simply in the greater Los Angeles area I am native to, which according to some estimates is among the cities with the most language diversity in the world (Lundy, 2003, p. 73).

The second is a long-spanning tradition of unbiased fact collection in human languages, starting with the phonological analysis of Panini in the 2<sup>nd</sup> Century, the morphological analysis of Dionysius Thrax in the 3<sup>rd</sup> Century, and the head-dependent syntactic analysis of Sibawayh in the 8<sup>th</sup> Century, and continuing to this day with the work of Ian Maddieson, William Croft and John Hawkins respectively.

The third system in place is Western academia, a flawed but functional system which does not always put scientific progress before politics, but tolerates inconvenient new discoveries enough to generally allow for progress even with the occasional bit of delay.

While the Movement-Based Grammar paradigm of Noam Chomsky has dominated the study of linguistics in America and much of the West for roughly half a century, history might very well look back on my mentor William Croft as the most

important theoretical linguist of the last thirty years. The empirically rooted nature of his work has exposed flaws in approaches which rely too heavily on deductive hypotheses that are based on small data sets. No less importantly, his trailblazing has encouraged other non-orthodox linguists to explore avenues deviating from conventional approaches. As such, while few can claim as their legacy the creation of a comprehensive theoretical framework and a corresponding school of thought, Dr. Croft, whether intentionally or not, can additionally claim being the face of the opposition to the Chomskyan megalith, and accordingly of a force of inspiration representing freedom of exploration and expression not only of new ideas in established alternative paradigms like his own but of entirely new modes of thought.

Similarly, while too many American linguists have become complacent with relying on and trying to make sense of previously recorded data, my former mentor at UCLA, Pamela Munro, has taken the initiative to seek out and deal with the new inconvenient data of less-documented indigenous languages of the Americas and Africa, all the while working on projects aimed at preserving the languages and the cultures they are part of. Following her lead, I have found myself seeking out and living among communities of endangered languages, hoping to do my part to preserve them through literacy which allows for the transmission of them, e.g. the morphophonology which constitutes my MA thesis (Adam 2003). And like her, I have come away with a better idea of how diverse and yet how similar human languages can be.

Likewise, Melissa Axelrod has worked with the less-documented languages of the Americas in an attempt to preserve this valuable information, which continually finds itself encroached upon by the influential media of the dominant world languages,

especially English and Spanish. Of critical importance to my work is not only the admirable purpose which drives Dr. Axelrod's research but also the vast body of knowledge that she brings to the table as a theoretical linguist who has not simply studied the details of a few familiar languages but rather one who lives immersed in a great number of languages as part of her regular lifestyle.

Ian Maddieson's work has closed the gap on what patterns we can expect to see in languages. In one of his landmark studies wherein he compiles and analyzes cross-linguistic patterns from 421 languages, he has not only clearly laid out limits on what languages regularly appear to do and not do, but through this body of data, he has also encouraged unique quantitative research of the sort which has led to valuable discoveries beyond the scope of his original work, bodies of research which in their own way have shed light on what languages appear to regularly do and not do.

Sharon Klein, the chair for my master's thesis at California State University Northridge in 2003, taught the syntax and morphology classes which shaped my views on these areas of inquiry more than any subsequent classes I have taken. Her inductive method of instruction, informed by (but not constrained by) prominent formal theories, encouraged and enabled me to synthesize what I find most useful from all existing theories and to explore totally new ways of analyzing language. The bulk of my work outside of this dissertation, which deals with the model of Equivalence Based Grammar (Adam, n.d.; Adam & Marks 2014b; Adam & Marks 2014c), is directly impacted by her lectures and assignments fifteen years ago.

No less crucial than the particular members of my committee is the environment of the linguistic department at the University of New Mexico itself. I am not familiar with

a department anywhere which manages to maintain a non-dogmatic approach, despite boasting of world class scholars working from a particular orientation. If more departments functioned this way, then linguistics as a science would likely have evolved much faster over the past half century. I can only hope that in coming decades more universities pursue this model of tolerance coupled with a strong regard for both inductive and deductive forms of analysis.

John Hawkins' work has been essential to my research, and during the brief time he guided my work after accepting mentorship over me, his work and personal guidance helped me patch in a number of pieces of the still incomplete quilt of my theory.

Calvert Watkins, who has seen my theory develop since I first started presenting it at UCLA, has played as much a part in his personal recommendations to me as his landmark work had on me before he began attending my presentations.

While most know Edward Keenan as one of the great names in linguistic typology, those at UCLA also know him as the creator of his own paradigm, one which strongly inspired the model expounded herein. His feedback and reading-list recommendations were instrumental in motivating me to explore questions of where recursivity in language use breaks down.

Aaron Marks, my co-author in a number of studies—related to this work in content and/or method—has provided invaluable feedback on this analysis for more than a decade. His rigorous data-collection methods have set the pace not only for our work together (Adam & Marks 2013; 2014a; 2014b; 2014c; 2015), but also for what I have written on my own, including the present work.

I might not ever have become interested in linguistics if not for both of my bilingual grandmothers, Raquel Ruiz-Adam and Cleopatra Georgeadis, along with my bilingual mother, Daphne Georgeadis-Porter, who all did their part in helping me learn our family languages of Mexican Spanish and Anatolian Greek.

I maintain a similar interest in the spoken languages of the world to this day in the company of my multi-lingual wife, a native speaker of Arabic, Kawthar El Elaoui, who is a constant source of data and ideas for me, especially with the attention she gives to our children, Salāḥuddīn and Maryam, learning Arabic.

Other speakers of the languages which I have learned to speak and/or read have opened my mind to the diversity of constructions and construals in human language. This includes all the speakers of Arabic who have patiently helped shape me into the fluent speaker it took me years to become. It also includes the speakers of Dihidx Bilyáhab who in the early 2000s taught me their language, of which I would later go on to write the first morphophonology for my master's thesis (Adam 2003). These two languages, more than any others, along with the linguistic tradition of the former (i.e. that of the 8<sup>th</sup>-Century Arabic grammarian Sībawayh), have helped me understand and address the gaps which need to be filled in most Western concepts of grammar.

Among fellow alumni from my undergrad alma mater of UCLA, none stand out more than Brandon Esten, who, in addition to collaborating with me in professional writing ventures outside of linguistics (Lee & Esten 2014),<sup>1</sup> has also provided invaluable feedback to assist me in expressing my linguistics-related ideas to non-linguists.

My father, Fred Adam VII, who just passed away less than a year ago, carried on a long legacy of manual labor which his father (Fred Adam VI) and his father's father

---

<sup>1</sup> Written under the pen name of Brutus J. Lee.

(Fred Adam V) inherited. The front page of the first *Los Angeles Times* ever printed in 1881 attests to this with an advertisement for the tailoring business of my great-great-great-grandfather (Fred Adam IV) in what is now referred to as Downtown L. A. (“Business Cards” 1881: 1). Even though my father got a degree in biology, he never ventured to leave the blue-collar labor force, let alone obtain a higher degree; however, he supported my decision to pursue an education up to the doctoral level (despite this decision coming at the cost of many practical opportunities to earn steady money along the way), and I wish he could have stuck around another year to see me finish this dissertation.

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**ABSTRACT**

Those advocating the existence of a distinct language instinct generally claim that human language is not reliant on general human cognition. However, limitations on recursive patterns in human language are universally attested, from the micro-level elements of phonology, throughout the mid-level elements of morphology and syntax, and up to the macro-level elements of reference in discourse. What these limitations appear to reveal is a pattern seen in other areas of human cognition, namely the human inability to actively recall and balance more than three interdependent variables at a time. Building upon these data patterns and an array of typological postulates, the theory developed in this work offers an alternative lens through which to view language as a landscape of three-dimensional cube patterns which routinely simplify to the two-dimensional square level but never venture up to the four-dimensional tesseract level. Since a better understanding of how the human mind processes information can come by way of knowing how the human mind does not process information, the findings in this

study, if borne out herein and beyond, promise to additionally inform cognitive science, computational linguistics, and artificial intelligence.

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# **1. Introduction: Three-Dimensional Constraints on Interdependent Structures in Human Language**

When you can measure what you are speaking about, and express it in numbers, you know something about it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science.

– Lord Kelvin (as cited in Lindley 2004: 294)

Various levels of linguistic analysis have traditionally been treated as entirely distinct realms, overlapping only with their nearest neighbor, e.g. syntax and morphology constituting morphosyntax, with morphology and phonology constituting morphophonology. This analysis attempts to unite even the non-neighboring areas of analysis under a single umbrella by examining the patterns of recursion which share common limitations, the goal being to provide a view of grammar as unified and linked to more general principles of cognition, as argued for within cognitive linguistics (Croft & Cruse 2004: 328; Langacker 2008: 8).

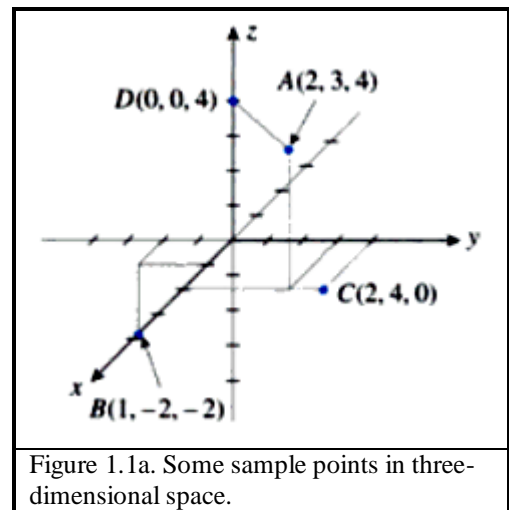
The limitations that these various levels of linguistic phenomena have in common are not only defined by commensurate variable-tracking tasks but also share the common trait of variable interdependency, and a constraint on more than three interdependent variables.

## **1.1. The Scope of this Analysis**

In all areas of linguistic analysis, from the most macroscopic to the most microscopic, the human mind appears to be capable of a cognitive manipulation of up to but not beyond three interdependent variables. The interdependency of these variables is such that one variable cannot be interpreted without reference to the other two, as is the case with a three-dimensional calculus function of the sort illustrated in Figure 1.1a (Tan

2006: 540), where we see that any given specific point cannot be spatially plotted without reference to all three variables in relation to each other. Likewise, when engaging in the linear task of spoken language, at the peak cognitive point of reaching the third variable, the interlocutor must deal with a given variable and interpret it with relation to two previously uttered variables, thus juggling a maximum of three interdependent variables, one being currently manipulated and two others being simultaneously recalled in anticipation of their complements.

What this hypothesis entails is not simply an interrelation between a number of interdependent variables in various human-language constructions but also a strict limitation on which types of thoughts humans are able to process in their use of language, thus addressing a perennially recurring problem in decision theory



(Bermúdez 2009; White 2009; Parmigiani & Inoue 2009), as well as in the design of neural networks in artificial intelligence (De Paz 2009; Maskara & Noetzel 1992)—this discussion is taken up in more detail in §6.6.

The following section analyzes the highly macroscopic level of reference,<sup>2</sup> focusing on recursive thought patterns such as *They know [you know [they know]]* (Winks 1996: 423) and how they are reflected in mental spaces, discrete propositional units, which can be nested inside of each other, as seen in (1). These structures occur with some regularity (Cohen 2010: para. 4); however, they are confined to representing three

<sup>2</sup> I here use “reference” to include what Hinzen & Sheehan (2013) refer to as either “grammatical reference” or “content nominals” (p. 209).

levels of thought (Cohen 2010: para. 15; Winks 1996: 423)—key recursions of mental-space builders appear in boxes for emphasis.

- (1) She knows<sub>x</sub> [that he knows<sub>y</sub> [that she knows<sub>z</sub> [which shell they're looking at]]

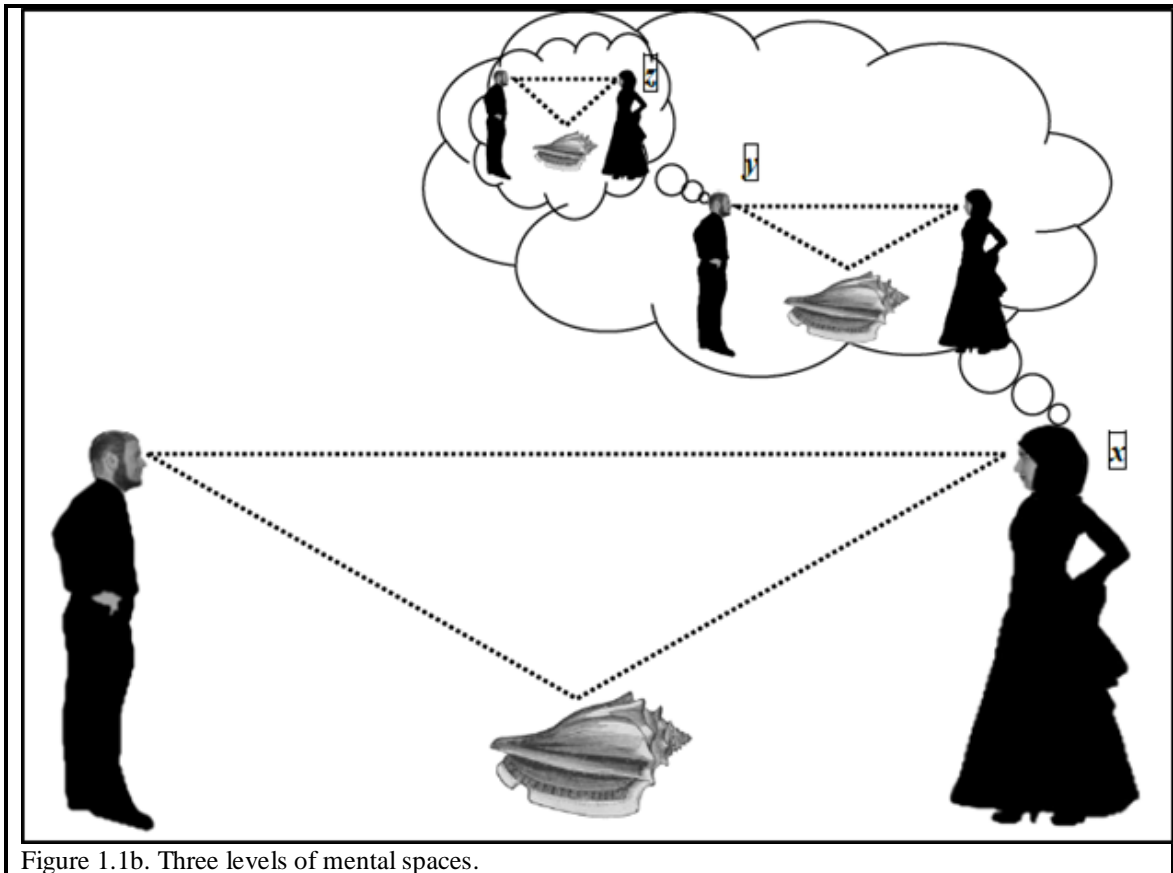


Figure 1.1b. Three levels of mental spaces.

At the peak cognitive point of reaching the  $z$ -value [that she knows <sub>$z$</sub>  [...]], the interlocutor has the task of dealing with this variable and interpreting it with relation to the  $y$ -value [that he knows <sub>$y$</sub>  [...]] and the  $x$ -value [She knows <sub>$x$</sub>  [...]], thus interpreting a maximum of three interdependent variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements. Figure 1.1b illustrates two things, first that the participant on the right is aware ( $x$ ) of the existence of something, second that she knows ( $x$ ) that the other participant is aware ( $y$ ) of the existence of such a thing (Fauconnier 1994: 15, 101), even if their understanding of that thing is distinct at a

fine-grain level (Fauconnier 1994: 59-62), and third that she knows ( $x$ ) that the other participant knows ( $y$ ) that she is aware ( $z$ ) of the existence of such a thing.

Zooming the lens in to syntax (as developed in §3), a level less macroscopic than reference, sentences do not go beyond the juggling of three interdependent variables. As Karlsson (2007) demonstrates with his corpus study, written language does not go beyond three levels, and spoken language almost never goes beyond two. The sentence in (2) is a rare instance of media English, a genre intended to be easily understood, using all three variables.

- (2) # ... the agreement <sub>$x$</sub>  [under which the man <sub>$y$</sub>  [that many Germans <sub>$z$</sub>  call <sub>$z$</sub>  “the father of MP3”] came <sub>$y$</sub>  to work at one of the premier U.S. research labs] was <sub>$x$</sub>  not as clear as it could have been... (Shinal 2007: para. 1)

As seen in Figure 1.1c, while producing or processing the expression in (2), the interlocutor has to keep in mind an unfinished level of a sentence to be picked up again after lower levels are resolved, in essence forcing the interlocutor to conceptually hop between the different sides of a valley, with walls consisting of incomplete antecedent thoughts, whose complement is equi-level on the opposite side—key antecedents and consequents appear in boxes for emphasis.

Level X	[... the agreement <sub><math>x</math></sub> was <sub><math>x</math></sub> not as clear as it could have been...]
Level Y	[under which the man <sub><math>y</math></sub> came <sub><math>y</math></sub> to work at one of the premier US research labs]
Level Z	[that many Germans <sub><math>z</math></sub> call <sub><math>z</math></sub> “the father of MP3”]

Figure 1.1c: A conceptual three-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

At the peak cognitive point of reaching the  $z$ -value [that many Germans <sub>$z$</sub>  call <sub>$z$</sub>  “the father of MP3”], the interlocutor has the task of dealing with this variable and interpreting it with relation to the  $y$ -value [under which the man <sub>$y$</sub>  [...]] and the  $x$ -value

[the agreement<sub>x</sub> [...]], thus interpreting a maximum of three interdependent variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements. Such limits on the processing of center-embedded structures in human language use are corroborated in other work (Bach, Brown, & Marslen-Wilson 1985; Foss & Cairns 1970; Marks 1968; Miller 1962; Miller & Isard 1964) and replicated in computer simulations (Christiansen & Chater 1999).

Likewise, at the more microscopic level of morphology (as developed in §4), human language does not go beyond the juggling of three interdependent variables of the sort seen in (3), where a singular quadriliteral (i.e. four-consonant) noun in Arabic uniformly takes the discontinuous three-vowel pattern  $a_x \cdot \bar{a}_y \cdot i_z$  to inflect for plurality (Wehr & Cowan 1979: 853), as in (4)—vowel patterns appear in boxes for emphasis.

(3) « فندق »  
 FuNDuQ  
 ‘a hotel’

(4) « فنادق »  
 FaNāDiQ  
 ‘(some) hotels’

In Figure 1.1d, the inflectional vowels are presented on a distinct tier from that of the templatic root consonants for illustrative purposes.

f(PLR)			·a <sub>x</sub>		·ā <sub>y</sub>		·i <sub>z</sub>	
ROOT	—	F	—	N	—	D	—	Q

Figure 1.1d: A discontinuous quadriliteral (four-consonant) template with discontinuous plurality morphology inserted into it at three distinct points.

At the peak cognitive point of reaching the z-value  $\cdot i_z$ , the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value  $\cdot \bar{a}_y$  and the x-value  $\cdot a_x$ , thus interpreting a maximum of three interdependent variables, one being

manipulated and two others being simultaneously recalled in anticipation of their complements. Such limits on the processing of analogous cross-dependency structures in human language use are corroborated in other work (Dickey & Vonk 1997) and replicated in computer simulations (Christiansen & Chater 1999).

Finally, at the highly microscopic level of phonology (as developed in §5), human language is not attested to go beyond the juggling of three homophonous segments belonging to distinct morphemes, of the sort seen in the Arabic of (5) (Al-ʔalbānī 2001: 1130), and even in such cases when this happens, haplology often collapses the first two identical syllables (De Lacy & Nowak 1999: 1, 2-6)—key homophonous segments appear in boxes for emphasis.

- (5) « أن تتتابع الآثار »  
 ʔan ta<sub>x</sub>·ta<sub>y</sub>·tā<sub>k</sub>biʕ·a l·ʔāθār·u  
 CMPL <sup>⚡</sup>:PL·REFL·succeed·SV DEF·effects·NOM  
 ‘that the effects succeed one the other’

At the peak cognitive point of reaching the z-value  $tā_z$ , the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value  $ta_y$  and the x-value  $ta_x$ , thus interpreting a maximum of three interdependent variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements.

As seen in the following chapters, while each of the foregoing levels of linguistic analysis, from reference to phonology, is constrained by a similar limit on the number of interdependent variables, any combination of these variable-balancing tasks only further burdens processing; it does not alleviate it.

## 1.2. Observed Pattern of Degradation

Throughout this analysis, data (both first-hand and second-hand) is observed to reveal the following pattern of degradation: 1 variable processed (maximally comprehensible and dominant in corpus searches), 2 interdependent variables processed (highly comprehensible and common in corpus searches), 3 interdependent variables processed (minimally comprehensible and rare in corpus searches), 4 interdependent variables processed (generally incomprehensible and absent from corpus searches).

Figure 1.2a provides a rough visualization of this degradation pattern.

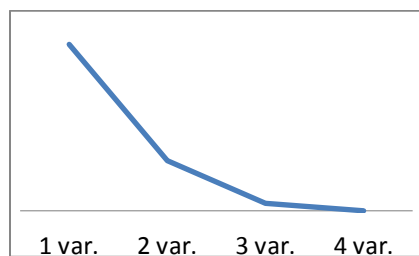


Figure 1.2a. Rough Visualization of Degradation Patterns as seen throughout the following chapters.

While the specific patterns of degradation vary from one area of investigation to another, the extreme drop after three interdependent variables is common to all areas under investigation, though it is also often the case that the use of three interdependent variables is so low that it is almost entirely absent.

Of important mention here is the concept of soft constraints (Bistarelli 2004: vii). The bulk of this analysis comprises hard constraints, i.e. boundaries which cannot be transgressed either willingly or unwillingly in natural speech; however, a small number of phenomena discussed are soft constraints, i.e. boundaries which can be transgressed willingly in natural speech, but this happens so rarely that, in data across corpora, such transgression almost never occurs. The fact that such soft constraints share the same three-dimensional cap as hard constraints makes them worthy of discussion herein.

### **1.3. The Traditional Appeal to “Reason” as the Limiting Factor**

Although the question of variable balancing has been brought up in linguistic inquiry for much of the last century, a common claim among prominent scholars has been that this sort of interdependent variable limitation is a result of humans constraining themselves in their usage, rather than them being constrained by forces beyond their control. For example, with regards to embedded reference of the sort seen in (1), Lewis (1969) claims that speakers are constrained by “ancillary premises about rationality” (p. 55). Chomsky and Miller (1963) make a similar claim for variable balancing in syntax of the sort seen in (2).

In addition to being much more difficult to measure than simply counting the number of interdependent variables, the claim of human rationality working as a constraint on the number of interdependent variables presupposes that any lack of rationality augments one’s faculty to balance such variables. One problem with such a perspective is that it has yet to be shown that the rationally challenged excel in processing such constructions.

The present analysis is the first to propose a specific number of interdependent variables by which all such constructions are commonly bound. It concludes by extending this analysis to other areas of general human cognition and proposes an evolutionary explanation.

### **1.4. Connectionist Models and their Applicability to the Analyses Herein**

Connectionist approaches to computation consist of models informed by psycholinguistic and acquisition data, with the aim of replicating human language

acquisition and interaction (Christiansen and Chater 2001: 2). In their connectionist analysis of recursive structures, Christiansen and Chater (1999) employ the Simple Recurrent Network (SRN) to model the performance deficiencies common to machines and humans. The feedforward network cyclically pairs input units with a set of “hidden unit values.” Accordingly, each value is interpreted with regards to previously inputted values, and likewise, previously inputted values are reinterpreted with regards to newly inputted values.

SRNs not only emulate the way humans parse language by processing input as it is produced linearly; they also emulate the degradation pattern of human performance by requiring a greater number of computational steps for determining the proper alignment of form to meaning in increasingly embedded structures, as Christiansen and Chater demonstrate throughout their study.

Figure 1.4a outlines the SRN model used by Christiansen and Chater, where layers of units are represented with rectangles, trainable weights by arrows with solid lines, and copy-back connections by arrows with dashed lines.

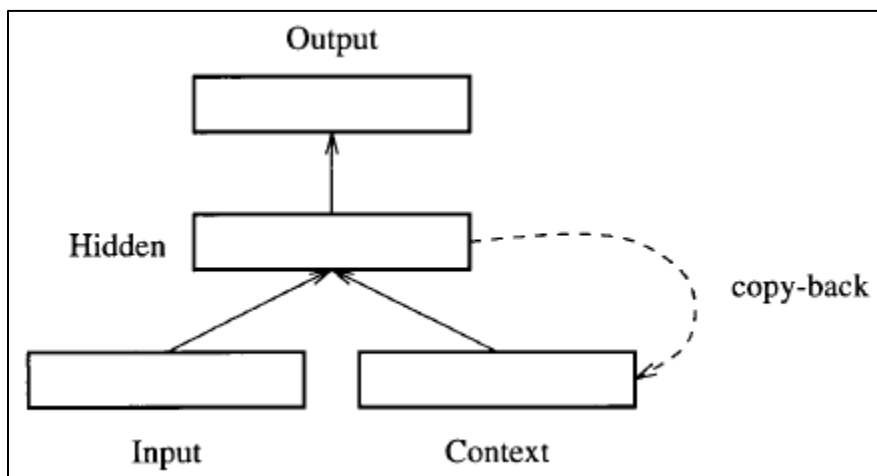


Figure 1.4a. The architecture of Christiansen & Chater’s simple recurrent network (SRN).

Christiansen and Chater tested the SRN of recursion learning with three complex recursive constructions measured against a baseline right-branching construction. They found that center-embedding tasks and cross-dependency tasks closely paralleled the degradation commonly seen in human performance.

With regards to the analysis herein, the Center-Embedding “Mirror” Recursion, which Christiansen and Chater’s analysis centers on, is applicable without modification to the analysis of syntactic center embedding in Chapter 3 of the current work, as well as the two types of center-embedding analyzed in Chapter 2—they use “mirror” to refer to the symmetrical valley seen in Figure 1.4b.

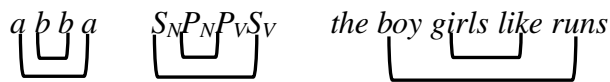


Figure 1.4b. Christiansen and Chater’s Center-Embedding “Mirror” Recursion.

The Cross-Dependency Recursion, which Christiansen and Chater’s analysis secondarily focuses on, applies to the analysis of morphological transfixing in Chapter 4 of the current work, as well as the *respectively* constructions analyzed in Chapter 2—they use “cross-dependency” to refer to the discontinuous units of meaning like those seen in Figure 1.4c.

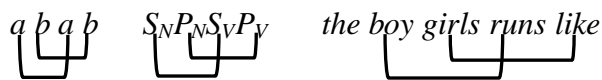


Figure 1.4c. Christiansen and Chater’s Cross-Dependency Recursion.

The cyclical loop with its “memory network” for past inputs is also highly suited to integrate other sorts of sequences of successive inputs, such as the phonological variable-tracking task. McClelland and Elman’s (1986) TRACE model is a variant of an SRN specialized for phonetic features and phonemic elements. If the TRACE model is given the task of parsing homophonous morphemes in sequence, it will reveal a

degradation pattern, as it would have a problem aligning them unambiguously with a template stored for recall. This applies to the analysis of phonological repetition in Chapter 5 of the current work.

Structurally, the *he-knows-that-she-knows...* mind-reading constructions in Chapter 2 should be part of the right-branching function normally used as a base-line for SRN tests. This would make sense for recursion with separate referents, e.g. *Matthew knows that Mark knows that Luke knows that John knows about it*, as this whole thing could be processed in abbreviation as *Matthew knows that [according to reports] John knows about it*, with a loss in meaning of the particular details in the chain of narration. However, when we change this to *He knows that she knows that he knows that she knows about it*, it is not a simple chain of narrative but one where each individual is reflecting on the other's thoughts about oneself. This structure too has the potential to allow for elision of the middle terms, e.g. *He knows that she knows about it [according to both of them]*, with a loss in meaning of the particular details in the chain of narration; however, the point before that happens (i.e. at the third level) is analogous to the repetition of homophonous morphemes, which is a tracking task like that of phonology, the difference being that, instead of associating each phonological segment with a different morpheme, the interlocutor must associate each report with a distinct embedded level of propositional mental space.

Ultimately, it is up to the computational linguists to sort through how they want to pursue unifying the diverse phenomena in the present work, which centers on balancing a maximum of three interdependent variables; this work can only hope to unite the data by

highlighting the diversity of linguistic phenomena which reveal the same three-dimensional cap on human cognition.

### **1.5. Goals and Outline of the Chapters Herein**

The current analysis deals with three goals, one primary and a two secondary: The primary goal is to document and discuss patterns of degradation in human usage of multiple interdependent variables across four levels of linguistic structure (i.e. reference, syntax, morphology, and phonology). One secondary goal is to explore the ways in which these similar limitations can be united into a single comprehensive theory, analyzable with a single computational model, or at any rate a set of closely related computational co-models which reflect the similarities inherent in these degradation patterns. The other secondary goal is to explore the ways in which such a comprehensive theory can be united with other, more general patterns of human cognition, thus further refuting the prevalent Chomskyan claim that human language data is processed in a still undiscovered black box called the LAD (Language Acquisition Device) (Chomsky 1966: 20; Cook 1996: 168) and is entirely independent of general human cognition (Chomsky 1983, para. 58).<sup>3</sup>

The four following chapters each start with a discussion of the data that characterizes the primary phenomenon under analysis. Discussion then turns to “pen-and-paper” constructions in written language which push or flout the limits for literary effect, with more data elucidating this point. Also present is a discussion which examines appeals made in earlier literature to the concept of human rationality as an explanation of the limit under analysis. Accompanying this is a discussion of how memory tasks are

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<sup>3</sup> Plaza et al. (2009) have already demonstrated that even the functions of Broca’s area, when lost gradually, can be taken over by another part of the brain.

distinct from variable balancing tasks, despite the common use of “memory” to refer to both types of phenomena. Consideration is finally given to literature on connectionist models which apply to the phenomenon under analysis.

## **1.6. Concluding Remarks on the Introduction of this Work**

It may be shown that the human mind has more access to balancing four or more interdependent variables than the data discussed in the present work suggests. That is not what matters most; of primary importance is that we measure the phenomena we discuss in order to justify any claims we make about them. Lord Kelvin, a scientist so renowned for his adherence to measurable phenomena that a unit of measurement was named after him, once said “When you can measure what you are speaking about, and express it in numbers, you know something about it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts advanced to the stage of science” (as cited in Lindley 2004: 294). As linguistics moves towards its inevitable evolution from soft science to hard science, this principle, above all others, must be embraced.<sup>4</sup>

With this aim in mind, we can cautiously take steps towards this by observing that, from the macro-level of reference to the micro-level of phonology, it appears to be the case that, at the peak point in time (i.e. when reading the z-variable in such cases as (1)-(5) above), the interlocutor is maximally working with three interdependent variables, one being currently manipulated and two others being simultaneously recalled in anticipation

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<sup>4</sup> Linguistics is widely regarded as a soft science, along with psychology, sociology, and related disciplines (Withers 2003: 251; Clayton & Simpson 2006: 533; Yngve 2004: 3; Clark, et al. 2008: ii; Seising & Sanz González 2011: 27), though some are pushing for recognition of at least certain branches of linguistics as a hard science (Kretzschmar 2015: 36-38; Yngve 2004: 3-5).

of their complements. The following chapters are dedicated to fleshing this out in more detail.

## 2. Three-Dimensional Constraints on Interdependent Structures in Reference

PRIME MINISTER: (to the SOVIET AMBASSADOR) They know you know they know...

SOVIET AMBASSADOR: (triumphantly) We know they know we know they know...

– Peter Ustinov's *Romanoff and Juliette* (as cited in Winks 1996: 423)

Possibly the most macroscopic level of language where we see a three-dimensional limit of human cognition in variable balancing is reference, which spans the level of discourse to that of morphophonology.

What the various types of constructions analyzed in this chapter all have in common is phrases which, while syntactically interpretable, cannot be semantically interpreted without reference to the interdependent phrases that share embedded constructions with them and determine which level of mental space they occupy.

Recursion beyond this limit is seen to be possible in literary wordplays, although while such phrases are analyzable with pen and paper, they are generally not meant to be interpreted compositely, word for word, but are instead meant to baffle the audience for literary effect (generally comical), such as to signify exaggeration or to express concepts of the *et cetera* variety.

Attention is also given to appeals made in earlier literature to the concept of human rationality as an explanation of the limitations on recursion. Accompanying this is a discussion of how memory tasks are distinct from variable balancing tasks, despite the common use of “memory” to refer to both types of phenomena. Consideration is finally given to literature on connectionist models which apply to the phenomenon under analysis.

## 2.1. Interdependent Structures in Recursive Mind-Reading: *He Said, She Said...*

In embedded reference, we see the limits of the human ability to actively keep track of information, such as that which is transmitted through *he-said, she-said* type recursions. Applying the work of the evolutionary psychologist Robin Dunbar (2000) to literary corpora, Lisa Zunshine (2006) discusses the limitation of three recursions in constructions of iterated common ground, as defined by Clarke (1996: 94). Citing literature, ranging from novels, to television series, to comic strips, she notes that in conversations of the *he said, she said...* sort, the human mind is highly constrained in terms of how many variables it can keep track of (pp. 29-30), adding that “Humans can comfortably keep track of three different mental states at a time” (Cohen 2010: para. 15).

A prime example Zunshine refers to can be seen in the episode of the TV sitcom *Friends*, as seen in (6), where Phoebe’s utterance of more than three interdependent variables in an embedded reference structure leaves Joey too baffled to register what he just heard.

- (6) PHOEBE: They don’t know<sub>w</sub> [we know<sub>x</sub> [they know<sub>y</sub> [we know<sub>z</sub>]]]. And Joey, you can’t say anything.  
JOEY: Couldn’t if I wanted to (Junge 1999).

At the peak cognitive point of reaching the z-value [we know<sub>z</sub> [...]], the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value [they know<sub>y</sub> [...]], the x-value [we know<sub>x</sub> [...]], and the w-value [They don’t know<sub>w</sub> [...]], thus surpassing the interpretable maximum of three interdependent variables and rendering this construction only interpretable in real-time speech as a hyperbole.

Like the Joey character in the dialog of (6), Zunshine confesses that she too is left unable to convey this convoluted message, in line with Joey's "Couldn't if I wanted to" with her own "I am afraid that neither could I" (p. 31). To this, she adds the following:

Watching this episode, many of us start feeling like Joey, who is generally portrayed as being a bit on the slow side. The situation is really not that complicated, and having live actors play it out helps to render it more comprehensible. Still, at some point, the agglomeration of multiply embedded minds proves too much of a cognitive load, and we begin to think of Phoebe's plotting in segments. We are keeping track, that is, of the two or three most immediate mind-readings (as in "now X doesn't know that Y knows what X does") and not of the whole series (as in "X doesn't know that Y knows that X knows that Y knows that X knows that Y knows that X knows that Y knows what X does"). (p. 31)

This observation is borne out step by step in Peter Ustinov's (1961) *Romanoff and Juliette*, where the "prime minister of a tiny, unaligned nation caught between the Russians and the Americans" engages the ambassadors of both nations and gets involved in the *he said, she said...* of Cold-War intrigue:

- (7)
1. PRIME MINISTER: (to the SOVIET AMBASSADOR) They know<sub>x</sub>...
  2. SOVIET AMBASSADOR (calmly) We know<sub>x</sub> [they know<sub>y</sub>]...
  3. PRIME MINISTER: (to the AMERICAN AMBASSADOR) They know<sub>x</sub> [you know<sub>y</sub>]...
  4. AMERICAN AMBASSADOR: (smiling confidently) We know<sub>x</sub> [they know<sub>y</sub> [we know<sub>z</sub>]]...
  5. PRIME MINISTER: (to the SOVIET AMBASSADOR) They know<sub>x</sub> [you know<sub>y</sub> [they know<sub>z</sub>]]...
  6. SOVIET AMBASSADOR: (triumphantly) We know<sub>w</sub> [they know<sub>x</sub> [we know<sub>y</sub> [they know<sub>z</sub>]]]...
  7. PRIME MINISTER: (to the AMERICAN AMBASSADOR) They know<sub>w</sub> [you know<sub>x</sub> [they know<sub>y</sub> [you know<sub>z</sub>]]]...
  8. AMERICAN AMBASSADOR: (repeating it after him and counting on his fingers and then crying out in horror) What?!? (as cited in Winks 1996: 423)

In line 5, at the peak cognitive point of reaching the z-value [they know<sub>z</sub> [...]], the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value [you know<sub>y</sub> [...]] and the x-value [They know<sub>x</sub> [...]], thus interpreting a

maximum of three variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements.

In line 7, however, at the peak cognitive point of reaching the z-value [you know<sub>z</sub> [...]], the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value [they know<sub>y</sub> [...]], the x-value [you know<sub>x</sub> [...]], and the w-value [They know<sub>w</sub> [...]], thus surpassing the interpretable maximum of three variables and rendering this construction only interpretable in real-time speech as a hyperbole.

According to Winks (1996), the point of the political interaction was “to ‘raise the tension one step higher’: never to allow your ambassador to be the one who must count on his fingers” (p. 423). Crucially, the point after which the American ambassador starts counting on his hands and crying out “in horror” is when the interdependent variables that one must keep track of surpass three.

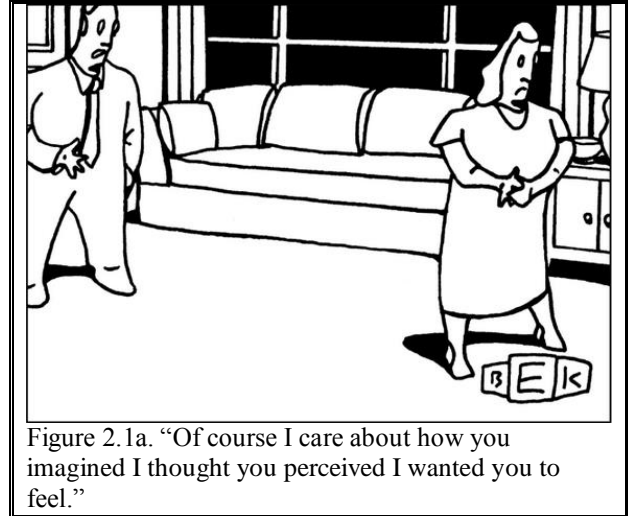
Cohen (2010) observes that skirting this limit and even flouting it are among what interest readers of fiction (par. 16, 20). In *Star Trek: Deep Space Nine*, Commander Sisko skirts such limits in the following dialog, as seen in (8).

- (8) PRIMMIN: If I could overhear it, so could half a dozen others...  
SISKO: Odo was probably making sure that [Quark knows<sub>x</sub> [we know<sub>y</sub> [he knows<sub>z</sub>]]] (Gendel, et al. 1993: 12:53).

The same limit is pushed in the children’s program *Clifford the Big Red Dog*, as seen in (9), though here it is acknowledged by the character uttering it as barely comprehensible.

- (9) T-BONE: Do you guys know something I don’t know?  
CLEO: Do you know something that you think we don’t know?  
T-BONE: No, I don’t know something that [I think<sub>x</sub> that [you don’t know<sub>y</sub> [that I know<sub>z</sub>]]], I don’t think. (Bridwell 2000).

Zunshine (2006) goes on to cite a popular comic strip from the *New Yorker*, seen in Figure 2.1a, which expresses the hyperbole of couples intentions to show that they understand each other and each other's understanding of each other, resulting in a hyperbolic expression of embedding



that reaches a “level at which our species is not that cognitively fluent” (p. 31).

#### *Pen & Paper*

Zunshine adds that the husband's statements is “literally incomprehensible and has to be deciphered with pen and paper, if one bothers to decipher it at all” (p. 30), but clearly, with six levels of interdependent embedding, the intended goal of the author is not for readers to decipher it literally but rather to “think... that the cartoon is funny” based on the “impenetrability of the husband's sentiment” which is “[o]verwrought to the sixth level of mental embedment” (p. 31). Such overwrought exaggeration then is understood to be interpretable as a copy-and-paste pattern signaling levity in the same sense as saying that one has had a “very, very, very, very bad day” (Causey 2008), which is a form of hyperbole (Nemesi 2010: 385) and is not literally intended to signal a greater degree than a *very, very, very bad day* or a lesser degree than a *very, very, very, very bad day*. Instead, as Hitchings (2011) claims, such overwrought exaggeration is not necessarily meant to signal a higher degree of “importance” but can even signify “triviality” (p. 277). Indeed, it comes as no surprise that an author using such a

hyperbolic phrase in earnest might feel compelled to acknowledge that this sort of phrasing is generally interpreted as exaggeration (Edwards 2007: 63), as seen with the repetition of *very* in (10).

- (10) I rephrase that: “it’s very, very, very, very, very important,” and that is no exaggeration.

Perhaps for this reason Khalil Gibran once noted that “Exaggeration is truth that has lost its temper” (Gibran, Wolf, Ferris, & Sherfan 2011: 19), and Madame de Faublas in the French drama *Mélanie* similarly observed that “To exaggerate is to weaken” (De La Harpe 1806: 76). Such repetitions are not intended to be processed for their cumulative value but defy literal meaning in the same way that repeating a syllable in a song does (see §5.5 below for more detailed discussion of morphemic repetition).

While savvy minds can toy with this limit on human cognition, it is often the cognitive limit itself which toys with the mind of writers. Those who are not aware of the need for pen and paper to navigate these perilous waters, which Zunshine discusses, can be misled by writers and even mislead themselves as writers (see §4.4 below for examples).

### *Rationality*

In his work from nearly half a century ago, the philosopher David Lewis (1969) discussed the fact that embedded interdependent constructions of the *he said, she said* variety appear to be limited to “the first few orders” (p. 56), attributing this limit to a “sufficient degree of rationality” on the part of the interlocutors (p. 55). In presenting a visual mapping of the schema for an “infinite sequence” (p. 55), Lewis notes that “there is nothing improper about its infinite length” (p. 53), but it is rather “ancillary premises

about rationality” which rule out such constructions (p. 55). Accordingly, the “generating process” of recursion “stops when the ancillary premises give out” (p. 56).

While Lewis had the right idea about the limited nature of such constructions, his explanation assumes that the human cognitive limit is hemmed in by a sense of reason, as if to say that the more reasonable a person is, the more limited their cognitive ability will be, while anyone lacking such reason would be more capable of balancing a greater number of variables. The reality is that all speakers, both the more rational and the less rational, are equally incapable of manipulating more than three variables, although the mere fact that highly irrational thinkers do not constitute a majority of string theorists suggests that those with more reason would more likely be the majority of those cultivating the sort of advanced variable-balancing skills required to transcend such limitations.

Years later, the psycholinguist Herbert H. Clark (1996) got a bit closer to measuring his observations by claiming that the “best known” notion of common ground, namely that of “iterated propositions,” is “impossible psychologically” (p. 93), with the explanation that it “cannot represent people’s mental state because it requires an infinitely large mental capacity” (p. 95). He went on to note that, while some have attempted to reform the concept of iterated common ground by setting a cut-off point, such measures “only sidestepped the problem posed by the infinite regress” (p. 100). However, as seen in the data of Kinderman et al. (1998) (discussed below), test subjects performed well with track-keeping tasks containing multiple variables with far fewer problems than they did with interdependent *he said, she said...* constructions.

The three-dimensional model, which reveals correlations with all other areas of human cognition, scientifically provides a better answer than Lewis's (1969) proposed "infinite length" limited only by the "ancillary" mechanism of "rationality" (p. 55), and it provides an alternative to Clark's (1996) notions of psychological impossibility (pp. 95-96), in both cases simply by measuring the phenomenon in question against other quantifiable limits in human cognition, which deal with similar three-dimensional interdependent functions recurring through disparate aspects of human thought processes.

### *Common Ground*

What lies behind the questions that Lewis and Clark set out to answer—and which Kinderman et al. (1998) comes very close to answering, though it was not his proclaimed intention to do so—is an attempt to understand the notion of common ground. Common ground is not simply knowledge that interlocutors share but the knowledge that each interlocutor knows the other's knowledge and the knowledge that the other shares a parallel understanding of the situation. Figure 2.1b illustrates the embedded nature of each thinker's understanding of the other's thoughts in the form of mental spaces, discrete propositional units, which can be nested inside of each other and are thus subject to embedding limitations much like the other forms of variable-balancing tasks analyzed herein.

A number of things are evident here. First, each participant is aware ( $x$ ) of the other participant and of the same third entity, namely a shell—even if their understanding of that thing is distinct at a fine-grain level (Fauconnier 1994: 59-62). Second, each participant is aware ( $x$ ) that the other participant is aware ( $y$ ) of the same object (Fauconnier 1994: 15, 101). Third, each participant is aware ( $x$ ) that the other participant

is aware ( $y$ ) that the first participant is aware ( $z$ ) of the same object. For instance, the man above might be aware ( $x$ ) that the woman is aware ( $y$ ) that he is aware ( $z$ ) of the conch shell, and likewise the woman might be aware ( $x$ ) that the man is aware ( $y$ ) that she is aware ( $z$ ) of the conch shell. And it is this awareness of each other's awareness which allows common ground and the cooperation which common ground makes possible.

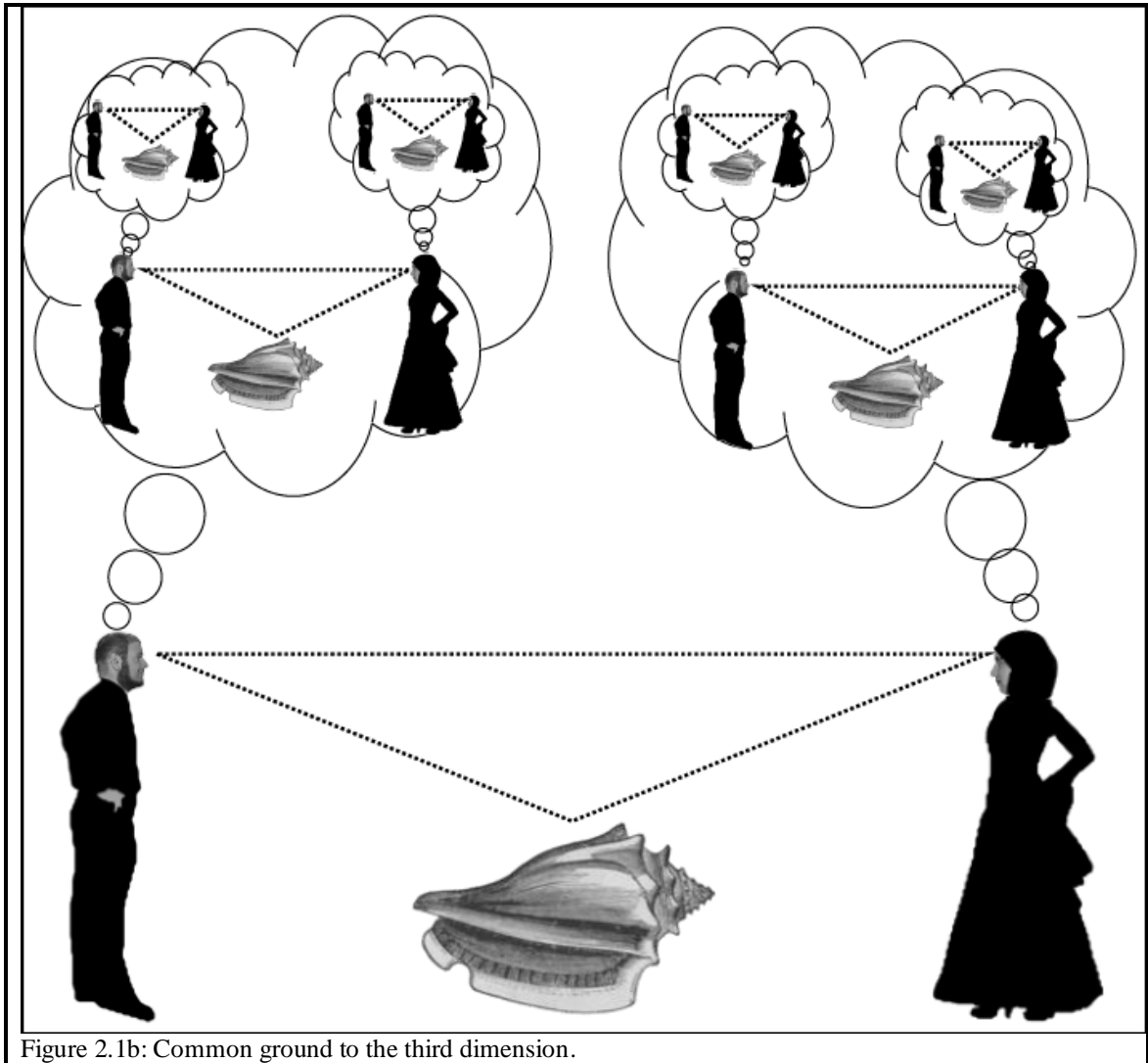


Figure 2.1b: Common ground to the third dimension.

What mental spaces provide us with is a set of propositions which are understood primarily with regards to their interrelationship. This approach to propositions as interrelated also sheds light on the Theory of Mind (ToM) of Kinderman, et al. (1998),

which distinguishes interdependent variable-balancing tasks involving interrelated mental spaces from simple memory tasks involving strings of propositional information.

### *Memory vs. Variable Balancing*

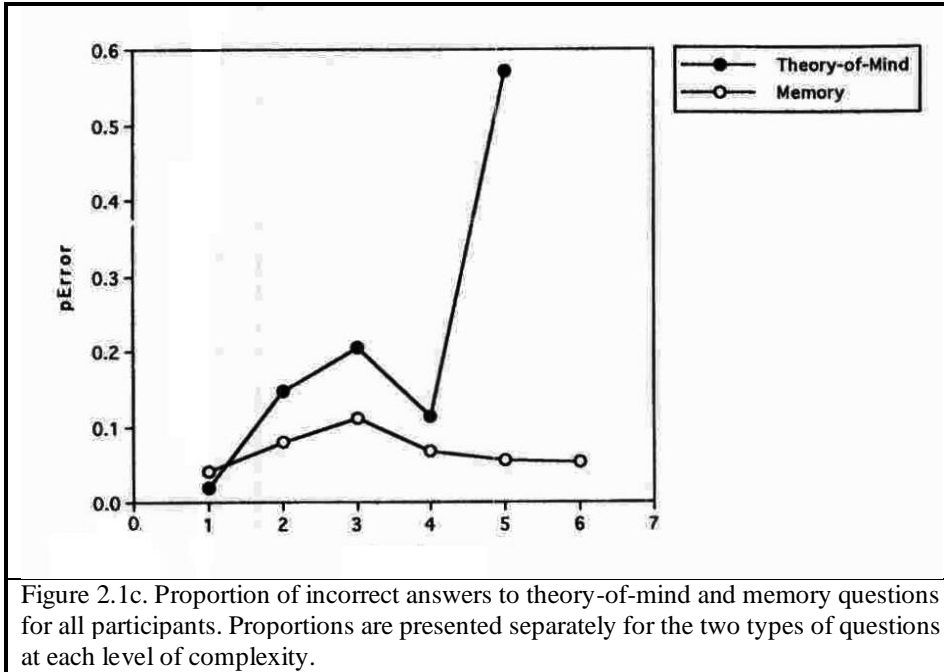
Dunbar (2000) and related works are ultimately based on the Theory of Mind (ToM) study done by Kinderman, et al. (1998), which, so far as Dunbar knows, “is the only published study of ‘advanced’ ToM in normal human adults” (2000: 240). The study in Kinderman, et al. (1998) is one wherein test subjects are given an Imposing Memory Task (IMT) test, which tests two different types of memorization tasks that Zunshine (2006) aptly summarizes as follows:

In those experiments, subjects were given two types of stories. One cluster of stories involved a “simple account of a sequence of events in which ‘A gave rise to B, which resulted in C, which in turn caused D, etc.’” Another cluster introduced “short vignettes on everyday experiences (someone wanting to date another person, someone wanting to persuade her boss to award a pay raise),... [all of which] contained between three and five levels of embedded intentionality.” Subjects were then asked to complete a “series of questions graded by the levels of intentionality present in the story,” including some factual questions “designed to check that any failures of intentionality questions were not simply due to failure to remember the material facts of the story.” (p. 28)

According to the test results, as seen in Figure 2.1c, the error rate for simple memory tasks stayed mostly below 10% for as far up as the maximum of six variables tested. The error rate for embedded reference constructions, however, drastically shot up from around 10% with four variables to 60% with five variables (Kinderman 1998: 197).

Clearly, *he said, she said...* constructions task test subjects more than the simple memory tasks to which the experiment of Kinderman, et al. (1998) compares them. However, test subjects’ not only seem comfortable with four variables of embedded reference but even appear to perform better with four variables than they do with three

variables. These results not only challenge the three-dimensional hypothesis but seem to directly contradict it.



To misquote Ludwig Mies van der Rohe, however, the Devil is in the details.<sup>5</sup> In Kinderman’s IMT, embedded reference structures are not all of the same composition, but rather of two distinct types, defined in Dunbar (2000). What Dunbar calls “sequential mind-reading” features a sequence of different subject referents (p. 240), as seen in (11). What Dunbar (2000) calls “recursive mind-reading” features a recursion of the same two subject referents (p. 240), as seen in (12).

(11) Jim<sub>w</sub> believed that Susan<sub>x</sub> thought that Edward<sub>y</sub> would like to marry Betty<sub>z</sub>.

(12) John<sub>x</sub> thought Sheila<sub>y</sub> would not like to go to the pub with him<sub>z/x</sub>.

For sequential structures, like the one in (11), the test subjects were able to process embeddings as far as the fourth order. The test subjects who took the IMT,

<sup>5</sup> Morson (2011) lists this as a number of famous misquoted phrases (p. 115). Frascari (1996) traces it back to Ludwig Mies van der Rohe (p. 500), who originally said that “God is in the details.”

however, were not observed to process recursive structures, like the one in (12), beyond the third order with any regularity.

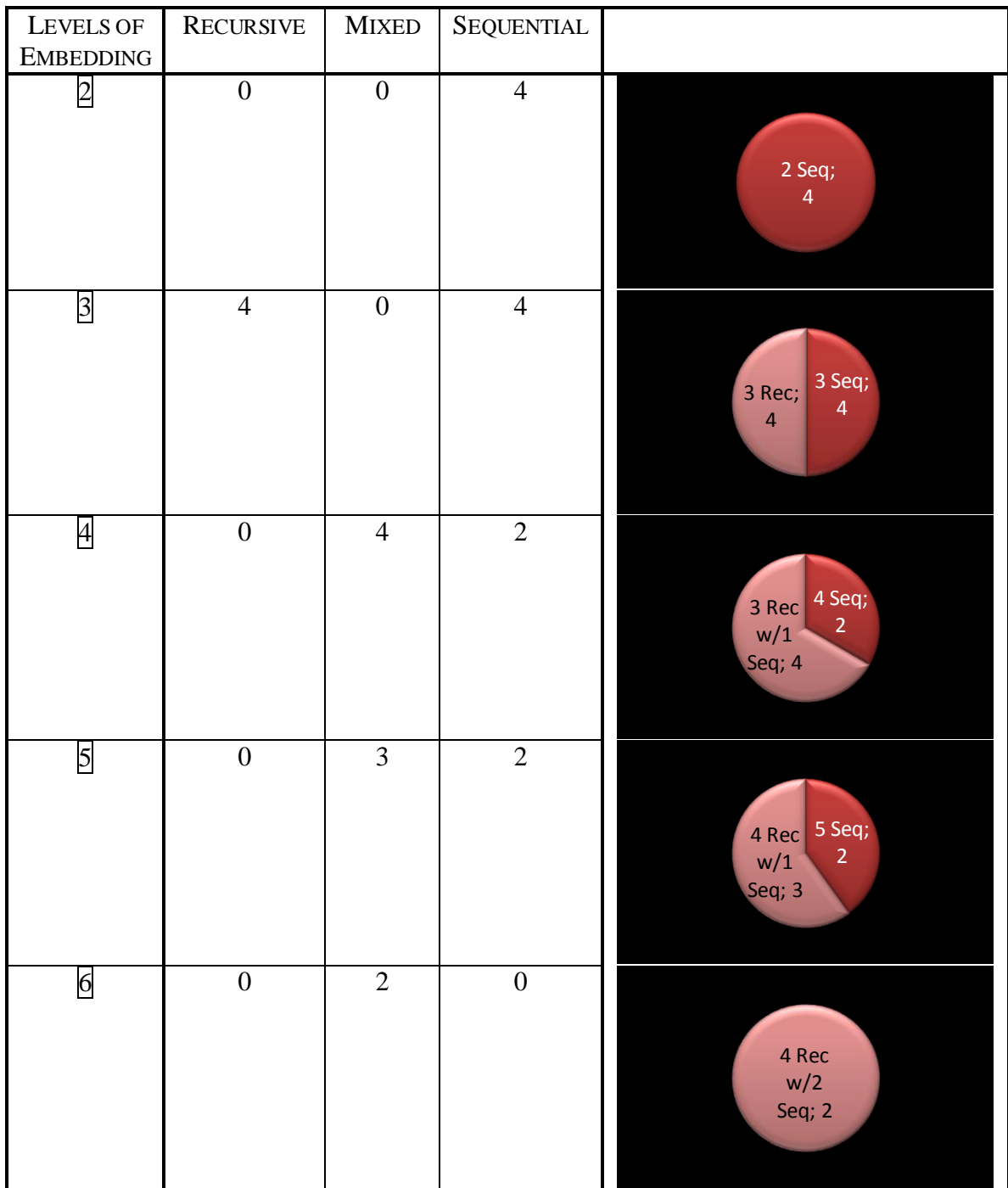


Figure 2.1d. Proportions of sequential and recursive embeddings in Kinderman's theory-of-mind and memory questions.

What the results of the test do not reveal is that the third-level embeddings which test subjects processed are just as often recursive (I.6 & II.4 of Appx. I), of the sort seen in (12), as they are sequential (II.6 & III.4 of Appx. I), of the sort seen in (11), while the fourth-level embeddings which test subjects processed either consist of purely sequential embedding (IV.6 of Appx. I), of the sort seen in (11), or limit any recursion to a single instance of a pronoun (II.8, III.6b, & IV.4 of Appx. I). Then, at the fifth level's so-called "cut-off point," the sentences jump to four levels of recursive embedding (II.10 & III.6a, which use proper nouns anaphorically), and this return to heavy recursive embeddings seems to explain the drastic cut-off point we see in the fifth-level examples. Figure 2.1d breaks down the embedded structures of the IMT experiments into recursive (Req), sequential (Seq), and mixed (further breaking down the mixed ratios, e.g. 2 Rec w/2 Seq), and shows how many levels of recursive embedding were maximized in each embedded referent count—the numeral preceding Rec/Seq refers to the number of variables; the number following refers to how many times the construction appears in Kinderman's questions.

As for why test subjects perform surprisingly better with the fourth-level embedded sentences than they do even with the third-level embedded sentences, the fourth-level embedded sentences in the IMT never have more than three levels of recursive embedding, of the sort seen in (12)—the fourth level is always sequential, of the sort seen in (11)—so there is never a greater interdependent processing task than there is with the third-level embedded sentences. Moreover, the fourth-level embedded sentences only make anaphoric use of pronouns, e.g. "Penny believed that John thought she would not..." while the third-level embedded sentences make anaphoric use of

proper nouns, e.g. “Sam thought that Henry believed that Sam wanted...” Figure 2.1e lists the number of recursive embeddings in third- and fourth-level embedded sentences and breaks down the anaphoric uses of pronouns (Pron) and proper nouns (Prop)—as with Figure 2.1d, the numeral following abbreviated terms, such as Pron and Prop, refers to how many times the construction appears in Kinderman’s questions.

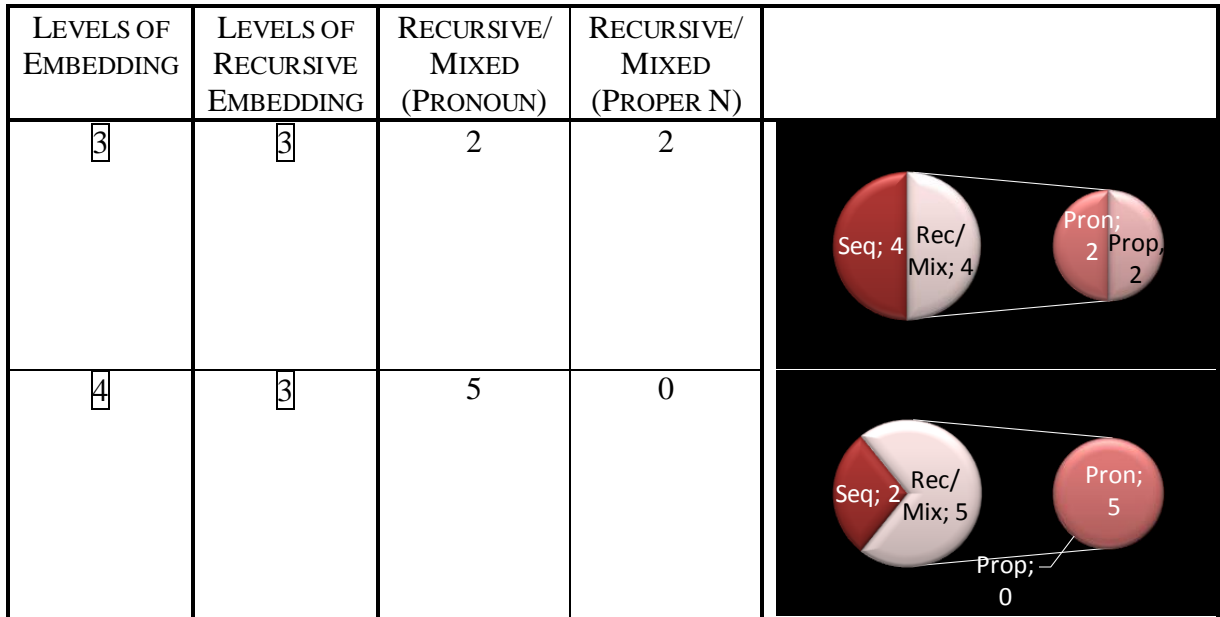


Figure 2.1e. Proportions of anaphoric uses of pronouns and proper nouns in the sentences with three and four levels of recursive embeddings in Kinderman’s theory-of-mind and memory questions.

While the IMT experiments of Kinderman et al. then prompt us to further test the data by systematically distinguishing sequential and recursive data and making the anaphoric elements more symmetrical, what we get from the existing work of Kinderman et al. is the result that test subjects who took the IMT were not observed to process recursive embedded structures, like the one in (12), beyond the third order with any regularity, and until the text is redesigned with the aforementioned symmetries in mind, this will remain all that we have to work with.

All we can do with the current evidence, then, is to conclude that Kinderman’s findings do not contradict those of Zunshine (2006) and Winks (1996), who also find a

clear cut-off point at three variables. After crossing that threshold, the repetition gets to the point where it is no longer interpretable in a literal sense but instead only in a hyperbolic cut-and-paste sense, or if literally interpretable at all, it becomes something one must count on one's fingers (Winks 1996: 423) or use some other external means (such as writing) to keep track of (Zunshine 2006: 30).

This again takes us to the question of which world humans live in and how they need to adapt to it. Based on how introspection of such thought processes is often explored in literature, Zunshine (2006) surmises that perhaps this is an instinctive need of the human social creature which evolved out of a necessity to navigate the intrigues of mating (Cohen 2010: para. 16). Winks (1996) has a more pragmatic view, which is simply that for purposes of intrigue it does not necessarily benefit one at a practical or even a diplomatic level to know more than the fact that others know something or possibly to know that others are aware of the fact that one knows something. Anything beyond this does not appear to offer easily applicable advantages (p. 424). Commenting on the same topic as Winks, Codevilla (2002) observes that "whether any item of knowledge, any penetration, is useful for either offense or defense, or becomes an asset for a hostile service, depends entirely on whether 'they' know that 'we' know" (pp. 28-29).

A simpler explanation exists than Codevilla's (2002), however, namely that humans, under normal circumstances, only balance three variables at a time, because that is what they are genetically programmed to do. It might not serve to advance one's balancing of variables beyond three in pre-digital world intrigues as one's competitors would most likely not be dealing with more than three levels either; after all both sides of

the human negotiations involve humans, whose natural environment has only required them to navigate and distinguish three spatial dimensions (see Chapter 6 for further discussion of this general trait of human cognition).

The human aptitude is evident in situations where the opportunity to act upon the knowledge is suppressed. For example, in attempting to clearly explain a very real situation of political oppression, Elena Gorokhova (2010) states what was understood to be the political reality of her contemporary Soviet Russia: “The rules are simple: they lie to us, we know they’re lying, they know [we know [they’re lying]], but they keep lying to us, and we keep pretending to believe them” (Gorokhova 2010: 172-173). The irony she comments on is that, far from living in two-dimensional ignorance, Soviet Russians lived with the same innate access to this three-variable level of understanding as those on the other side of the iron curtain did; however, they still preferred the safety of not engaging their leaders at a level of intellectualism which would put them in danger.

The data suggests that the limitations on what Dunbar (2000) calls “recursive mind-reading” represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. Of critical importance to this analysis is that this variable-balancing task of embedding mental spaces has many structural parallels within language, not the least interesting of which deal with other areas of interdependent reference.

## **2.2. Interdependent Structures in Center-Embedded Reference**

In addition to *he-said, she-said* type recursions, center-embedded reference with reflexives involves holding no more than three separate ordered variables in the mind simultaneously in anticipation of the same number of separate ordered complements

applying to each one. Such constructions are limited to the sentential level and even overlap with syntactic constraints of the sort discussed in the next chapter; however, they are an important instance of the limited recursion of reference.

In English, reflexive pronouns show a degree of asymmetry, with accusative and dative pronouns requiring the suffix *-self*, which is not always found on prepositional-object pronouns used as locative adjuncts.

(13) ACCUSATIVE: He<sub>x</sub> saw himself<sub>x</sub>. (Uhlmann 2009: 65)

(14) DATIVE: He<sub>x</sub> gave himself<sub>x</sub> a false identity. (Wright 2003: 478)

(15) PREPOSITIONAL OBJECT: He<sub>x</sub> felt it within him<sub>x</sub>. (Major 2006: 113)

English three centuries ago, however, featured a different distribution of reflexive prepositional-object pronouns with *-self*, as in (16), and some of this can still be seen in English of the last century, as seen in (17).

(16) He<sub>x</sub> that gives alms must do it in mercy... first feeling it<sub>y</sub> within him<sub>x</sub> self<sub>x</sub>. (Taylor 1719: 248)

(17) Nevertheless, the Lord has given man<sub>x</sub> the faculty of feeling it<sub>y</sub> in him<sub>x</sub> self<sub>x</sub>. (Swedenborg 1947: 71)

In rare cases, prepositional reflexives with *-self* can even be found when multiple layers of center-embedded reflexivity co-occur, as in the sentence with an embedded non-finite clause in (18), though I personally find less awkward the sentence with an embedded finite clause in (19), taken from my field notes.

(18) he<sub>x</sub> starts to kiss her<sub>y</sub> mouth, feeling [her<sub>y</sub> taste herself<sub>y</sub>] on himself<sub>x</sub>. (Antoni & Antoni 1997: 35)

(19) They<sub>x</sub> should use the gun [she<sub>y</sub> killed herself<sub>y</sub> with] on themselves<sub>x</sub>.<sup>6</sup>

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<sup>6</sup> From my field notes, originally overheard in a conversation between two café patrons

A survey of embedded reflexives also displays revealing limitations. Performing a search of news archives on *Google News* (on September 26, 2013) for all instances of the embedded reflexive strings “herself on himself” and “herself with himself” provides 47 results, none of which have an additional third level of embedding, let alone a fourth. (The reason for this undershot of the predicted limit is taken up at the end of the next chapter.)

The data suggests that the limitations on center-embedded reference represent a hard constraint, in that no reliable data shows more than three levels (or for that matter even two levels) of interdependent variables produced or processed in natural language usage. Like *he-said, she-said* type recursions, this sort of center-embedded reference appears to be a phenomenon restricted to the syntactic level; however, it is also conceivable that the same sort of embedded reflexivity could occur at a morphological level. More importantly, analogous constraints on variable-balancing tasks are found in extra-sentential reference constructions, as seen below (in §2.4).

### **2.3. Interdependent Structures in Cross-Dependent Reference**

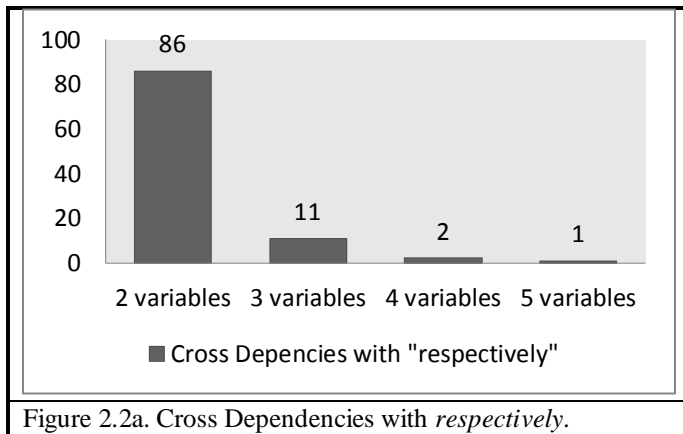
Constructions with *respectively* represent yet another form of limitation on interdependent reference that involves holding up to three separate ordered variables in the mind simultaneously in anticipation of the same number of separate ordered complements applying to each one. Such constructions can appear at or beyond the sentential level.

Church (1980) describes such constructions with *respectively* as being “notorious” for their particular variety of “crossing dependencies” and offers his opinion about how

they become progressively unacceptable with every variable that is added (13), as seen in the hypothetical examples he offers in (20).

- (20) a. John and Jack knew Tim and Mike, respectively.  
 b. ? John, Jack and Sam knew Tim, Mike and Rob, respectively.  
 c. ?? John, Jack, Sam, and Tom knew Tim, Mike, Rob and Bill, respectively.  
 d. ??? John, Jack, ... , Sam, and Tom knew Tim, Mike, ... , Rob and Bill, respectively.

Church's intuition was correct, but the degrees of unacceptability are not as symmetrical as the question marks make them appear. As seen in Figure 2.2a, performing a search of news archives *Google News* (on September 26, 2013) for the first 100 instances of the high-frequency complement string “and Chicago respectively” reveals that *respectively* constructions are overwhelmingly less frequent with even three variables and disappear almost entirely after three variables.<sup>7</sup>



The clear majority is two-variable constructions, as seen in (21), with a notable minority of three-variable constructions, as seen in (22).

- (21) Tomorrow will be a day of rest for the pennant-contenders, with the exception of Cincinnati<sub>x</sub> and Brooklyn<sub>y</sub>, who play Philadelphia<sub>x'</sub> and Chicago<sub>y'</sub>, respectively.  
 (“Babe,” 1920: 2)

<sup>7</sup> This service has since been renamed as *Google Newspapers*.

- (22) Wisconsin<sub>x</sub>, Ohio<sub>y</sub> and Illinois<sub>z</sub> have it in their power this coming Saturday to eliminate the conference leaders, Michigan<sub>x'</sub>, Iowa<sub>y'</sub> and Chicago<sub>z'</sub> respectively. ("Michigan-Wisconsin," 1922: 6)

What we see, however, is that there appears to be some acceptability for four-variable and even five-variable constructions. However, looking at these closer is revealing. The single case of five variables preceding *respectively* does not involve five cross dependencies since all five variables predicate a single antecedent *they* within its own sentence and, as far back as the beginning of the article (in the previous sentence), predicates the single plural antecedent *Five of the wives*, as seen in (23).

- (23) Five of the wives<sub>v-z</sub> of Harold C. Mills, under indictment for bigamy, assembled in the State Attorney's office yesterday and exchanged reminiscences of their married life. They were from Pittsburg<sub>v</sub>, Cincinnati<sub>w</sub>, Detroit<sub>x</sub>, St. Louis<sub>y</sub> and Chicago<sub>z</sub>, respectively. ("Five," 1903: 1)

As for the two cases of four-variable constructions, they refer to the same hockey events on the same day, written with identically worded paragraphs in two different newspapers, only one of which gives credit to The Associated Press, as seen in (24), which suggests either single authorship or an extreme instance of plagiarism.

- (24) Only 11 goals were scored in the four opening games Thursday night as the Canadiens<sub>w</sub>, St. Louis Blues<sub>x</sub>, Los Angeles<sub>y</sub> and New York<sub>z</sub> skated to 1-0 leads in their best-of-7 series against Boston<sub>w'</sub>, Philadelphia<sub>x'</sub>, Minnesota<sub>y'</sub> and Chicago<sub>z'</sub>, respectively (Associated 1968: 11; "Defence," 1968: 13).

This leaves us with a single instance in the hundred inspected of a *respectively* construction exceeding three variables. It must be determined how easy this sentence would be to process without Zunshine's (2006) aforementioned recourse to "pen and paper" (p. 30). The fact that it only shows up once out of a hundred samples minimally suggests that it should be examined closer for non-written comprehension.

Another notable feature about *respectively* constructions is that they are routinely extra-sentential in that *respectively* appears in sentences independent of the items it refers to. Performing a search of *Google News* (on October 20, 2015) for the first 10 instances of the high-frequency complement string “They respectively” reveals that half of the instances *respectively* appeared in sentences independent of the items it referred to, as seen in (25).

- (25) a. Competing with Facebook is Snapchat, the photo-messaging app created by 25-year-old Evan Spiegel<sub>x</sub>—the world’s youngest billionaire—and 27-year-old Bobby Murphy<sub>y</sub>.  
 b. They respectively weigh in with \$2.1 billion<sub>x</sub> and \$1.8 billion<sub>y</sub> fortunes. (Wang, 2015, para. 5)

Indeed, the *respectively* sentences can appear after a buffer of multiple sentences (and even a paragraph division) separating it from the items it refers to, as seen in (25), where the presence of *respectively* in Sentence d prompts connection of the two following nouns with those of Sentence a, which is separated from it by a buffer of three sentences and a paragraph division.

- (26) a. That list definitely includes Roadside Attractions’ Love & Mercy<sub>x</sub> and Universal’s Straight Outta Compton<sub>y</sub>.  
 b. The former is out on DVD, and the latter is still in theaters.  
 – PARAGRAPH BREAK –  
 c. The two are fact-based tales about the music scene in Southern California;  
 d. they respectively deal with Brian Wilson and the Beach Boys<sub>x</sub> in the 1960s, and with N.W.A.<sub>y</sub> in Compton in the 1980s. (Gray, 2015, para. 2-3)

The data suggests that the limitations on cross-dependent reference represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. Unlike the foregoing types of recursion, this sort of cross-dependent reference is not restricted to the syntactic level;

however, as seen below, parallel constraints on variable-balancing tasks are found exclusively in extra-sentential reference constructions.

#### **2.4. Center-Embedded Reference Beyond the Syntactic Level**

In addition to *respective* cross-dependencies, center-embedded reference occurs at the extra-sentential level. Fox (1987) demonstrates that center-embedded reference is constrained in discourse beyond the syntactic level. Referring to corpora drawn from spoken dialog and written English, Fox notes that an entity introduced with an open-class noun phrase is thereafter referred to in dialog with a pronoun, even across long distances; however, if the distance is broken up by an embedded discussion, then expository writing will invariably revisit the noun in question by restating an open-class noun phrase rather than make use of a pronoun (p. 140); spoken discourse is less predictable in this regard, possibly because one speaker's digression might not be regarded as a structurally significant embedding by another interlocutor.

The constraints on pronoun use are especially notable given the preference pronouns have over open-class nouns when center-embedded discourse is not present. Du Bois (2003) notes that while pronouns may, in general, seem more marked than common and proper nouns, it is common and proper nouns which carry the heaviest cognitive load on the interlocutor, as they introduce new information (pp. 65-66).

Du Bois found that, even in corpora with a mere 3/2 ratio of intransitive to transitive verbs across languages (p. 64), the number of tokens with one lexical argument ( $\approx 44.25\%$ ) was relatively close to the number of tokens with zero lexical arguments ( $\approx 52.5\%$ ), while there were very few tokens with two lexical arguments ( $\approx 3.25\%$ ), and none with three lexical arguments ( $\approx 0\%$ ), as seen in Table 2.4a.

<i>Quantity:</i>	0		1		2		Total	
<i>Language</i>	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Hebrew	261	(50)	252	(48)	9	(2)	522	(100)
Sakapultek	211	(46)	240	(53)	5	(1)	456	(100)
Papago	430	(57)	307	(40)	22	(3)	759	(100)
English	252	(47)	241	(45)	39	(7)	535	(100)
Gooniyandi	2318	(62)	1305	(35)	114	(3)	3737	(100)

Table 2.4a. Lexical Argument Quantity in Five Languages (Du Bois 2003: 62).

Croft, in earlier (1995) and later (2007) work, finds similar results in English and Wardaman data elicited through reporting a series of events in a silent film, as seen in Table 2.4b, which shows that sentences with one lexical argument are, on average, about five times more common than sentences with two lexical arguments and are, on average, about seventy-four times more common than sentences with three lexical arguments are. He furthermore cites data from Matsumoto (2000) with more general but still telling results from Japanese, as seen in Table 2.4c, which shows that sentences with one lexical argument are about thirteen times more common than sentences with two lexical arguments.

<i>Quantity:</i>	0	1	2	3+	Total
<i>Language</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>
English	404	834	161	12	1411
Wardaman	—	583	137	7	727

Table 2.4b. Lexical Argument Quantity in English and Wardaman (Croft 2007: 20).

Du Bois defines such strong tendencies as “soft constraints,” in that “They may be violated without precipitating either ungrammaticality or processing failure” (p. 80). However, “soft constraints” seems like an unduly soft description. What the data shows is that there is not merely a drop off, but such a drastic one that there is apparently less of an esthetic preference to stop than there is a processing burden which constrains speakers’ ability, despite the fact that written works, such as didactic grammars, often surpass this limit for purposes of meta-linguistic analysis.

<i>Quantity:</i>	1–	2+	Total
<i>Language</i>	<i>n</i>	<i>n</i>	<i>n</i>
Japanese	1,041	80	1,121

Table 2.4c. Lexical Argument Quantity in Japanese (Matsumoto 2000: 21).

Du Bois (2003) notes that, in the corpus he studies, there are indeed sentences with three lexical noun phrases containing new information “within one clause—and within one intonation unit,” and “Speakers have no trouble verbalizing” such sentences (p. 74); however, such additional lexical noun phrases are not arguments of the sentences but merely modifiers, such as preposition-governed adjuncts to a clause (p. 75) or possessor nouns (p. 75).

Solving for one of three interdependent variables is a much simpler task than solving for two of three interdependent variables, which is in turn much simpler than solving for three. Argument noun phrases are interdependent in that the meaning of the sentence relies on processing their interaction with each other within the grammatical framework of a single clause. This is not the case for nouns working as modifiers to clauses or other nouns. These can merely be tacked on as dependent modifiers of the standing variables, not as interdependent ones since the interaction of entities in a given proposition is not complicated by the presence of modifiers—though modifiers (especially clausal modifiers) do bring about other processing complications (as seen in Chapter 3 below).

What is clear here is that reference operates at a level overlapping with yet autonomous of syntax (and likewise with morphosyntax and morphophonology). Certain attested limitations of reference are found only at the level of syntax, yet they are distinct from other limitations of reference not involving syntax, as well as from other limitations of syntax not involving reference.

The data suggests that the limitations on center-embedded reference represent a soft constraint rather than a hard one since speakers involved in dialog with each other can transgress this limit (possibly as a simple result of disregarding each other's embedded discourse); however, the fact that corpora show this pattern to numerically correlate with the hard constraints constituting the bulk of the present work makes it worthy of inclusion in this discussion.

## **2.5. Center-Embedded Scenarios**

Center-embedded scenarios do not involve interdependencies such as reference, and as such, they are not subject to the foregoing constraints on interdependent structures with reference. The purpose of this examination, then, is to discuss the unbound nature of such structures, given the lack of grammatical interdependency.

The nature of center-embedded scenarios beyond the level of discourse is notably distinct from interdependent forms of reference. Of primary importance is that center-embedded scenarios can be dealt with separately, as fully comprehensible narratives which are abandoned and returned to, in much the same way that different social relationships can be revisited during the course of a day or a week without significant confusion arising as to who one did what with. A prime example of the comprehensibility of revisiting various cohesive narratives is Christopher Nolan's (2010) blockbuster movie *Inception*, which migrates among five levels of center-embedded dream worlds—see Figure 2.3a—without the audience losing sight of the main plot (Corliss 2010; James 2010; Sinopoli & Tyler 2010).

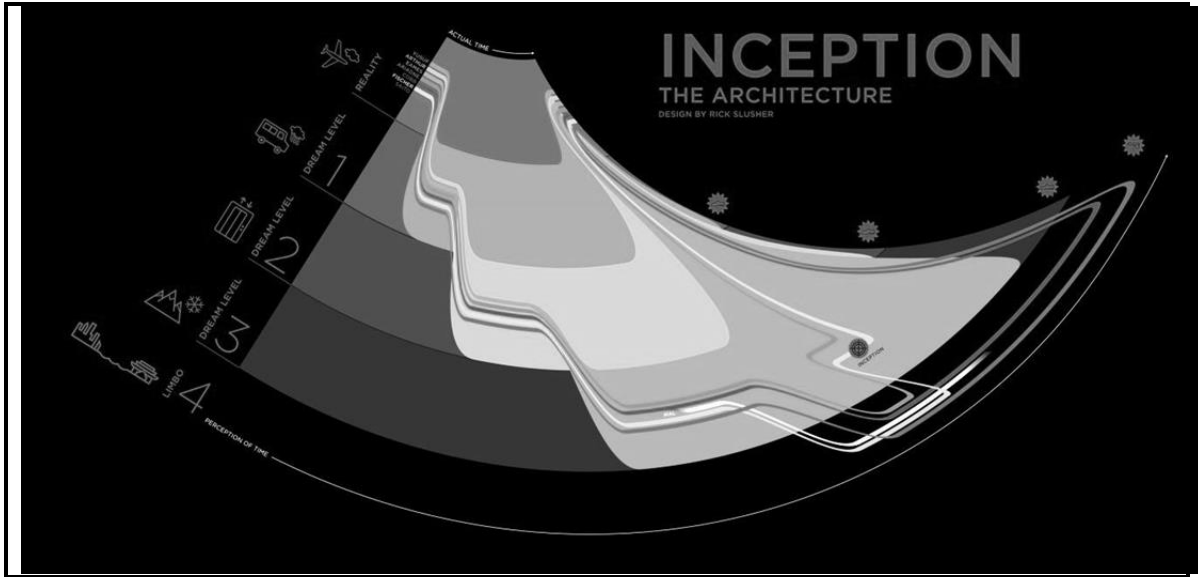


Figure 2.3a. Five center-embedded levels of the movie *Inception* (Stolt 2010).

What is remarkable about *Inception* is not the complexity of the plot, but rather how it manages to effectively use this to entertain the audience while not losing them, despite the migration among up to five levels of center-embedded plots (Stolt 2010; Fonceca 2010). As a movie of the mind-bender genre, it certainly takes audiences on an intellectual ride, but if audiences somehow lost a hold of the thread during that ride, the film would likely not have succeeded as a blockbuster, pulling in a box-office revenue of \$825,532,764 worldwide, thus giving it the 30th highest international box office of all time (“*Inception*,” n.d.).

The success of *Inception* moreover has prompted *Time Magazine* to comment on a positive note that “*Inception* is precisely the kind of brainy, ambitious, grand-scale adventure Hollywood should be making more of” (Corliss 2010: 7), and has prompted *Newsweek’s Daily Beast* to comment on a negative note that *Inception* exemplifies “Pop culture’s latest fix” of this cerebral genre (James 2010).

To highlight this contrast between the comprehensibility of center-embedded scenarios with that of center-embedded reference, it is informative to look at the highly

popular Xzibit (Yo Dawg) internet meme—which in two non-adjacent weeks from separate years was documented by *Google Trends* to have peaked at 10% of all internet searches (Dubs 2009). The Xzibit meme is based on a recursive formula, of the sort seen in Figure 2.3b, which comments about elaborate video games that have smaller “sub-games” inside of them, which appear to be played by the protagonist of the game, though ultimately controlled by the human playing the main video game, who is thus playing a game within a game: “Yo dawg[,] I he[a]rd you like games[,] so we put a game in yo[ur] game[,] so [yo]u can play while you play.” Fans of this meme naturally capitalized on the center-embedded levels of *Inception*, as seen in Figure 2.3c, which reads “Yo dawg[,] we heard you like dreams[,] so we put a dream in your dream in your dream in your dream[,] so you can dream while you dream while you dream while you dream...”



Unlike the comprehensible center-embedded scenarios in the actual movie, the center-embedded reference in the meme is incomprehensible because it calls for a simultaneous processing of multiple interdependent variables in order to understand just one.

Christopher Nolan's (2001) classic *Memento* was not technically a blockbuster, since it grossed what appears to be a less impressive \$40 million ("Memento," n.d.). While structurally more complex than *Inception*, *Memento* still drew a loyal fan base which it has since maintained. Like *Inception*, it takes its audience on an intellectual ride, and as with *Inception*, if its audience somehow lost a hold of the thread during that ride, it would likely not have succeeded to the extent it has—and considering that the production cost was only \$5 million ("Memento," n.d.), it ended up yielding eight times the amount invested, while *Inception* yielded just over five times the amount invested, considering that the production cost was roughly \$160 million (Fritz 2010: 7).

The structure of *Memento* weaves between two converging timelines, one starting at the end of the story, the other at the beginning, with both ultimately meeting in the epiphanic middle of the story which explains everything that chronologically precedes and follows it in the two converging plots (Klein 2001: para. 15-16), as seen in Figure 2.3d. The fact that the two converging story lines have twenty-two degrees of cross-dependent discontinuity and still managed to produce relatively successful box-office sales serves as a testimony, at least, to the structure's comprehensibility and, at most, to a narration with a flow unobstructed enough to not put off viewers.

In his study comparing center-embedded syntax and center-embedded discourse, Levinson (2013) comes to the same conclusion about non-reference-based discourse structures. Center-embedded syntax (covered briefly in §1 above and discussed further in Chapter 3 below) is like the center-embedded reference discussed in this chapter in that it requires the simultaneous processing of multiple interdependent variables in order to process any given one, but center-embedded syntax differs from center-embedded

reference in that the latter allows for comprehension of complete thoughts which are abandoned and then revisited (ideally in a symmetrical fashion), just like what happens in center-embedded narratives like that of *Inception*.

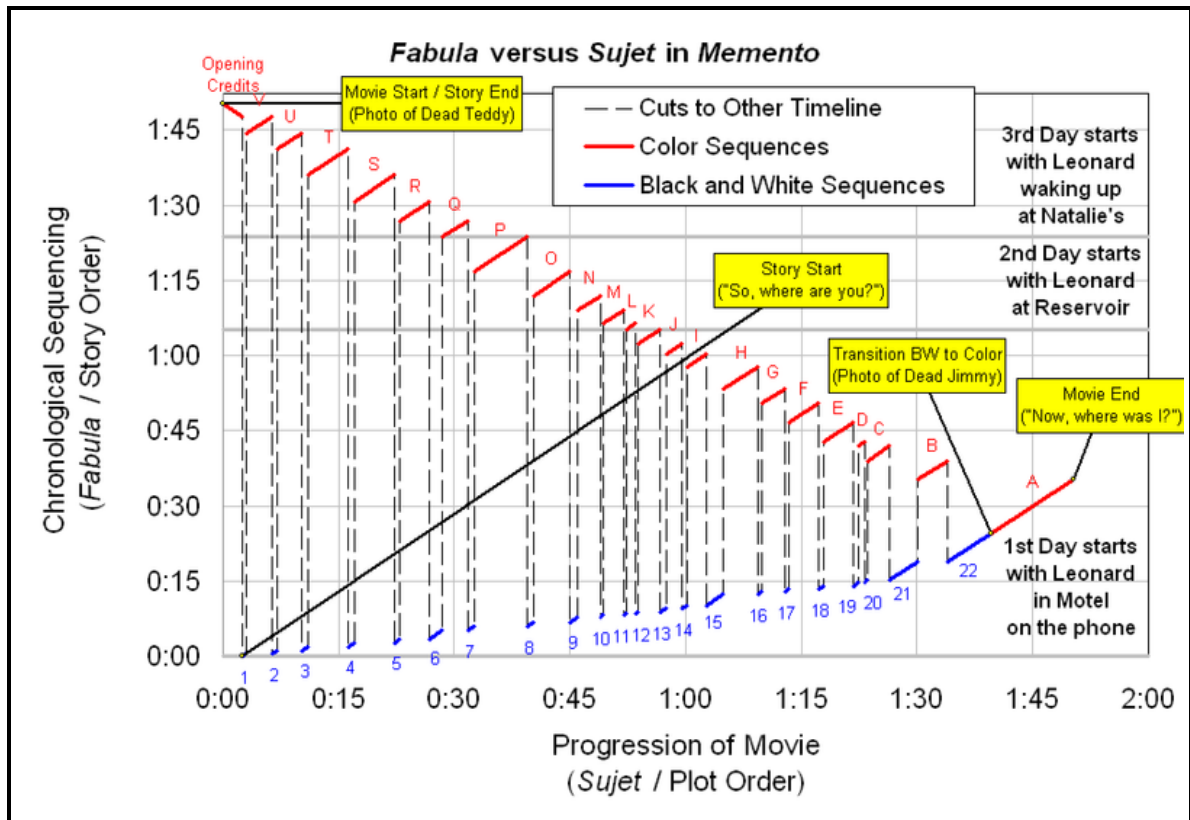


Figure 2.3d. Twenty-two levels of discontinuity in *Memento* (Arahamian 2009).

In *Inception*, a number of elements conspire to facilitate maintaining comprehension during the narrative center-embedding, one of the most notable being the color schemes which define each level of the narrative (Pond 2011: para. 5); however, the symmetry of the center-embedded narrative might also play an important role, and future studies should explore this question further.

The data suggests that the unlimited nature of center-embedded discourse represents a lack of constraint of the sort seen with the foregoing phenomena. With this examination of discourse, what becomes clear is that reference operates at a level overlapping with yet autonomous of discourse. Certain attested limitations of reference

are found only at the level of discourse, yet they are distinct from other limitations of reference not involving discourse, as well as from other possible limitations of discourse not involving reference.

## **2.6. Relevant Connectionist Models**

Appropriate to the types of discourse-related variable balancing surveyed in this chapter are connectionist models which measure the limitations on cross-dependencies (§2.3) and center-embedding (§2.2 & 2.4), among other types of variable-tracking tasks.

Following the experiments of Bach, Brown, and Marslen-Wilson (1986) with human test-subjects, Joshi (1989) uses EPDAs (embedded push-down automata) to show that, while cross dependencies are somewhat less difficult than center embedding at two and three levels (p. 2), both types of tasks “cannot be instantiated for sentences containing more than three matched NPs and Vs” (p. 28). Christiansen and Chater’s show the same thing with SRNs designed to process cross-dependency recursion.

Ultimately, in reference, there is not so much a dearth of applicable connectionist models as there is an absence of applying these models to processing the limitations of reference embedding and cross dependency as analogous extensions of the processing limitations in other areas of human language, as well as in other types of limitation patterns in general human cognition.

## **2.7. Concluding Remarks on Reference**

As seen in the foregoing analysis, authors occasionally exploit *he-said-she-said* word games, journalists sometimes overuse *respectively*, and grammarians routinely give hypothetical examples with multiple arguments to highlight all of the available positions

for nominals. However, like other experts with cultivated skills, they are making use of intellectual devices that have limited applications, rather than making spontaneous use of inborn abilities that have universal applications. Performing these linguistic tasks is a highly cultivated skill, and those with the greatest understanding of these intricacies are aware of how they dazzle the layman. As such, the comic writer uses such cultivated skill to great effect for humor while the grammarian explaining causative verbs gives examples with multiple proper nouns to great didactic effect for illustrating how paradigms hypothetically work.

Some are able to peer outside of the three-dimensional cubic life that we are physically and psychologically limited by so as to analyze the manipulation of greater numbers of variables, but this study is not about them; it is about the majority of humans, like those depicted in the *New Yorker* comic strip (1998), or those tested by Kinderman, et al. (1998), Du Bois (2003), and Croft (1995; 2007), whose minds are cognitively fine-tuned to operate in a world bound by three dimensions.

Various factors can conspire to further complicate variable-balancing tasks in reference, such as the task of processing embedded reference in (19) (repeated below for convenience) being additionally burdened by the interference of syntactic center-embedding—see §3.1 below for a full discussion of this phenomenon and the processing burdens it entails.

(19) They<sub>x</sub> should use the gun [she<sub>y</sub> killed herself<sub>y</sub> with] on themselves<sub>x</sub>.

Any such sort of linguistic interference only increases the constraints already imposed by the cognitive limit of three dimensions; it does not alleviate them, just like the fact that wind-pressure complicates aviation does not negate the existence of gravity's

effect on flight; it simply adds an additional complicating factor. The next section examines this syntactic complication in isolation and examines parallels between variable-balancing tasks at that level of analysis and those explored in this chapter.

### 3. Three-Dimensional Constraints on Interdependent Structures in Syntax

A promise not to do a thing which the person that made the promise cannot do is nothing.

– John Adams (as cited in Wroth & Zobel 1965: 19)

The second largest level of language where we see a three-dimensional limit of human cognition in variable balancing is syntax, which extends to the sentence-level configuration of open-class words.

What the various types of constructions analyzed in this chapter all have in common is phrases which, while morphologically parsable, cannot be syntactically interpreted without reference to the interdependent phrases that share center-embedded constructions with them and determine which level of syntactic center-embedding they occupy.

Recursion skirting this limit is seen to be possible in literary styles, which while analyzable with pen and paper, are detached enough from speech to be almost entirely missing from spoken corpora. Constructions of this sort are occasionally used to intentionally baffle the audience for literary effect, such as to signify exaggeration or the like.

Attention is also given to appeals made in earlier literature to the concept of human rationality as an explanation of the limitations on recursion. Accompanying this is a discussion of how memory tasks are distinct from variable balancing tasks, despite the common use of “memory” to refer to both types of phenomena. Consideration is finally given to literature on connectionist models which apply to the phenomenon under analysis.

### 3.1. Interdependent Structures in Center-Embedded Syntax

Syntax is often cited in analyses claiming that the rules of recursivity are infinite or practically infinite (Pinker 2011: 8-9; Keenan & Moss 2004: 13-16). However, such discussions of nearly endless recursion generally refer to linear strings, such as (27).

- (27) **Channel 4 News broadcasted pictures of the house** [that was bought by the student [who is hosted by the university department [that is funded by your company [through which occurred the embezzlement [that was perpetrated by the clerks [who were employed by the bank [that recently burned down]]]]]]].

The visually tiered analysis of (27) in Figure 3.1a illustrates the fact that, in producing or processing a right-branching construction, the interlocutor can comprehend each embedded phrase as part of a continuous narrative, because each new clause depends on nothing more than the previous clause for reference.<sup>8</sup>

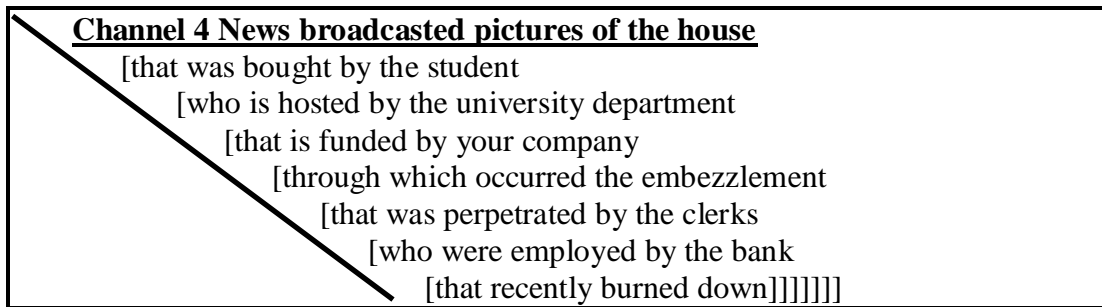


Figure 3.1a: A conceptual eight-tier hill, with progressively lower-level clauses, each of which is interpretable with reference only to its respective upper-neighbor clauses.

In fact, such formulas as this, while far from typical in speech, are satisfactory and even appealing for purposes of telling stories in traditional songs, such as “The House that Jack Built” (Green 1899: 94), seen in (28), which was first published in the 1600’s (Hazen 1992: 325) and likely goes back further (Smith 1849: 6).

- (28) This is the maiden all forlorn [that milked the cow with the crumpled horn [that tossed the dog [that worried the cat [that killed the rat [that ate the malt [that lay in the house [that jack built]]]]]]].

<sup>8</sup> The fact that such narratives are related backwards in time does not seem to affect their comprehensibility; however, further tests could demonstrate a difference (or lack thereof) between forward and backward narration at the extra-sentential comprehension.

The visually tiered analysis of (28) in Figure 3.1b illustrates the fact that, in producing or processing a right-branching construction, the interlocutor can comprehend each embedded phrase as part of a continuous narrative.

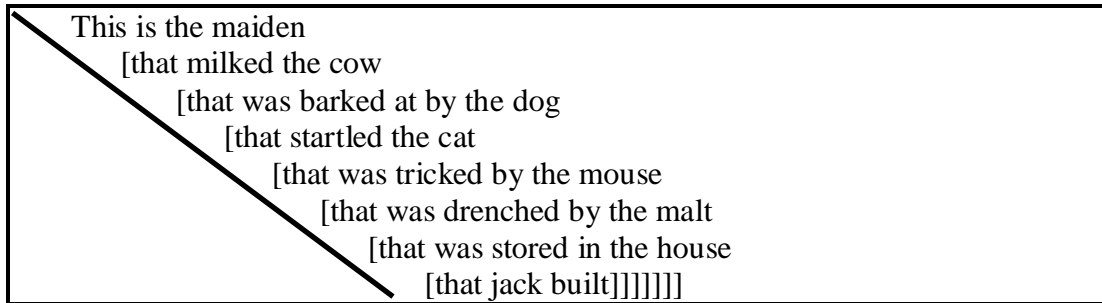


Figure 3.1b: A conceptual eight-tier hill from English-language folklore, with progressively lower-level clauses, each of which is interpretable with reference only to its respective upper-neighbor clauses.

Far from being specific to one language family, this sort of poetic story is also found in the Aramaic song “Ḥad Gadyā,” seen in (29), dating back to the 1500’s (Abrahams 1906: 103). The  $\overline{di}$ • which is preposed to each phrase is the Aramaic relative pronoun.

- (29) ... and smote the angel of death, [who slew the slaughterer, [who killed the ox, [that drank the water, [that extinguished the fire, [that burned the stick, [that beat the dog, [that bit the cat, [that ate the goat, [Which my father bought for two zuzim]]]]]]]]].

The visually tiered analysis of (29) in Figure 3.1c illustrates the fact that, in producing or processing a right-branching construction, the interlocutor can comprehend each embedded phrase as part of a continuous narrative.

Linear (non-interdependent) recursions, like those of (27) through (29), can be practically limitless in length since higher clauses are not dependent on lower clauses for their meaning and lower clauses only need to refer to the clause immediately above them in order to be understood. However, interdependent constructions involving syntactic center embedding differ from linear embedding constructions in that each phrase is

separated from its head by one or more intervening phrases, thus creating a structure which is clearly not limitless, as seen in (27)'.

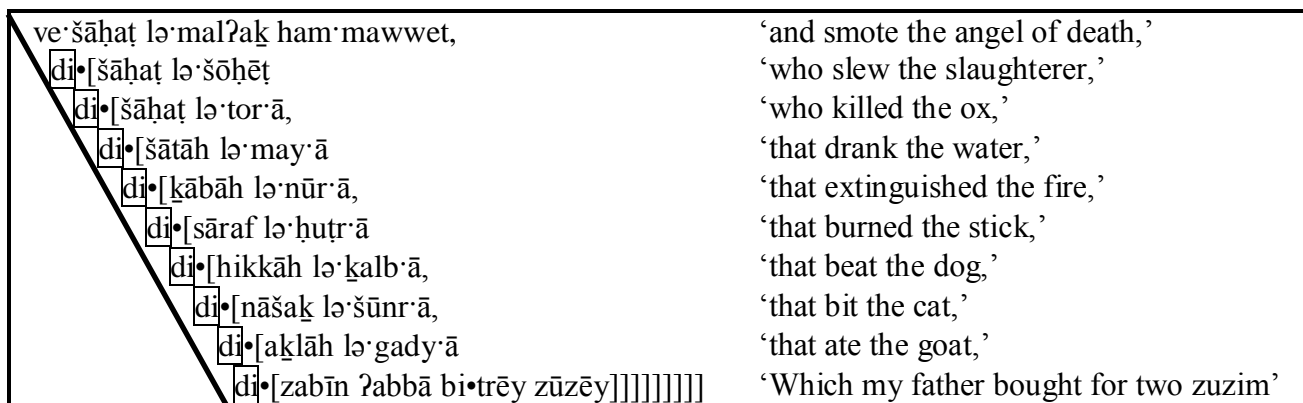


Figure 3.1c: A conceptual ten-tier hill from Aramaic-language folklore, with progressively lower-level clauses, each of which is interpretable with reference only to its respective upper-neighbor clauses.

(27)' \* Pictures<sub>x</sub> of the house [that the student<sub>y</sub> [whom the university<sub>z</sub> [that your company<sub>w</sub> [which the embezzlement<sub>v</sub> [that the clerks<sub>u</sub> [whom the bank<sub>t</sub> [that<sub>s</sub> recently burned down<sub>s</sub>] employed<sub>t</sub>] perpetrated<sub>u</sub>] occurred<sub>v</sub> through] funded<sub>w</sub>] hosts<sub>z</sub>] bought<sub>y</sub>] were<sub>x</sub> broadcasted.

The visually tiered analysis of (27)' in Figure 3.1d illustrates the fact that the interlocutor must conceptually hop between the different sides of an eight-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side, in order to complete each clausal construction.

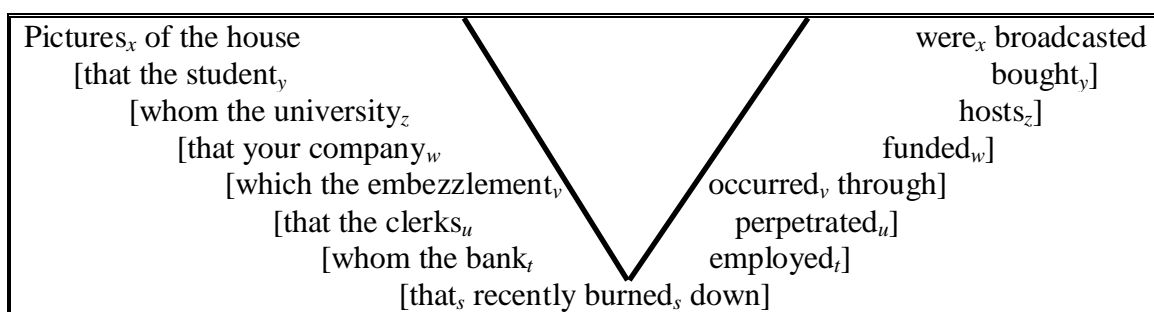


Figure 3.1d: A conceptual eight-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

Since center embedding requires recalling the informational value of variables on the other side of a valley of sorts, it should come as no surprise that center embedding is strictly limited to no more than three levels of valley depth, much like other tracking

tasks involving interdependent variables in human language, as seen in the three-level center-embedded sentence of (27)".

(27)" # Pictures<sub>x</sub> of the house [that the student<sub>y</sub> [I<sub>z</sub> know<sub>z</sub>] bought<sub>y</sub>] were<sub>x</sub> broadcasted.

The visually tiered analysis of (27)" in Figure 3.1e illustrates the fact that the interlocutor must conceptually hop between the different sides of a three-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

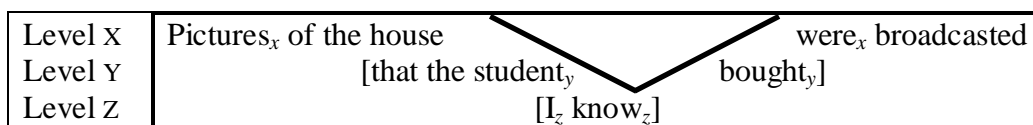


Figure 3.1e: A conceptual three-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

While structures like those in (27)" are not by any means preferred, they represent the outer limits of what is possible in human cognition. Comprehension tests conducted by Babyonyshev & Gibson (1999) reveal that the structures of "maximal complexity" in both SVO and SOV never went beyond balancing three variables, and often were not sustainable with merely two variables. Such limits on the processing of center-embedded structures in human language use are corroborated in other work (Bach, Brown, & Marslen-Wilson 1985; Foss & Cairns 1970; Marks 1968; Miller 1962; Miller & Isard 1964) and replicated in computer simulations (Christiansen & Chater 1999). Karlsson (2007) moreover conducts the most extensive cross-corpora study to date, demonstrating that, even in written language, there is never a transcendence beyond three levels of interdependency, and in spoken language, speakers rarely go beyond two levels.<sup>9</sup>

<sup>9</sup> Karlsson's (2007) study builds upon and includes the well-known corpus studies of De Roeck et al. (1982) and Sampson (1996).

In media meant to be understood, instances of these sentences, though rare, are not unknown. Performing a search of published sources through *Google News* (both standard and archives) and *Google Books* (on November 11, 2012) for the strings in (30) provided scarce but diverse results.

- (30) a. “which the person that”  
 b. “which the man that”  
 c. “which the boy that”

Despite the hundreds of years of English writing accessible through these engines, only the four sentences seen in (31)-(33) and (2) (repeated here for convenience) turned up.

- (31) A promise not to do a thing<sub>x</sub> [which the person<sub>y</sub> [that<sub>z</sub> made<sub>z</sub> the promise] cannot do<sub>y</sub>] is<sub>x</sub> nothing (John Adams as cited in Wroth & Zobel 1965: 19)
- (32) The vast attention<sub>x</sub> [which the boy<sub>y</sub> [that<sub>z</sub> remained below<sub>z</sub>] paid<sub>y</sub> to the various groups...] struck<sub>x</sub> him (“Painter,” 1810: 255)
- (33) Those responsibilities, areas<sub>x</sub> [in which the man<sub>y</sub> [that Mr. Bennett<sub>z</sub> will be succeeding<sub>z</sub>...] showed<sub>y</sub> himself<sub>y</sub> effective], will be<sub>x</sub> left to others (“William,” 1990: 8)
- (2) # ... the agreement<sub>x</sub> [under which the man<sub>y</sub> [that many Germans<sub>z</sub> call<sub>z</sub> “the father of MP3”] came<sub>y</sub> to work at one of the premier U.S. research labs] was<sub>x</sub> not as clear as it could have been... (Shinal 2007: para. 1)

As seen in (31)-(2), none of the search results required handling more than three variables. In media intended for communicating ideas, the thought of a passage exceeding human capability is inconceivable (primarily because it does not meet the market demands of written media), which is why even three variables, which lie at the limits of human cognitive capability, are so exceedingly rare.

The visually tiered analysis of (2) in Figure 1.1c (repeated here for convenience) illustrates the fact that the interlocutor must conceptually hop between the different sides

of a valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

Level X	[... the agreement <sub>x</sub> was <sub>x</sub> not as clear as it could have been...]
Level Y	[under which the man <sub>y</sub> came <sub>y</sub> to work at one of the premier US research labs]
Level Z	[that many Germans <sub>z</sub> call <sub>z</sub> “the father of MP3”]

Figure 1.1c: A conceptual three-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

At the peak cognitive point of reaching the z-value [that many Germans<sub>z</sub> call<sub>z</sub> “the father of MP3”], the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value [under which the man<sub>y</sub> [...]] and the x-value [the agreement<sub>x</sub> [...]], thus interpreting a maximum of three variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements.

The present account contrasts with that of Blaubergs and Braine (1974), who claim that “the breakdown of comprehension at the three-degree level can be accounted for by the assumption that the limitation of short-term memory to approximately seven items at a time (Miller, 1956) is first exceeded at this level of complexity” (p. 747). Such an analysis assumes that the third and second levels are still not processed for comprehension even after their complements have been paired up.<sup>10</sup>

While Lewis (1996b) tightens up the analysis by claiming that three co-indexing variables are indeed the limit, he still attributes this to a type of “memory,” which he does not differentiate from the distinct short-term memory of narratable events, along the lines that Kinderman et al. (1998) do.

<sup>10</sup> Blaubergs and Braine’s (1974) association of the third-level limit with a seven-variable limit also overlooks an important point that Miller (1956) makes in the first section of his analysis (“Information measurement”), which is that three binaries account for eight possibilities. This might explain Miller’s account of humans being able to subitize up to eight points on a two-dimensional surface, based on the experiments of Kaufman (et al. 1949: 500), which Miller cites—see Chapter 6 for further discussion.

In sentence data from spoken corpora, even three-variable balancing is barely present (Croft 1995; Karlsson 2007). In one corpus analyzed by Croft (1995), a total of 933 NPs included 78 singly embedded NPs but only 3 doubly embedded NPs and, not surprisingly, no triply embedded NPs (pp. 870-871). According to the data that Croft analyzes, moreover, singly embedded information tends to consist of “stored/precompiled constructions” and is established as modifying information to the extent that it is no more likely to break the intonation unit than non-clausal modifiers like adjectives (p. 872). In contrast, multiply embedded constructions in the same corpus involve more novel compositions and, being less like adjectival modifiers, typically break intonational units (p. 872).

An intonation-based analysis explains what makes certain types of embedded phrases like (27)'' more tolerable than those like (27)'''. While the highly conventionalized embedded modifying phrase [ $I_z$  know $_z$ ] in (27)'' is intonationally similar to an adjective, the non-conventional embedded phrase [whom the university $_z$  hosts $_z$ ] in (27)''' requires a strong intonation break, and is consequently far less acceptable, while the intermediary (27)''' falls somewhere in between.

(27)'' ? Pictures $_x$  of the house [that the student $_y$  [ $I_z$  know $_z$ ] bought $_y$ ] were $_x$  broadcasted.

(27)''' ?? Pictures $_x$  of the house [that the student $_y$  [that  $I_z$  know $_z$ ] bought $_y$ ] were $_x$  broadcasted.

(27)''' ??? Pictures $_x$  of the house [that the student $_y$  [whom the university $_z$  hosts $_z$ ] bought $_y$ ] were $_x$  broadcasted.

Karlsson (2007) even goes so far as to claim that the possibility of three levels of interdependent variables is an artefact of written language, and cites the development of Europe classical literature as an example of the emergence of this stylistic feature.

However, as Lewis (1996a) and Joshi (1989) note, three levels of center-embedded structures seem to be less problematic in Japanese than in English, and in such harmonically head-final languages, this higher tolerance might not be fully unexpected.<sup>11</sup>

### *Pen & Paper*

As with interdependent variable tracking in reference, interdependent variable tracking in syntax can use writing to aid in parsing, with test subjects generally increasing “their ability to comprehend center-embeddings by one level” (Lewis 1996a).

One such study (Blauberg & Braine 1974) found that, with training, test subjects were able to improve their understanding of center embedded structures at the second and third levels, but even with training, there was a sharp drop off in comprehension beyond the third level. However, Lewis (1996a) adds that even “very deep embeddings” can be worked out with pen and paper, given “enough time and patience,” though this sort of puzzle solving on paper is a far cry from real-time comprehension, which Lewis concedes is not possible, stating that fourth-level “embeddings exceeded” speakers’ “short-term capacity” (p. 35).

### *Rationality*

If Lewis’s (1969) claims about rationality in reference are misleading, Chomsky’s are even more so. Chomsky & Miller (1963) create hypothetical sentences that go far beyond three variables, which they claim must be “Accounted for by a real grammar of a natural language... If the grammar is to have any psychological relevance” (pp. 286-

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<sup>11</sup> Notably, English’s cousin German, tolerates embedded sentences of three levels more readily than English even though it’s only slightly more head-final than English (e.g. in that many embedded clause types are canonically OV), (Bach, Brown, and Marslen-Wilson 1986; Joshi 1989; Karlsson 2007; Lewis 1996b).

287)—the numerical co-indexation is theirs and unlike the co-indexation variable letters above is not limited to co-indexing subjects and verbs.

- (34) \* Anyone<sub>2</sub> [who feels that<sub>3</sub> [if<sub>4</sub> [so-many<sub>5</sub> [more students<sub>6</sub> [whom we haven't actually admitted]<sub>6</sub> are sitting in on the course]<sub>5</sub> than ones we have]<sub>4</sub> that the room had to be changed]<sub>3</sub>, then probably auditors will have to be excluded]<sub>2</sub>, is likely to agree that the curriculum needs revision.

Despite Chomsky & Miller's claims that the ability to process this sort of hypothetical sentence is necessary for a system of human language processing (p. 286),<sup>12</sup> just the opposite is true. The inability to understand which variables delineate the boundaries of human thought (in and beyond language processing) is what decision theory attempts to answer (Bermúdez 2009; White 2009; Parmigiani & Inoue 2009) and what neural networks in artificial intelligence attempt to emulate (De Paz 2009; Maskara & Noetzel 1992)—this discussion is taken up in more detail in §6.6. In designing machines to imitate the flight of birds, it has been necessary to understand and work with a number of complicating factors, such as atmospheric pressure and gravity which conspire to complicate propulsion and lift, yet in designing mechanistic models meant to imitate the human mind, Chomsky and many others have neglected the need to appropriately weigh the multitude of constraining factors which could perturb the parsing of linguistic units, a case in point being the Chomskyan movement-based grammar paradigm, which hypothesizes movement-based derivations that create embeddings which the human mind cannot process because of variable-tracking constraints—see §3.3.

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<sup>12</sup> Miller and Chomsky (1963) claim that such a sentence has “complexities that must in principle be accounted for by a real grammar of a natural language” in a section explaining why invented multiply-embedded sentences are “perfectly grammatical” and have “clear and unambiguous meaning” (p. 286). The claim in the present work is that a “real grammar of a natural language” should draw a clear line excluding such sentences.

Rather than measure the cut-off point of where such sentences become unusable, Chomsky & Miller merely claim that sentences with such structures as (34) are not found simply because they are “of no use” and thus do not appear for the same reason that we do not see other such “perfectly well-formed sentences” as “*black crows are black, black crows are white, and Tuesday follows Monday.*” As with Lewis’s (1969) claims in §2, Chomsky & Miller (1963) do not address why an irrational person would not have the cognitive ability to transcend the three-dimensional limitations, which rein in all human speech alike, and or why, when such limitations are transcended with for analytical purposes pen and paper (such as his own work on the topic), this is accomplished by someone at least rational enough to cultivate analytical thinking.

#### *Memory vs. Variable Balancing*

Tests by Blaubergs and Braine (1974) confirm that after three levels of interdependent variables, there is an extreme degradation. They claim that this processing limitation is “presumably due to structurally intrinsic short-term memory limitations”; however, as Kinderman et al. (1998) show, the balancing of interdependent variables is a task fully independent of memory. The fact that the comprehensibility of deep non-center embedding, such as that of “The House that Jack Built” in (28), is nearly infinite, though not infinitely memorizable, also attests to this vital distinction.

A problem with Blaubergs and Braine’s analysis is that the linear syntactic string in center-embedded structure is not reparsed when the narrative is recalled for factual recollection. The actual short-term memory of events is recalled. But in order to arrive at narrative understanding of the events in question in the first place, the syntax must be

parsed at one point in real time, when the variables are being balanced, a process quite distinct from event memory.

Pinker (1995) seems to agree that “What boggles the human parser” is a certain “kind of memory” and even adds that the “the human sentence parser” has trouble leaving off in the middle of a clause, “intending to get back to it” (p. 207). However, he goes on to claim that the human cognitive faculty does not keep track of “currently incomplete phrases in the order in which they must be completed” but instead keeps track of how many different types of verbs are on the right side of the valley, and if two of them are of the “identical type of phrase... there is not enough room on the checklist for both numbers to fit, and the phrases cannot be completed properly” (p. 207).

There are three problems with Pinker’s hypothesis. First, as seen in the contrast between (27)", (27)", and (27)", two verbs of identical morphophonological structure and valence can vary in acceptability contingent upon intonational characteristics. Second, Pinker fails to show that his master checklist can support more than three variables, provided that no two levels contain the “identical type of phrase” (p. 206). Finally, a problem that both he and Blaugher and Braine (1974) fail to explain is the difference between variable balancing and memory of narratable events.

#### *Conventionality and intonation*

Pinker’s position is not fully novel. Bolinger’s (1971) earlier work on this topic does not propose a master checklist in the mind that keeps track of similar types of verb phrases, but like Pinker, he claims that, when the VP chain at the right-side of the valley comprises diverse VP types, there is greater intelligibility (p. 29). For example, while (35)

with two simple verbs at the right-side of the valley is less readily intelligible, (36) with differentiated VP types at the right-side of the valley is more readily intelligible (p. 29).

(35) # The cat<sub>x</sub> [that the dog<sub>y</sub> bit<sub>y</sub>] ran<sub>x</sub>...

(36) The cat<sub>x</sub> [that the dog<sub>y</sub> bit<sub>y</sub>] ran away<sub>x</sub>...

The observations about intelligibility may be factually accurate, but like Pinker, Bolinger does not note that conventionality and intonation breaks brought about by such embedded phrases play a significant part in the intelligibility of such embedded sentences. For example, while (37), according to Bolinger's estimation, is only marginally acceptable, (38) is quite indisputably clear, despite that both (37) and (38) have no differentiation in the consecutive verb types.

(37) # The cat<sub>x</sub> [(that) the dog<sub>y</sub> bit<sub>y</sub>] ran<sub>x</sub>...

(38) That guy<sub>x</sub> [(that) you<sub>y</sub> know<sub>y</sub>] left<sub>x</sub>...

The determining factor is, in accordance with Croft's (1995) observations (p. 872), a prosodic one, in that (37) features an intonation break while (38) does not. This is distinct from Pinker's "master list," which seeks out differentiation. The differentiation of sequential sound segments, like prosody, is indeed a factor which can compound the limitations of the already-present variable tracking task, since the repetition of similar segments puts an extra burden on the interlocutor's mind in the same way that repeating identical syllables prompts haplology (see Chapter 1 above & Chapter 5 below).

An additionally attested processing burden is that of object-relativizing markedness (as opposed to subject-relativization unmarkedness) in English and other European languages: "Double relativization of objects (The rat the cat the dog chased killed ate the malt) does not occur" (Karlsson 2007: 2). This could be attributed to the

shift to a marked OSV word order in relative clauses, which notably differs from the unmarked SVO order of the languages examined. There could very well be additional reasons for the difficulty of these constructions, but they would only compound the processing problems posed by OSV word order, not alleviate them.

Rather than focus on differentiation, like Pinker does, Bolinger entertains the hypothesis that three variables might be the cognitive limit of sentence formation and parsing, but then he goes on to fabricate a four-variable center-embedded sentence, as seen in (39), which he deems “not deviant” provided that “the prosodic disjunctures are properly handled”; however, such a structure never appears in any of the above-noted corpora, most likely because it is an intellectual fabrication which, while parsable through study, does not constitute part of the natural world.

(39) \* The one time<sub>x</sub> [that the only car<sub>y</sub> [any dealer<sub>z</sub> [I<sub>w</sub> could find<sub>w</sub>] was<sub>z</sub> willing to guarantee] turned<sub>y</sub> out to be a Ford], was<sub>x</sub> when I was hunting around second-hand places in Phoenix ...

Bolinger’s claim then that four-variable sentences would simply “not occur often” is a misleading understatement about a sentence type which, as noted above, does not appear in the extensive corpora studies by Karlsson (2007), any of the SOV data studied by Babyonyshev & Gibson (1999), the spoken English data of Croft (1995), or in the 500 years of recorded English media for commonplace nouns like *person*, *man* and *boy* discussed herein.

The data suggests that limitations on the center-embedding of clauses represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. Like the variable-balancing tasks for reference in the preceding chapter, the variable-balancing task of center-

embedding clauses involves three interdependent variables that must be dealt with simultaneously at the peak cognitive point of reaching the third variable. While this sort of syntactic center-embedding in language is the most common and certainly the most routinely analyzed, it is not the only type of center-embedding at the syntactic level.

### 3.2. Center-Embedding in Noun Phrases

While the most discussed instances of center embedding involve verb phrases, center-embedded noun phrases are subject to the same limitations. Hudson (1996) notes that, in Classical Greek, three levels of interdependent variables are found, as seen in (40), but nothing beyond this.

- (40) « τὸ τῆς τοῦ ξαίνοντος τέχνης ἔργον » (Plato, Politicus 281a)  
 [t·o<sub>x</sub> [tēs<sub>y</sub> [t·û<sub>z</sub> ksainont·os<sub>z</sub>] tekhn·ês<sub>y</sub>] erg·on<sub>x</sub>]  
 [the·ACC<sup>♂</sup><sub>x</sub> [the·GEN<sup>♀</sup><sub>y</sub> [the·GEN<sup>♂</sup><sub>z</sub> wool-carder·GEN<sup>♂</sup><sub>z</sub>] technology·GEN<sup>♀</sup><sub>y</sub>]  
 work·ACC<sup>♂</sup><sub>x</sub>]  
 ‘the work of art of the wool-carder’

At the peak cognitive point of reaching the z-value [ $t\hat{u}_z$  [...]], the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value [ $t\hat{e}_y$ , [...]] and the x-value [ $t\hat{o}_x$  [...]], thus interpreting a maximum of three interdependent variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements.

The visually tiered analysis of (40) in Figure 3.3a illustrates the fact that the interlocutor must conceptually hop between the different sides of a valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

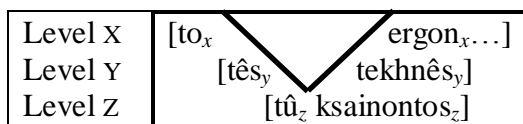


Figure 3.3a: A conceptual three-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

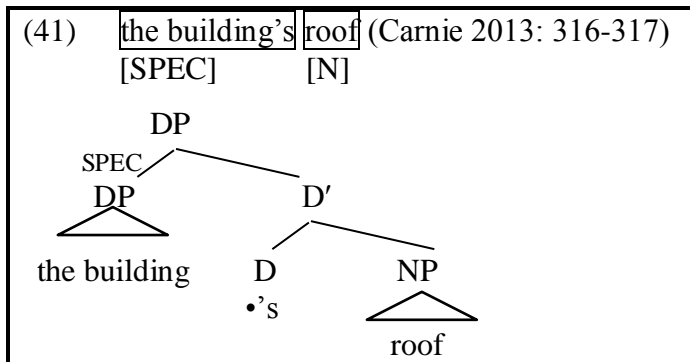
The data suggests that limitations on the center-embedding of noun phrases represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. The relative cross-linguistic rarity of center-embedded noun phrases suggests that there is not anything universal about them. However, because they are constrained by the same limits which apply to center-embedded clauses, they demonstrate that the three-dimensional limit on embedding is not limited to verb phrases. Of critical importance is that an understanding of this unifying constraint on variable-balancing tasks in language and especially of how it applies to center-embedding phenomena precludes the putting forth of hypotheses presupposing that human language use involves balancing an endless number of interdependent variables.

### **3.3. Problems with Center-Embedding in Movement-Based Derivation Systems**

The inability to quantify the constraint on variable-balancing tasks is not negligible, as it can lead and has led to hypotheses presupposing unlimited degrees of center-embedding, such as Chomsky's movement-based grammar. At the core of the center-embedding problem in the Chomskyan movement-based paradigm is phase movement to a part of a ternary branching system known as a SPEC position (Chomsky 1970; 1986; Stowell 1983), in particular the SPEC genitive analysis, the movement rules of which allows for the manipulation of up to and even beyond seven interdependent variables simultaneously.

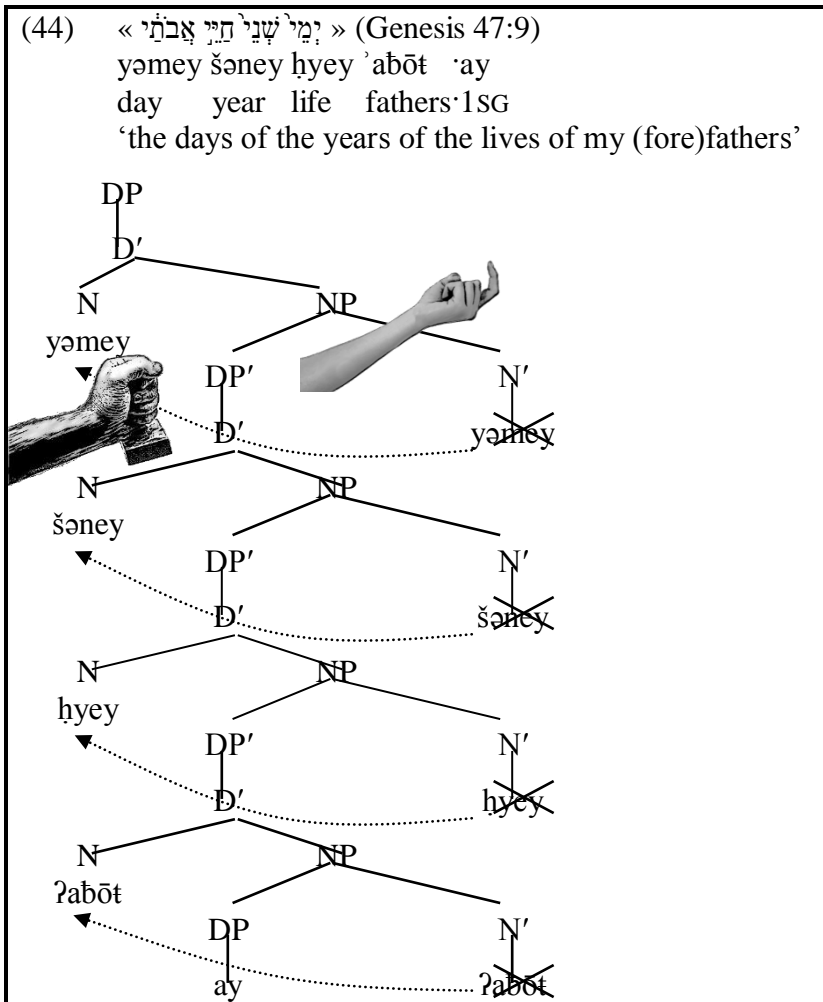
Generative grammar theories, both derivational (Chomsky 1986: 116, 188) and non-derivational (Pollard & Sag 1994: 51), employ a SPEC node to account for left-

branching elements in otherwise head-initial languages (Tokizaki & Kuwana 2013: 222). Key among these is the use of SPEC for the left-branching genitive of languages which are otherwise mostly right-branching (Abney 1987: 79; Radford 2004: 369; Carnie 2013: 316-317), such as the noun's possessor in English, as seen in (41).



An explanation for possessed chains in Semitic languages, generally accepted in movement-based grammar, originally put forth by Elizabeth Ritter (Ritter 1988: 121, 154) and subsequently developed by (Ritter 1991: 47; Carnie 2013: 218; Ouhalla & Shlonsky 2002: 33), among others, uses the English-centered mechanism of this SPECIAL structural node to explain why the definite article only appears once in Semitic noun possessed-state possessor chains. This narrative, like that for English above, involves head adjunction, with a proposed “reduction” of the possessed element thereby accounted for. Accordingly, note how the Hebrew of (42) (Numbers 21:21), just like the Arabic of (43) (*Qur’ān* 114:2), purportedly derives its head-initial N-G word order from a more deep-down head-final G-N construction, purportedly inherent in all head-initial languages—the beckoning finger and the hand stamp represent the respective processes of drawing





Given that Classical Hebrew and Arabic are harmonically head initial in all ways, the possessed head must always follow the possessor dependent, as no other word order could possibly exist. There is no reason a language as harmonically aligned as Classical Hebrew or Arabic, which both have so much cross category consistency and are either twinned or mirrored by languages all over the world should have to be subjected to this type of analysis, simply to appease the movement-based claim that English's head-final possessor is a universal of head-initial languages, which it clearly is not. The fact that center embedding of the sort seen in (44) is proven not to exist anywhere in human language, however, shows that this movement-based grammar derivation is not only

uneconomical but unprocessable, given the enormous burden of tracking eight interdependent variables.

As each dependent possessor is added to the head noun above it, the conceptual valley between the proposed moved head's origin and destination widens, and in addition to (a) the inelegance of this derivation, (b) the lack of empirical proof of such a base-generated position, (c) its lack of correspondence with harmonic norms, it also proposes infinite central embedding, which is impossible in any human language beyond three variables (Karlsson 2007; Babyonyshev & Gibson 1999), and (d) as Hawkins (1983) demonstrates, there is not a language we know of, which is fully harmonically head-initial but varies only with regards to the alignment of a possessor dependent preceding its possessed head (pp. 283, 286). In other words, in harmonically head-initial and head-final languages, any element can break ranks and initiate a shift in alignment, but the G|N alignment will not move unless something else does first (pp. 282-290).

According to the movement-based grammar view, the problem with center embedding is one of performance, not competence (Miller & Chomsky 1963; Miller & Isard 1964). Accordingly, the grammar can generate center embeddings of arbitrary depths, but they simply cannot be processed. Since, in the Genesis-47:9 example in (44), what the speaker processes is the surface form (which does not have center embedding) there does not seem to be a problem for center embedding at a deeper level of representation.

However, it is the very claim that the mind performs these operations before a sentence is uttered which is significant. According to movement-based grammar theories, branches cannot be crossed (Carnie 2013: 16), which means that, while the movements of

the Genesis-47:9 variety are taking place, the human mind must minimally keep track of all of the branches that are not being crossed, hence juggling the same number of center-embedded variables that one would be dealing with in an overt case of center embedding.

To top this off, it is notable that this unseen movement is not paralleled (even in diminished form) in overt movement in the languages where Chomsky claims it takes place. Even in English, the instances of what could legitimately be called overt movement rarely coincide with one another (in highly contrived constructions), and in the rare cases when they do, there are never even three of them at the same time, let alone more than three. For example, *Beans I love; toast I don't* could be seen as an instance of “movement” in English, as could “wh-movement,” but the two never occur together:

*\*How beans I love? (how) toast I don't? OR \*How beans do I love? How Toast don't I?*

Of course, this is all just an elaboration on the fact that a left-branching SPEC for head-initial languages is empirically seen to exist in zero of Hawkins' 336 languages (1983: 282-290), thus making it anything but “universal.” It is simply the fact that multiple measurable phenomena militate against the Chomskyan idea of phrase movement to SPEC.

The resistance of the noun-genitive alignment to shift until other elements have shifted is not accidental. For one, there is no clear G|N dominance pattern (Greenberg 1963: 60-61; Croft 2003: 61). The reason Hawkins gives, however, is that G|N relationships consist of two words of the same category and thus listeners could only process such a break from harmony if there were at least one other precedent of disharmony in the language (personal discourse, 2008). Indeed, this is the only existing alignment pair consisting of two elements from the same category appearing in the

harmony and dominance analyses of Greenberg (1966), Hawkins (1983) or Croft (2003: 75). And if all noun modifiers in a language are, for instance, head-initial and a speaker is to interpret a pair of nouns, there is no motivation to interpret them as head-final. This is clearly the case with asyndetic constructions, as well as with syndetic constructions employing head-final linking particles like the •'s clitic, the postpositional nature of which definitively breaks ranks with the head-initial nature of prepositions.

Any research operating without information on variable-balancing constraints runs the risk presupposing endless center-embedding of the sort discussed in this section. What matters most is that hypotheses about what human language can do be guided by data patterns showing where recursivity in human language breaks down. Linguistic formalism which revisits the goals of the Chomksyan program, but does so armed with empirical information about the three-dimensional cap on human variable-balancing tasks, could potentially put together a formal model of language which accounts for human language at the universal level which Chomsky and his successors originally aimed for.

The data suggests that the limitations on movement-induced center-embedding represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. The relative rarity of genuinely attested movement (as opposed to hypothetical movement from a deeper structure to a more surfacy structure) suggests that there is little opportunity for multiple types of movement even to coincide. Of critical importance is that an understanding of this unifying constraint on variable-balancing tasks in language and especially of how it applies to center-embedding phenomena rules out hypotheses about human language employing unconstrained levels of center embedding.

### 3.4. The Cross-Dependency Recursion in Interdependent Syntax

While the structure of syntactic cross-dependency constructions is distinct from center-embedded constructions, it involves an analogous variable-balancing task and consequently shares a limitation on the number of interdependent variables.

The cross-dependency of Dutch, as seen in the two-variable construction of (45) and in the three-variable construction of (46), is much like the English *respectively* constructions discussed in §2.2 above, in that the first item of the first set corresponds with the first item of the second set, while the second item of the first set corresponds with the second item of the second set, etc. (Christiansen & Chater 1999: 162)—co-referential strings appear in boxes for emphasis.

- (45) Jantje heeft de lerares de knikkers | helpen opruimen.  
Jantje has<sub>x</sub> the teacher the marbles<sub>y</sub> | help<sub>x</sub> collect up<sub>y</sub>.  
'Jantje helped the teacher collect up the marbles'.
- (46) Aad heeft Jantje de lerares de knikkers | laten helpen opruimen.  
Aad has<sub>x</sub> Jantje<sub>y</sub> the teacher the marbles<sub>z</sub> | let<sub>x</sub> help<sub>y</sub> collect up<sub>z</sub>.  
'Aad let Jantje help the teacher collect up the marbles'.

At the peak cognitive point of reaching the z-value 'the teacher the marbles'<sub>z</sub>, the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value 'Jantje'<sub>y</sub> and the x-value 'Aad has'<sub>x</sub>, thus interpreting a maximum of three variables (Bach, Brown, & Marslen-Wilson 1986: 249), one being manipulated and two others being simultaneously recalled in anticipation of their complements.

The data suggests that the limitations on syntactic cross-dependency represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. On the one hand, syntactic cross-dependency is analogous to cross-dependent reference, while, on the other hand, it

operates at the syntactic level like syntactic center-embedding does. What these intersecting phenomena share is a common variable-balancing task limited by the three-dimensional constraint that appears to rein in human language structure at multiple levels of analysis.

### 3.5. Other Limitations on Interdependent Syntax

Garden path sentences provide yet another blind spot which reveals limitations of human language processing similar to those of the center-embedding and cross-dependency varieties analyzed above. As Croft (1995) notes, “garden-path sentences are sentences that native speakers tend to misparse, producing an incorrect analysis” (p. 873). In constructions with such grammatically ambiguous beginnings, not only the meaning but even the category of polysemous words can vary depending on which words follow them. Croft gives the examples seen in (47)-(49).

- (47) The horse raced past the barn fell.  
\*[NP V PP] vs. [NP RCp V].
- (48) The patient persuaded the doctor that he was having trouble with to leave.  
\*[NP V NP that + S'] vs. [NP V NP that + RC VPi].
- (49) I told the boy the dog bit Sue would help him.  
\*[NP V NP S'] vs. [NP V NP RC S'].

Croft notes that sentences with ambiguous beginnings, moreover, tend to the simplest (i.e. typologically least marked) interpretation of the first words, even when such an interpretation is disjoint with the rest of the sentences (1995: 874); for example, the interpretation of *raced* as a past-tense verb of the subject *horse* is less marked than its use as a participle of an asyndetic relative clause preceding a delayed verb like *fell*. Similarly, in the classic example of (50), since the first sentence establishes *flies* as a verb and *like*

as a preposition, the second sentence initially tends toward that interpretation of *flies* and *like* simply to follow the parallelism set out by the first sentence, until the meaning makes clear that *flies* here makes more sense as a noun and *like* makes more sense as a verb.

(50) Time<sub>w</sub> flies<sub>x</sub> like<sub>y</sub> an arrow<sub>z</sub>; fruit<sub>w</sub> flies<sub>x</sub> like<sub>y</sub> a banana<sub>z</sub>.

Example (50) contains the minimal elements required to confuse a reader. Since the first clause *Time flies like an arrow* in (50) relies on an understanding of all four words to interpret a single one, it goes beyond the human ability to interpret more than three interdependent variables, creating an unexpected result for the following clause *Fruit flies like a banana* which can only be correctly reparsed in retrospect as *Fruitflies like a banana* with *fruitflies* understood as a compound noun, rather than the subject *fruit* noun followed by the tensed verb *flies*.

The humorous blunders that humans make when reading garden-path sentences are based on the way language is comprehended, linearly, with only inferential cues given about what sort of word(s) will follow.

Using a computational parsing model called Parsifal, Marcus (1979) demonstrates that garden paths are difficult to identify because the parser must process a core word (such as a subject, verb, or verbal complement) in the context of the words which immediately follow it. In other words, a subject like *horse* is processed interdependently with the following words. The parser has to decide what to do at each point based upon a limited look ahead involving three constituents, as the meaning of one core word is based on the meaning of all of them.

According to the present model, at the peak cognitive point of reaching the z-value *the barn*, the interlocutor has the task of dealing with this variable and interpreting

it with relation to the y-value *past* and the x-value *raced*, thus interpreting a maximum of three interdependent variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements. Thus, assuming that *raced* is the first in a string of three constituents processed interdependently (the other two being *past* and *the barn*), the verb *fell* lies beyond the range of interdependent processing with *raced*, and as such plays no part in the initial parsing of *raced*.

As Church (1980) notes, “all the garden path sentences [discussed in his work] would require a four constituent look ahead to disambiguate correctly,” and, as such, the parser’s “three constituent limit” appears to provide “a very good description” (1980: 19).<sup>16</sup>

The data suggests that the limitations on processing garden paths approximate a hard constraint, in that data shows confusion with more than three levels of interdependent variables processed in natural language usage; however, familiarity with certain types of ambiguous constructions might have an effect which soften this constraint in ways not yet explored in any of the literature surveyed in the present work. Garden-path constructions that complicate the syntactic parsing task reveal a constraint on human variable-balancing skills, analogous to the foregoing phenomena of embedding and cross-dependency tasks, which share a common constraint of dealing with three interdependent variables.

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<sup>16</sup> Neither Church, nor his sources like Marcus (1979), nor Croft (1981) address the shorter garden-paths like *The old man the boats*. Such studies have yet to demonstrate how much easier a phrase is to process than the others.

### 3.6. Three-Dimensional Constraints on Introducing New Information

Given the cognitive limit of balancing three interdependent variables, it is not surprising that syntactic constructions tend to encode entities previously introduced in the discourse through closed-class marking, such as pronominal affixes or clitics, rather than introducing new entities, as this intersecting complication adds a further cognitive burden. In fact, sentences, regardless of the number of constructions they comprise, rarely introduce even two new entities into the discourse with full open-class nouns (Croft 1995: 859; Croft 2007: 20), and the introduction of more than two new entities is so rare as to be non-existent in Croft's samples.

While it is true that languages can have analytical causative forms of verbs like *help* or *make* followed by a clause, as seen in (51), or synthetic causal forms like *give*,<sup>17</sup> as seen in (52), they too are limited by the same constraints on introducing multiple entities, and most of the participants in the action are encoded through closed-class marking.

(51) Help me help you make next year the very best. (Piranian 1966: 34)

(52) It gave me a cold. (Hutchinson 1884: 276)

It is doubtful, moreover, that there even exists statistically significant corpus-based evidence of even three entities introduced into the discourse with full open-class nouns, despite how compelling descriptive and didactic grammar books are with their attempts to fill all the possible slots of a complete paradigm.

As noted in §2.4 above, the introduction of new grammatical arguments is highly constrained in natural language use, which is why syntactic forms of causativity are so highly constrained in natural-setting usage across languages, just as morphological forms

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<sup>17</sup> In its two meanings of 'make have' or 'make go to' (Green 1973; Oehrle 1976; Goldberg 2006).

of causativity are so highly constrained in form across languages, keeping in mind that morphological form is merely a fossilized form of earlier syntactic usage. The following discussion of constraints on the nuclei of syntactic constructions addresses an intersecting set of phenomena which suggests ways in which formalized models of grammar might approach accounting for soft constraints on new information.

The data suggests that the limitations on introducing new information represent a soft constraint rather than a hard one since speakers involved in dialog with each other can transgress this limit (even without pen and paper); however, the fact that corpora show this pattern to numerically correlate with the hard constraints constituting the bulk of the present work makes it merit inclusion in this discussion.

### 3.7. Three-Dimensional Constraints on the Nuclei of Syntactic Constructions

According to theories of construction grammar, constructions may have other constructions nested within them (Croft 2001). However, simple non-nested constructions are limited in their complexity; for example, none of the individual constructions cataloged in Goldberg (1995) go beyond balancing three variable branches of a construction nucleus; accordingly, the following is proposed for a sentence like *He ate figs* in Figure 3.7a.

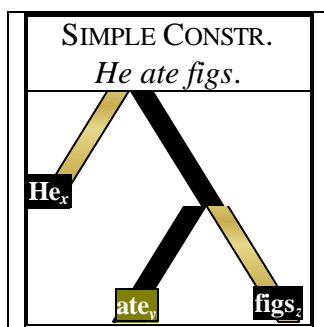


Figure 3.7a: A simple construction.

At the peak cognitive point of reaching the z-value *figs*, the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value *ate* and the x-value *He*, thus interpreting a maximum of three variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements.

In complex constructions, the nested construction is dealt with independently, and it as a bundle is treated as a variable in the construction wherein it is nested. A nested construction would thus look like *It gave me a cold* in Figure 3.7b.

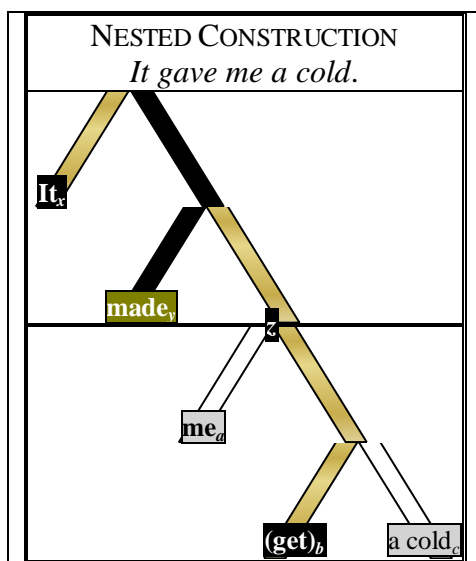


Figure 3.7b: A nested construction.

At the peak cognitive point of reaching the z-value *me (get) a cold*, the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value *made* and the x-value *It*, thus interpreting a maximum of three variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements. Within the nested phrase *me (get) a cold*, at the peak cognitive point of reaching the c-value *a cold*, the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value *get* and the x-value *me*, thus interpreting a

maximum of three variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements.

Adjuncts to the constructions in question, such as adverbs, adjectives, and other modifiers of the verb or noun, could embellish the components of the constructions in question, but since they do not affect the makeup of the construction in terms of its basic components, such as verb valency, or other aspects of argument structure, such adjunction would presumably only interfere with construction processing inasmuch as it creates more situational complexity and more prosodic distance between a construction's components.

The data suggests that the limitations on the nuclei of syntactic constructions represent a soft constraint rather than a hard one since speakers involved in dialog with each other can transgress this limit (even without pen and paper); however, the fact that documented constructions in common use across languages show this pattern to numerically correlate with the hard constraints constituting the bulk of the present work makes it worthy of inclusion in this discussion. Across languages, nestings which complicate the verb appear to be among the most limited since these have the potential to increase the number of grammatical arguments participating in the action of the verb, thus potentially overloading the human ability to balance up to three interdependent variables in a given proposition. Nestings which merely complicate nouns don't complicate the argument structure of the verb per se, but it is possible for them to incur other transgression of the three-dimensional cap on human thought.

### **3.8. Relevant Connectionist Models**

Appropriate to the types of syntactic variable balancing surveyed in this chapter are connectionist models which measure the limitations on center-embedding (§3.1, 3.2, & 3.3) and cross-dependencies (§3.4), among other types of variable-tracking tasks.

Following the experiments of Bach, Brown, and Marslen-Wilson (1986) with human test-subjects, Joshi (1989) uses EPDAs (embedded push-down automata) to show that, while center embedding is somewhat more difficult than cross dependencies at two and three levels (p. 2), both types of tasks “cannot be instantiated for sentences containing more than three matched NPs and Vs” (p. 28). Christiansen and Chater’s (1999) findings show the same thing with SRNs designed to process center-embedding “mirror” recursion.

Ultimately, in syntax, there is not so much a dearth of applicable connectionist models as there is an absence of a single model which captures the parallels between the processing limitations of syntactic embedding and other types of limitation patterns in human language, as well as other types of limitation patterns in general human cognition.

### **3.9. Concluding Remarks on Syntax**

As with the recursive limits on reference seen in the previous chapter, the simplest explanation is the easiest to quantify and corroborate with various other forms of typological phenomena. In syntactic center embedding, there is a three-dimensional limit of human cognition in variable balancing, which keeps track of both sides of the embedding valley. However, unlike reference which can be manipulated by literary artists, syntactic embedding is bound to the constraints of three variables without any

attested exceptions in media meant to be understood; only contrived exceptions by linguists are routinely observed.

Various factors can conspire to further complicate variable-balancing tasks in syntax, such as the task of processing syntactic center-embedding in (40) (repeated below for convenience) being additionally burdened by the interference of distributed case marking—see §4.3 below for a full discussion of this phenomenon and the processing burdens it entails.

- (40) « τὸ τῆς τοῦ ξαίνοντος τέχνης ἔργον » (Plato, Politicus 281a)  
 [t·o<sub>x</sub> [tê<sub>s<sub>y</sub></sub> [t·û<sub>z</sub> ksainont·os<sub>z</sub>] tekhn·ês<sub>y</sub>] erg·on<sub>x</sub>]  
 [the·ACC<sub>x</sub> [the·GEN<sub>y</sub> [the·GEN<sub>z</sub> wool-carder·GEN<sub>z</sub>] technology·GEN<sub>y</sub>]  
 work·ACC<sub>x</sub>]  
 ‘the work of art of the wool-carder’

Again, however, such interference only increases the constraints already imposed by the cognitive limit of three dimensions; it does not alleviate them. What is clear is that the human mind is pushed to its limits with any individual three-dimensional juggling task, and thus working with multiple simultaneous three-dimensional juggling tasks. The human mind, like a computer’s CPU, is capable of multitasking, but as with a computer, too many oversized processes at once can overburden the CPU and compromise all functions, which is why it is not common to solve math problems while simultaneously playing the piano and debating someone about politics. The next section examines morphological complications like those of (40) in isolation and examines parallels between variable-balancing tasks at that level of analysis and those explored in this chapter.

#### 4. Three-Dimensional Constraints on Interdependent Structures in Morphology

... we will proceed with our anti-anti-missile missile plan, which will knock any anti-missile missile you develop out of the sky...

– (Art Buchwald 1966: para. 5)

Morphology is the second smallest unit of language bound by the same three-dimensional constraints on processing as are the larger levels of reference and syntax and the smaller units of phonology. What the various types of constructions analyzed in this chapter all have in common is constructions which, while phonologically parsable, cannot be interpreted at the word level without reference to the interdependent morphology that shares embedded constructions with them and determines which level of syntactic embedding they occupy.

Literary styles are seen to permit recursion to skirt the cognitive limits of these constructions, but while such literary creations are analyzable with pen and paper, they are generally difficult to interpret in auditory uses of language, as seen from their near absence from spoken language. Recursion can be seen transcending these limits in meta-linguistic analyses, generally concocted by linguists or cognitive psychologists attempting to understand constraints on human comprehension.

Attention is also given to appeals made in earlier literature to the concept of human rationality as an explanation of the limitations on recursion. Accompanying this is a discussion of how memory tasks are distinct from variable balancing tasks, despite the common use of “memory” to refer to both types of phenomena. Consideration is finally given to literature on connectionist models which apply to the phenomenon under analysis.

#### 4.1. Three-Dimensional Constraints on Affixing

Morphology is occasionally cited in analyses claiming that the rules of recursivity are infinite or practically infinite (Pinker 1995: 129-130). However, such discussions of nearly endless recursion generally refer to linear strings, such as the examples given by Pinker (1995: 135), in (53), where he adds suffixes to the stem *Darwin*.

- (53) a. Darwin  
b. Darwin<sup>ian</sup>  
c. Darwinian<sup>ism</sup>  
d. Darwinianisms<sup>s</sup>

Pinker (1995: 129) even makes a point of showing that there is no limit to word length or morpheme number, in (54), by adding suffixes to the already long base of *floccinaucinihilipilification*.

- (54) a. floccinaucinihilipilification  
b. floccinaucinihilipilification<sup>al</sup>  
c. floccinaucinihilipilificational<sup>ize</sup>  
d. floccinaucinihilipilificationaliz<sup>ation</sup>

Linear (non-interdependent) recursions, like those of (53) and (54), can be impressively long in length since processing the derivation at hand is not contingent on processing previous steps of earlier derivations; the *-ation* ending is easily understood to be the nominal form of the redundantly (intentionally) overlength base of *floccinaucinihilipilificationalize-* (even with no understanding of what the base actually means), on the patterns of much smaller pairs like *realiz(e)-* and *realization*.

In contrast, embedded (interdependent) recursions, like those of (55) Buchwald (1966), are clearly not limitless since processing difficulties become apparent after the first circumfixation occurs.

- (55) a. <sup>anti-</sup><sup>-missile</sup> missile  
b. ? <sup>anti-</sup>anti-missile-<sup>missile</sup> missile

- c. ?? anti-anti-anti-missile-missile-missile missile  
d. ??? anti-anti-anti-anti-missile-missile-missile-missile missile

The visually tiered analysis of (55) in Figure 4.1a illustrates the fact that the interlocutor must conceptually hop between the different sides of a valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

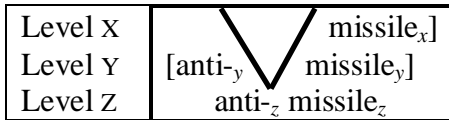


Figure 4.1a: A conceptual three-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

At the peak cognitive point of reaching the z-value [anti-<sub>z</sub> ... missile<sub>z</sub>], the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value [anti-<sub>y</sub> [...]] and the x-value a noun which still has not been heard yet—in Buchwald (1966), the noun portion of this construction consisted of either *missile* or *plan*—thus interpreting a maximum of three variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements.

### *Memory vs. Variable Balancing*

Pinker claims that “a chaining device” cannot process embedded words like *anti*<sub>x</sub>-[*anti*<sub>y</sub>-[*missile*<sub>z</sub>]-*missile*<sub>y</sub>]*missile*<sub>x</sub>, “because it has forgotten the pieces that it laid down at the beginning of the long word by the time it gets to the end,” but then he goes on to claim that this is possible with a “word structure grammar (a phrase structure grammar for words) that can embed a word in between an *anti*- and its *missile*” (p. 130), not recognizing that no natural mechanism of human language can actually process such embeddings without the aid of writing, since it is not a memory-related task at all but one of balancing interdependent variables.

It should be noted that this particular variable-balancing task is also burdened by a phonological problem of the sort discussed in Chapter 5, since the string of prefixes and suffixes equally suffer from additional problems of homophony.

### *Rationality*

The limits on the recursive building up on of an *anti<sub>x</sub>-[missile<sub>y</sub>] missile<sub>x</sub>* complex fall within the purview of both Chomsky's claim about the rational decision that speakers make to not center-embed more than they contextually need to (as discussed in greater detail in §3.1). Again, what such a claim fails to address is why an irrational person would not have the cognitive ability to transcend the three-dimensional limitations, which rein in all human speech alike, and or why, when such limitations are transcended with for analytical purposes pen and paper (such as his own work on the topic), this is accomplished by someone at least rational enough to cultivate analytical thinking.

### *Pen & Paper*

The pen-and-paper nature of the counting-game is consciously acknowledged in Buchwald's parody about *anti<sub>n</sub>-missile<sub>n</sub> missiles*, which discusses countering missiles with an *anti<sub>x</sub>-[missile<sub>y</sub>] missile<sub>x</sub>*, which can itself be countered with an *anti<sub>x</sub>-[anti<sub>y</sub>-[missile<sub>z</sub>]-missile<sub>y</sub>] missile<sub>x</sub>*, which can in turn be countered with an *anti<sub>w</sub>-[anti<sub>x</sub>-[anti<sub>y</sub>-[missile<sub>z</sub>]-missile<sub>y</sub>]-missile<sub>x</sub>]-missile<sub>w</sub>*. Ultimately, the dialog degenerates into a counting game with comments such as, "You're betting six antis and seven missiles against my four anti's and five missiles?" (1966: para. 9). Such a counting game is only possible when observing the words on paper, as part of a game that the author is playing with his readers.

Pinker (1995) too notes the need to “keep track of all the *anti*’s at the beginning of the word so that it can complete the word with an equal number of *missile*’s, plus one, at the end” (p. 130), acknowledging the meta-linguistic task at hand, which is inherently a task of written language.<sup>18</sup>

In cases where morphological repetition is used in actual language, it is generally conventionalized through the process of recoding, which Miller (1956) defines as “grouping or organizing the input sequence into units or chunks.” Accordingly, the counting tasks involved in the composition of certain words can be circumvented by language users who simply learn them as words, without directly counting them; however, the opportunity to count their parts is available for those with recourse to the written word and analysis thereof.

One notable example involves word for the musical note a *quaver* (an 8<sup>th</sup> note), which, with the addition of the prefix *semi*- ‘half’, becomes a semi*quaver* (a 16<sup>th</sup> note), which in turn, with the addition of the prefix *demi*- ‘half’, becomes a demi*semiquaver* (a 32<sup>nd</sup> note), which in turn, with the addition of the prefix *hemi*- ‘half’, becomes a hemi*demisemiquaver* (a 64<sup>th</sup> note), all stages of which are exemplified in (56), with marked morpheme boundaries.

- (56) a. quaver  
 b. semi·quaver  
 c. demi·semi·quaver  
 d. hemi·demi·semi·quaver

Similarly, the pattern resulting in stress at the end of a word is known as *ultimate* stress, which, with the addition of the prefix *pen*- ‘almost’, becomes a pen*ultimate stress*,

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<sup>18</sup> In *The Language Instinct*, Steven Pinker attributes the exchange described in this 1960s parody to a real-life exchange between the critics of 1980s president Ronald Reagan and the engineers working on his Star Wars program (1994: 130). The dialog cited above was actually published by Buchwald two decades before Reagan became president and three decades before Pinker wrote about it.

which in turn, with the addition of the prefix *ante-* ‘before’, becomes a ante*penultimate*, which in turn, with the addition of the prefix *pre-* ‘before’, becomes a pre*antepenultimate*, which in turn, with the addition of the prefix *pro-* ‘before’, becomes a pro*preantepenultimate*, all stages of which are exemplified in (57), with marked morpheme boundaries.

- (57) a. ultimate  
 b. pen·ultimate  
 c. ante·pen·ultimate  
 d. pre·ante·pen·ultimate  
 e. pro·pre·ante·pen·ultimate

In the cases of words like *hemidemisemiquaver* and *propreantepenultimate*, the aid of written language makes parsing the words more easily attainable, but even then, the words tend to be learned and uttered as chunks by those using them, namely scholars of music and language respectively. In everyday language, such strings of same-meaning morphemes are not such a common sight, with morphemes meaning ‘before’ rarely occurring more than once at a time. For example, a number of languages have lexicalized expressions for ‘the day before yesterday’, using the same sort of compositionality. For example, in Spanish (as in Greek, Hungarian, etc.), the word *anteayer* ‘the day before yesterday’ is composed of the affix *ante* ‘before’ added to *ayer* ‘yesterday’, as seen in (58). Contrarily, in Swahili (as in Japanese, Urdu, etc.), the word *juzi* ‘the day before yesterday’ has no apparent relation to *jana* ‘yesterday’, as seen in (59). Accordingly, Miller’s (1956) idea of chunking could apply to even composite words for ‘yesterday’ since they are seen to represent distinct ideas in languages where unrelated words are used.

- (58) MORPHOLOGICALLY BASED ON THE ROOT OF ‘yesterday’ (SPANISH)

a. ayer	b. ante·ayer
yesterday	before·yesterday
‘yesterday’	‘the day before yesterday’

- (59) UNRELATED TO WORD ‘yesterday’ (SWAHILI)

a. jana	b. jusi
‘yesterday’	‘the day before yesterday’

It should also be noted that, in Maori (as in Turkish, Telegu, etc.), there are no purely lexical means of denoting ‘the day before yesterday’, so the concept must be described syntactically, as seen in (60).

- (60) SYNTACTICALLY CENTERED ON THE WORD ‘yesterday’ (MAORI)

a. inanahi	b. ra i·mua·i inanahi
yesterday	day before yesterday
‘yesterday’	‘the day before yesterday’

This could suggest that, in different languages, the concept of ‘the day before yesterday’ is construed in two or three distinct ways, or it could mean that across languages, speakers universally think of ‘the day before yesterday’ as a chunk, regardless of whether they use a single distinct word, a composite word built on ‘yesterday’, or a composite phrase centered on ‘yesterday’. In contrast, the idea that language speakers universally think of the concept of ‘the day before yesterday’ compositely is not supported by the existence of languages where the word for ‘the day before yesterday’ is completely unrelated to the word for ‘yesterday’.

In the instantiations of affix derivation for ‘the day before yesterday’, while the potential exists for recursive morpheme stacking to denote the days preceding it, these conventionally never reach three, such as in a ‘pre-pre-pre-yesterday’ word, let alone

surpass three, such as in a ‘pre-pre-pre-pre-yesterday’ word.<sup>19</sup> Such constructions are conceivably possible only for literary games of the pen-and-paper variety; in the languages discussed above, anything passing the day before yesterday is conventionally either referred to by name or numbered by date.

One morpheme which shows an exceptional tolerance for recursion is the prefix *great-*, as used in *great-grandfather*, *great-great-grandfather*, *great-great-great-grandfather*, etc., the latter form of which is used in the acknowledgements of the present work, with reference to my actual great-great-great-grandfather.

Performing a search of published sources through *Google News* (on July 14, 2015) for recursions of *great-* preceding *grandfather*, seen in Figure 4.1b, clearly showed its most pronounced drop from one instance of *great-* to two, and its second most pronounced drop from two instances of *great-* in a row to three, after which it mostly levels off. *Google Books* (accessed on the same day) showed a similar pattern.

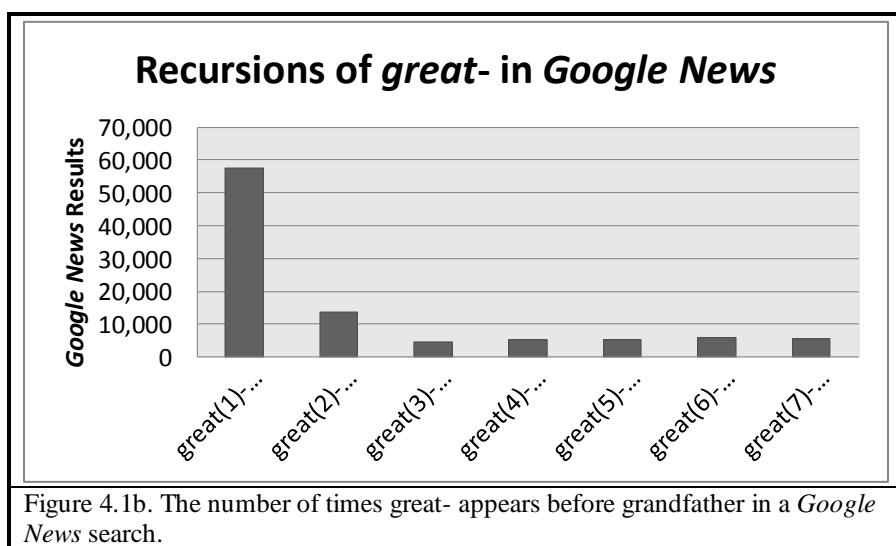


Figure 4.1b. The number of times *great-* appears before *grandfather* in a *Google News* search.

<sup>19</sup> Even ‘pre-pre-yesterday’ words are rare but not non-existent, such as the Qiang word *dʒəʔdʒəʔs* ‘the day before the day before yesterday’, derived by reduplication of the first element of *dʒəʔs* ‘the day before yesterday’ (LaPolla & Huang 2003: 380). Other languages with specific terms for ‘pre-pre-yesterday’ include Savosavo (Wegener 2012: 112) and Zaiwa (Lustig 2010: 414).



As such, while the appearances of recursive *great*- surpassing three are not themselves absent from written English, any use denoting real-world referents is limited to historically-significant (and/or literarily-significant) genealogies. Such highly recursive constructions do not appear in writing meant to reflect actual human dialog since they are pen-and-paper constructions, dependent on a visual counting task.<sup>20</sup> The compounding complication of repeating a string of identical symbols, which appears to complicate what would otherwise be a relatively limitless linear task, is taken up in the next chapter—see §5.1.

The data suggests that the limitations on morphological center-embedding represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. In contrast, the limitations on the linear affixation of homophonous morphemes appear to represent a soft constraint rather than a hard one since speakers involved in dialog with each other can transgress this limit (even without pen and paper). Moreover, the unlimited nature of the affixing of non-homophonous morphemes appears to represent a lack of constraint of the sort seen with the foregoing phenomena.

Like the variable-balancing tasks for syntactic center-embedding in the preceding chapter, the variable-balancing task of morphological center-embedding involves three interdependent variables that must be dealt with simultaneously at the peak cognitive point of reaching the third variable. While this sort of morphological center-embedding in language is not as common and certainly not as routinely analyzed as syntactic center-

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<sup>20</sup> It is notable that genealogy websites forego traditional terms with *great*- and *opt* instead to label with a simple numerical system, such as the labels *G1*, *G2*, *G3*, etc. used on the website *Geni.com*.

embedding, it is an important area to consider in the broader analysis of recursion limitations.

#### 4.2. Three-Dimensional Constraints on Transfixing Morphology

There is a less discussed but no less interesting limit on morphological variable balancing, which involves keeping track of morphemes that mark multiple parts of a word

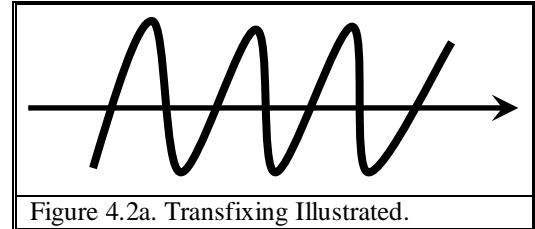


Figure 4.2a. Transfixing Illustrated.

simultaneously. The constituent but discontinuous nature of this sort of morphology can be likened to a needle entering, exiting, and reentering a piece of fabric, as seen in Figure 4.2a. Following the model of Kaye (2007), I will herein refer to this sort of infixing as “transfixing” morphology (p. 211).

As with reference and syntax, morphology does not go beyond the juggling of three discontinuous variables, so only three such variables can be woven into a consonant template in any human language.

Arabic words with the so-called broken plural pattern are marked for plurality by extracting root consonants from a word in order to create a consonantal template to transfix with inflectional vowel patterns. This is the case with quadriliteral nouns, like the Arabic word ثعلب/*θaʕlab* ‘fox’ in (64).

First, the quadriliteral root of *θaʕlab* is isolated as  $\theta - \text{ʕ} - l - b$ , as seen in (64)'. Then, it is inflected for plurality by mapping the three-variable pattern  $a_x \cdot \bar{a}_y \cdot i_z$  onto the transfixing function, as in (64)" (Wehr & Cowan 1979: 853).

(64) « ثعلب »

θ a ʕ l l a b

‘fox’

θ	a	ʕ	–	L	a	B
---	---	---	---	---	---	---

(64)’ θ – ʕ – l – b

EXTRACTED ROOT

ROOT	–	θ		ʕ		L

(64)'' « ثعالب »

θ a ʕ ā l l i b

‘foxes’

f(PLR)			·a <sub>x</sub>		·ā <sub>y</sub>		·i <sub>z</sub>
ROOT	–	θ	–	ʕ	–	L	–

At the peak cognitive point of reaching the z-value ‘i<sub>z</sub>’, the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value ‘ā<sub>y</sub>’ and the x-value ‘a<sub>x</sub>’, thus interpreting a maximum of three variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements.

In Arabic, foreign-origin nouns are also marked for plurality by extracting consonants from a word in order to create a consonantal template to transfix with inflectional vowel patterns. One example is فندق/*funduq* ‘inn’, as seen in (65), from the Greek word πανδοχεῖον/*pandokheion* (Constable 2001: 146), which like *θaʕlab* above is inflected for plurality by mapping the three-variable pattern *a<sub>x</sub>·ā<sub>y</sub>·i<sub>z</sub>* onto the transfixing function, as in (65)’ (Wehr & Cowan 1979: 729)—templatic consonants appear in boxes for emphasis.

Such limits on the processing of analogous cross-dependency structures in human language use are corroborated in other work (Dickey & Vonk 1997) and replicated in

computer simulations (Christiansen & Chater 1999); however, such analyses have hitherto only been applied to discontinuous syntax, not to discontinuous morphology.

(65) « فندق »

funduq  
'a hotel'

(65)' « فنادق »

fanādīq  
'hotels'

f(PLR)			·a <sub>x</sub>		·ā <sub>y</sub>		·ī <sub>z</sub>	
ROOT	–	F	–	N	–	D	–	Q

Since transfixing is limited to three-coordinate function values, even words which appear to have more consonants in their base form, like the so called quinquiliterals and sextiliterals, are reduced to four consonants when undergoing transfixing inflection or derivation in order to accommodate the human limit on the processing of three-dimensional transfixation. As such, the apparently sextiliteral *إمبراطور* /*ʔimbarāṭūr* 'emperor' (from the Latin *imperātōr*), seen in (66), is reduced to the four radicals ʔ – B – Ṭ – R, as seen in (66)', before it can be inflected for plurality by mapping the three-variable pattern  $a_x \cdot \bar{a}_y \cdot i_z$  onto the reduced four-consonant template, as seen in (66)", thus limiting the transfixation to three interdependent variables.

(66) « إمبراطور »

ʔimbarāṭūr  
'an emperor'

		ʔ	im	B	ara	Ṭ	ū	R
--	--	---	----	---	-----	---	---	---

(66)' ʔ – b – ṭ – r

EXTRACTED ROOT

ROOT	–	ʔ	–	B	–	Ṭ	–	R

(66)" « أباطرة »

ʔabāṭūr·a<sup>21</sup>

‘(some) emperors’

f(PLR)			·a <sub>x</sub>		·ā <sub>y</sub>		·i <sub>z</sub>	
ROOT	–	ʔ	–	B	–	ṭ	–	R

When the root-extracting mould can be applied to words derived from formulaic strings with more than four scaffolding consonants, these consonants are reduced to four, just as they are with quinquiliteral and sextiliteral words in order to accommodate the human limit on the processing of three dimensions. Like *ʔimbarāṭūr* above, *ʕabd·u·l·lāh* ‘Abdullah’, seen in (67), is inflected for plurality by mapping the three-variable pattern  $a_x·ā_y·i_z$  onto the reduced four-consonant template the four radicals ʕ – B – D – L, as in (67)', before transfixing can occur based on the limitation to three transfixed variables, as seen in (67)" (Wright 1896: 231).

(67) « عبد الله »

ʕabdu l·lāh

slave·NOM the·God

‘Abdullah’

		ʕ	a	B	–	D	·u l·	L	āh·i
--	--	---	---	---	---	---	-------	---	------

(67)' ʕ – b – d – l

EXTRACTED ROOT

ROOT	–	ʕ	–	B	–	D	–	L

(67)" « عبادة »

ʕabādill·a

‘Abdullahs’ (males named Abdullah)

f(PLR)			·a <sub>x</sub>		·ā <sub>y</sub>		·i <sub>z</sub>	
ROOT	–	ʕ	–	B	–	D	–	L a

<sup>21</sup> The animacy-marking suffix ·a is part of a separate one-dimensional operation which does not transfix the template.

Such transfixing morphology can also be applied to the derivation of verbs, such as the phrase *bi•smil•lāh* ‘in the name of God’, seen in (68), which the four-consonant template B – S – M – L (68)’ is extracted from and the three-variable pattern  $u_x \cdot a_y \cdot i_z$  is then mapped onto, in order to derive the verb *yu•basmil•u* ‘say, *In the name of God*’ (68)” (Wright 1896: 48).

(68) « بسم الله »

bi•sm il•lāh

in•name the•God

‘in the name of God’

		B	i•	S		M•i		l•L	āh
--	--	---	----	---	--	-----	--	-----	----

(68)' b – s – m – l

ROOT	B	_	S	_	M	_	L

(68)" « يسمل »

y•u•basmlil•u

I say:in:the:name:of:God•IND

‘I say, In the name of God’

f(PRES)				•a <sub>x</sub>				•i <sub>y</sub>	
ROOT	y•	u•	B	_	S	_	M	_	L

Similar to the way in which Semitic languages, like Arabic, extract consonants from a word in order to create a transfixing template from which to form derivations, Muskogean languages, like Chickasaw, extract entire syllables from a word in order to create a transfixing template from which to form derivations.

The Chickasaw verb *chofata* ‘to be clean’, as seen in (69), is reduced to the three templatic syllables  $\check{c}o - fa - ta$ , as seen in (69)', before transfixing can occur based on the limitation of no more than three transfixed variables (69)'''-(69)'''' (Munro & Willmond 1994).

(69)	« chofata »
	čo fa ta
	be:clean
	‘to be clean’
	f(DRV)
	Č o F a T a
(69)'	« čo-fa-ta »
	EXTRACTED ROOT
	ROOT
	Č o F a T
(69)''	« chofánta »
	čo fa-~ta
	be:cleaner
	‘to be cleaner’
	f(DRV)
	Č o F a ~x Ta

(69)'''	« choffá'ta »
	čof-fa-·?ta
	be:quite:clean
	‘to be quite clean’
	f(DRV)
	Č o Cx Fa ·?y Ta
(69)''''	« chofáyya'ta »
	čo fa-·y·yay?ta
	be:very:clean
	‘to be very clean’
	f(DRV)
	Č o Fa ·y <sub>x</sub> -y <sub>v</sub> ?y Ta

Keeping track of three variables via transfixation so pushes the mind to its cognitive boundaries that inflectional transfixation perturbs concurrent one-dimensional suffixing patterns. For example, in Arabic, most nouns which take two-variable transfixing patterns are TRIPTOTES (with distinct nominative, genitive and accusative suffixes), such as *mudun* ‘cities’ in the first part (i) of Table 4.2a. However, nouns which take three-variable transfixing patterns are DIPTOTES (with only two case suffixes, one for the nominative case and another for the oblique case, which subsumes the accusative and genitive), such as *ḥadāʔiq* ‘gardens’ in the second part (ii) of Table 4.2a.

i.	TRIPTOTE ‘(some) cities’	ii.	DIPTOTE ‘(some) gardens’
NOMINATIVE	مُدُنْ/mudun·u·n	NOMINATIVE	حَدَائِقُ/ḥadāʔiq·u·∅
ACCUSATIVE	مُدُنْ/mudun·a·n	OBLIQUE	حَدَائِقُ/ḥadāʔiq·a·∅
GENITIVE	مُدُنْ/mudun·i·n		

Table 4.2a. Case and indefiniteness marking for diptote and triptote nouns in Arabic.

A striking peculiarity of diptotes is that they also lack an overt indefinite suffix. It is notable, however, that omitting the indefinite suffix avoids encoding four inflectional vowels within consonantal bounds.

This peculiarity is not one of blocking a feature, such as that of definiteness marking, for when marked with the definite prefix, no such blocking of the definiteness feature occurs. Moreover, since possessed state nouns are not marked for definiteness anyways, there is no definiteness marker to block. What is striking is that in both cases, when the indefinite-marking suffix is not optional, these otherwise diptotes become triptotes, for example, with the definite form, as seen in the first part (i) of Table 4.2b, or the possessed-state form (regardless of definiteness), as seen in the first second part (ii) of Table 4.2b.

i. DIPTOTE → TRIPTOTE 'the gardens'		ii. DIPTOTE → TRIPTOTE 'gardens of (some) cities'	
NOMINATIVE	حَدَائِقُ / al-ḥadaʔiq·u	NOMINATIVE	حَدَائِقُ مُدُنٍ / ḥadaʔiq·u mudun·i·n
ACCUSATIVE	حَدَائِقُ / al-ḥadaʔiq·a	ACCUSATIVE	حَدَائِقُ مُدُنٍ / ḥadaʔiq·a mudun·i·n
GENITIVE	حَدَائِقُ / al-ḥadaʔiq·i	GENITIVE	حَدَائِقُ مُدُنٍ / ḥadaʔiq·i mudun·i·n

Table 4.2b. Diptotes treated as triptotes when either definite or possessed.

Lest it be thought that any of these variations are brought about by semantics, it is insightful to observe any number of triliteral nouns whose third radical is a semi-consonant (Wright 1896: 246-247). Such nouns as the plural of the triptote *ṣaḥrāʔ* 'desert', as in Table 4.2c, follow the norms of three-variable transfixing when inflected for plurality. However, since the final semi-consonant has the potential to coalesce with high vowels, closed-syllable case endings with high vowels coalesce with the semi-consonant and collapse what would otherwise be an inflection resulting in four enclosed

vowels (e.g. the *a-ā-i-u* of *\*ṣaḥāriyun* ‘a desert’) into one with only three enclosed vowels (e.g. the *a-ā-i* of *ṣaḥārin* ‘a desert’), effectively shortening the word enough to neutralize the otherwise expected perturbation patterns involving the loss of the indefinite suffix and the three-case distinction.<sup>22</sup>

	DIPTOTE ‘deserts’	→	TRIPTOTE ‘deserts’
NOMINATIVE	*صَحَارِيّ/ṣaḥāriy·u·n	→	صَحَارٍ/ṣaḥār·i·n
ACCUSATIVE	*صَحَارِيًّا/ṣaḥāriy·a·n	→	صَحَارِيّ/ṣaḥāriy·a·∅
GENITIVE	*صَحَارِيّ/ṣaḥāriy·i·n	→	صَحَارٍ/ṣaḥār·i·n

Table 4.2c. Syllabically motivated perturbations of case marking in triptote noun paradigms.

While the transfixing pattern only consists of three variables, the indefinite suffix forces the speaker to keep track of another vowel enclosed within the consonantal boundaries of the fully inflected word. Removing the final inflectional consonant averts this need; however, collapsing two of the syllables word-internally also resolves the transfixing problem and eliminates the need to lose the final inflectional indefinite suffix.

The data suggests that the limitations on morphological cross-dependency represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. Like the variable-balancing tasks for syntactic cross-dependency in the preceding chapter, the variable-balancing task of morphological cross-dependency involves three interdependent variables that must be dealt with simultaneously at the peak cognitive point of reaching the third variable. While this sort of morphological cross-dependency in language is

<sup>22</sup> Interestingly, while this syllabic collapse makes the accusative and genitive once again distinct (making it, in one sense, a triptote in theory), it simultaneously renders the nominative and genitive indistinct (making it, in another sense, a different type of diptote in practice).

neither as common nor as regularly analyzed as syntactic cross-dependency, it is an important area to consider in the broader analysis of recursion limitations.

#### 4.3. Three-Dimensional Constraints on Multiple-Case Marking

A number of classical languages and modern languages have case affixes which mark not only the noun but also its adjectival dependents, as seen in the Biblical Greek of (70), where both *paráklêsi* ‘encouragement’ and *aiônía* ‘eternal’ are marked by the accusative *·n* (2 Thessalonians 2:16).

- (70) « δὸς παράκλησιν αἰωνίαν »  
do·us paráklêsi·n aiônía·n  
give·ing encouragement·ACC eternal·ACC  
‘giving eternal encouragement’

Some languages, known as “double marking languages” (Plank 1995), go a step further, by marking not only adjectival dependents for case but also marking nominal dependents for case, in addition to the case marking they already have. In the Tangkic language Kayardild of Australia (71), the *·nguni* affix signifying ‘with’ appears on both the head noun *walbu* ‘raft’ and on its dependent possessor noun *dangka* ‘man’, which is already marked with its own genitive *·(ki)naba*, and both nouns further distribute their respective case affixes onto their own dependent adjectives (Evans 1995: 105).

- (71) [{dan·kinaba<sub>y</sub>·nguni<sub>x</sub> dangka·naba<sub>y</sub>·nguni<sub>x</sub>} {mirra·nguni<sub>x</sub> walbu·nguni<sub>x</sub>}]  
[{{this·GEN<sub>y</sub>·with<sub>x</sub> man·GEN<sub>y</sub>·with<sub>x</sub>} {good·with<sub>x</sub> raft·with<sub>x</sub>}]  
‘... with this man’s good raft’

This phenomenon is not limited to nouns. Similarly, in Kayardild, as seen in (72), affirmative mood marking (generally with the suffix *·ntha*) is distributed on the nominal dependents of the verb (Plank 1995: 29)—note the suppletive form *ngijuwa* for the first-person singular pronoun.

- (72) [ngijuwa yalawu·jarra·ntha yakuri·naa·ntha]  
 [I:SBJ:AFRM catch·PST·AFRM fish·IRREAL·AFRM]  
 waytpala·karra·nguni·naa·ntha mijil·nguni·naa·ntha]  
 white:man·GEN·with·IRREAL·AFRM net·INS·IRREAL·AFRM]  
 ‘But yes, I did catch some fish with the white man’s net’

This downwards distribution of morphology to increasingly deeper levels of dependents is attested at up to three levels, though even this is exceedingly rare (Wegner 1995: 145; Hetzron 1995: 327). One such instance is that of Awngi, as seen in (73), where the locative *·da* marks not only the location which heads the phrase but also its possessor dependent ‘house’ and the house’s possessor dependent ‘woman’.

- (73) [[{gud·a·ws<sub>x</sub>·k<sup>w</sup><sub>y</sub>·da<sub>z</sub>      yun·a·ws<sub>x</sub>·k<sup>w</sup><sub>y</sub>·da<sub>z</sub>]      cənkút·ək<sup>w</sup><sub>y</sub>·da<sub>z</sub>  
 [{good·♀·GEN<sup>♂</sup><sub>x</sub>·GEN<sup>PL</sup><sub>y</sub>·LOC<sub>z</sub> woman·♀·GEN<sup>♂</sup><sub>x</sub>·GEN<sup>PL</sup><sub>y</sub>·LOC<sub>x</sub>] nice·♂·GEN<sup>PL</sup><sub>y</sub>·LOC<sub>z</sub>  
 ɲən·ək<sup>w</sup><sub>y</sub>·da<sub>z</sub>}      wodel·ka·da<sub>z</sub> ábjél·ka·da<sub>z</sub>]  
 house<sup>♂</sup>·GEN<sup>PL</sup><sub>y</sub>·LOC<sub>z</sub>} large·PL·LOC<sub>z</sub> doorway·PL·LOC<sub>z</sub>]  
 ‘in the large doorways of the nice house of the good woman’ (Hetzron 1995: 327)

Analyzing (73) further in Figure 4.3a, it is clear that the interlocutor must utter the most embedded nominal dependent with a clear understanding of not only the role it plays as a modifier but also of the role played by its governing noun, and of the role played by the noun governing its governing noun.

Level x		wodel·ka·da <sub>x</sub> ábjél·ka·da <sub>x</sub> ] large·PL·LOC <sub>x</sub> doorway·PL·LOC <sub>x</sub> ]
Level Y		cənkút·ək <sup>w</sup> <sub>y</sub> ·da <sub>x</sub> ɲən·ək <sup>w</sup> <sub>y</sub> ·da <sub>x</sub> } nice·♂·GEN <sup>PL</sup> <sub>y</sub> ·LOC <sub>x</sub> house <sup>♂</sup> ·GEN <sup>PL</sup> <sub>y</sub> ·LOC <sub>x</sub> }
Level Z	[[{gud·a·ws <sub>z</sub> ·k <sup>w</sup> <sub>y</sub> ·da <sub>x</sub> yun·a·ws <sub>z</sub> ·k <sup>w</sup> <sub>y</sub> ·da <sub>x</sub> ] [{good·♀·GEN <sup>♂</sup> <sub>z</sub> ·GEN <sup>PL</sup> <sub>y</sub> ·LOC <sub>x</sub> woman·♀·GEN <sup>♂</sup> <sub>z</sub> ·GEN <sup>PL</sup> <sub>y</sub> ·LOC <sub>x</sub> ] ‘in the large doorways of the nice house of the good woman’	

Figure 4.3a. The most embedded noun (and its adjectival modifier) reflecting not only the role it plays in the sentence, but also the role of its governing noun and the role of the noun governing its governing noun.

At the peak cognitive point of processing the z-value of the case-marking *·da<sub>z</sub>*, the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value case-marking *·k<sup>w</sup><sub>y</sub>* and the x-value case-marking *·ws<sub>x</sub>*, thus interpreting a

maximum of three variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements.

What the foregoing demonstrates is that no form of embedded information in single words can surpass a three-dimensional calculus function. Given this instance of a limitation on tracking three interdependent variables, what appears to be simple algebraic distribution of values within bracketed terms is actually constrained by the same three-dimensional calculus which constrains other areas of human cognition.

The data suggests that the limitations on multiple case marking represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. This distribution of values to inner terms of a polynomial appears to be a phenomenon restricted to the morphological level; however, it is conceivable that the same distribution of case marking could take place at the morphophonological level in cases where inflection is marked by suprasegmental information, such alterations in tone or stress.

#### **4.4. Three-Dimensional Constraints on Negation**

The recursive iteration of negation involves negating negation, as seen in (74), where a doctor describes her dilemma of either allowing her patients to continue harmful ear-cleaning practices or give them harmless (but also useless) directions, just to prevent them from taking damaging actions. She opts to give them the useless directions since she feels that she cannot simply tell them to desist from action altogether, as seen in (74), which she puts into the following wording (as cited in Beck, 2012: para. 29).

(74) ... because they are not<sub>x</sub> capable of doing no<sub>y</sub> thing.

The counting of reiterated negation has a long history of controversy, given that a number of languages and even dialects of English do not seem to observe this logic, with constructions of the *ain't seen nobody* type, where two negatives apparently make a negative, as in the Spanish example of (75) (Poli, 2010: 144) and the AAE example of (76) (Jeffries 2006: track 5).

(75) no puedo hacer nada.  
not can:I doing nothing  
 'I cannot do anything'

(76) I ain't seen nobody.

But even these languages and dialects display systematic patterns of double negation, with constructions of the *it ain't impossible* type, as seen in the Spanish of (77) (Calderón, 1905: 61) and the AAE of (78) (Smith & Harmony, 2007, track 12).

(77) no es [im]possible.  
not is:it [not] 'possible'  
 'It is not impossible.' = 'It is possible.'

(78) It ain't [im]possible.

In constructions of the *ain't seen nobody* type, like those of (75) and (76), the apparent flouting of double negation occurs where standardized English uses a so-called negative-polarity words, like *any* or *ever*.

(79) I cannot do anything.

(80) I haven't seen anybody.

(81) I don't want to see you ever again.

Overlooking this one complication in the functional vocabulary, these languages and dialects have just as much of a double-negative rule as standardized English does. However, instead of a separate set of words for polarity purposes, like the standardized

English *any/ever*, these languages and dialects recycle the corresponding negative morphemes as polarity words.<sup>23</sup> This is especially obvious when we see what these languages do with words serving the purpose English ‘ever’, as in (82) (Olvera & González, 1994, track 1), and (83) (Pérez de Oliva, 1991: 115).

(82) te adoro más que nunca.  
 you love:I more than never  
 ‘I love you more than ever’

(83) no lo vimos nunca.  
 not him saw:we never  
 ‘We didn’t see him ever’

The double negative rule thus cannot be ruled out by a misrepresentation of the logical organization of other languages and other dialects of English. The logic is represented but restricted to non-polarity usages, which in Spanish and AAE includes such morphology as adjectival negation affixes.

The encoding of linguistic negativity with mathematical negativity apparently also allows for the negation of negated negation  $(-1)(-1)(-1)$ , as in (84). Again, this is limited by the same processing limitations which hem in all human cognition.

(84) It is  $n't_x$  the case that [it's  $not_y$  [ $im_z$  possible]].

At the peak cognitive point of processing the z-value of  $im_z$ , the interlocutor has the task of dealing with this variable and interpreting it with relation to the y-value  $not_y$  and the x-value  $n't_x$ , thus interpreting a maximum of three variables, one being manipulated and two others being referred to in memory.

Language users who skirt these limits without awareness of this need for pen and paper can unintentionally end up confusing their audiences or, in some cases, even

<sup>23</sup> Haspelmath (1997) demonstrates that the fusion of polarity and negation is generally a diachronic trend, albeit one which standard dialects of English have reversed (Horobin 2013: 9).

themselves, as in the case of a *New York Times* writer who, balancing three counteracting negatives, inadvertently said the opposite of what he intended to say, as seen in (85).

(85) That is not to say that real spies are any less immune to the allure of the city.

Allowing two of these negatives to cancel each other out, we get a sentence claiming that “real spies” are immune to the allure of the city in question, as seen in (85)’ (Arango 2014: para. 18).

(85)’ That is   to say that real spies are   immune to the allure of the city.

The actual meaning of (85), however, is clearly not the intention of the author, as seen in the following sentence of the article, where he cites a “C.I.A. officer” who claims that the city “has more of a sense of intrigue than any other city in the world” (par. 20).

For this reason, it is not surprising that performing a search of published sources through *Google Books* (on November 11, 2012) for the string “it isn’t the case that it is not” provided only one result, and this only contained negated negation  $(-1)(-1)$ , not the negation of negated negation  $(-1)(-1)(-1)$ , let alone anything beyond that.

The data suggests that the limitations on multiple self-canceling negation represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. This sort of mathematical process appears to be a phenomenon shared by the morphological and syntactic levels, and indeed, in languages where purely syntactic negation works polarity-wise, it is necessary for morphological negation to cancel out syntactic negation.

#### **4.5. Relevant Connectionist Models**

Appropriate to the types of morphological variable balancing surveyed in this chapter are connectionist models which measure the limitations on center-embedding (§4.1) and cross-dependencies (§4.2), among other types of variable-tracking tasks.

Following the experiments of Bach, Brown, and Marslen-Wilson (1986) with human test-subjects, Joshi (1989) uses EPDAs (embedded push-down automata) to show that, while cross dependencies are somewhat less difficult than center embedding at two and three levels (p. 2), both types of tasks “cannot be instantiated for sentences containing more than three matched NPs and Vs” (p. 28). Christiansen and Chater’s show the same thing with SRNs designed to process cross-dependency recursion.

Ultimately, in morphology, there is not so much a dearth of applicable connectionist models as there is an absence of applying these models to processing the limitations of morphological embedding and cross dependency as analogous extensions of the processing limitations in other areas of human language, as well as in other types of limitation patterns in general human cognition.

#### **4.6. Concluding Remarks on Morphology**

As with the recursive limits on reference and syntax seen in the previous chapters, the simplest explanation is the easiest to quantify and corroborate with various other forms of typological phenomena. Highly embedded morphological affixing, like that of reference and syntax, can be exploited by the literary artist for purposes of dramatizing confusion and/or intentionally confusing the audience; however, it is not characteristic of normal human language usage. In contrast, the far more opaque process of morphological

transfixing is inflexibly bound to the balancing of three variables without any attested exceptions, even highly contrived ones.

Various factors can conspire to further complicate variable-balancing tasks in morphology, such as the task of processing syntactic center-embedding in (55)b (repeated below for convenience) being additionally burdened by the interference of homophonous morpheme strings—see §5.1 below for a full discussion of this phenomenon and the processing burdens it entails.

(55) b. ?anti-anti-missile-missile missile

Again, such compounding of variable tracking can complicate the task of dealing with the constraints already imposed by the cognitive limit of three dimensions; it is not a neutral addition, and it is certainly not one which alleviates the cognitive burden. What is clear is that the human mind is pushed to its limits with any individual

three-dimensional juggling task, and thus working with multiple simultaneous three-dimensional juggling tasks. Perhaps this explains why drivers turn the volume of the music down when they are trying to look for a street sign or landmark; the sensory overload of multiple stimuli can make an already complicated task even more burdensome (Fernandez, 2008, para. 4-5)—see Figure 4.6a. The next section examines



this phonological complication in isolation and examines parallels between variable-balancing tasks at that level of analysis and those explored in this chapter.

## 5. Three-Dimensional Constraints on Interdependent Structures in Phonology

What we've got here is failure to communicate.  
– Cool Hand Luke (Rosenberg 1967)

Phonology, like the larger levels of morphology, syntax and reference, displays a three-dimensional limit on the variables kept track of in human cognition. Although a string of homophonous (or nearly homophonous) morphemes is linear, not embedded, the recurring articulation of a single sound segment is not a so much a linear task as it is a multi-variable tracking task.

In this way, keeping track of identical segments is not too different from watching cups being shuffled while keeping track of which one the coin is under or walking down a hallway with identical-looking unmarked doors. Since the homophonous sound segments are only distinct from each other in terms of the order in which they occur, the mind of the interlocutor must keep track of the identical segments with reference to each other, thus limiting the process to a balancing of three variables.

Recursion beyond this limit requires a super-imposed metric system of repetition, such as a musical rhythm. Even so, such a metric system of repetition fits into the mould of either duple meter or triple meter, both of which are constrained to managing three variables at most (Rice 2000: 198). Repeating syllables with the scaffolding of musical rhythm renders the syllables (or at least their repetition) meaningless except in so far as they mark such a beat. In other words, the rhythm is the cohesive force of such repetitions, not the individual morphemes, which are rendered meaningless or never intended for meaning at all.

This chapter also gives attention to literature on connectionist models which apply to the phenomenon under analysis.

## 5.1. Haplogy as a Strategy for Avoiding Homophonous Syllables

One manifestation of the human mind's aversion to repeating identical sound sequences is the phenomenon of haplogy, whereby homophonous (or nearly homophonous) pairs of syllables are reduced to a single syllable. The homophonous segments quite typically belong to morphemes with different functions.

A common example is *idolatry*, which originates from the reduction of historical *idololatria* from *idolo* 'idol' + *latría* 'worship' to *idolatria*. In spoken English, *probably* is routinely haplogized as *probly* and (often with an additionally elided *b*)—and *probably* is itself a haplogy of the trimorphemic *probablely*.

Hock (1986) cites cases where haplogy is diachronic and thus obligatory (86)a, and others where it is synchronic and optional (86)b & (86)c (109).

- (86) a. Latin: \*nutrī·trīx > nutrīx 'nurse'  
 b. Homeric Greek: amphi·phoreús > amøphoreús 'two-handled pitcher'  
 c. Latin: trier·archus > trierøchus/triøarchus 'captain of a triera'

In Arabic, the right combination of person markers, derivational markers, and root-initial consonants can conspire to create three identical consecutive onsets, as in (87) (Al-ʔalbānī 2001: 1130).

- (87) « أن تتابع الآثار »  
 ʔan [ta<sub>x</sub>·ta<sub>y</sub>·tā<sub>k</sub>biʕ·a l·ʔāθār·u  
 CMPL ʔ:PL·REFL·succeed·SVJ DEF·effects·NOM  
 'that the effects come one after the other'

At the peak cognitive point of reaching the *z*-value *tā<sub>z</sub>*, the interlocutor has the task of dealing with this variable and interpreting it with relation to the *y*-value *ta<sub>y</sub>* and the *x*-value *ta<sub>x</sub>*, thus interpreting a maximum of three variables, one being manipulated and two others being simultaneously recalled in anticipation of their complements.



Gen-Gen-Gen” in their Georgian samples. As such, they speculate that this “kind of case-stacking is also ruled out by a haplological constraint” (p. 690). These results correspond with those of Simon and Zhang (1985) who demonstrated with experiments in the homophone-rich language Mandarin that, while test subjects normally recalled strings of six or seven words, they could not recall strings of more than three homophonous words (p. 195).

(90) Genitive Haplology

- i.      z·isa                      kac·isa·jsa  
          son·GEN              man·GEN·GEN  
          ‘of the son of man’
- ii.     z·isa                      kac·isa  
          son·GEN              man·GEN  
          ‘of the son of man’

(91) Plural Oblique Haplology

- i.      \*kar·ta                      kalak·ta·ta  
          door·PL:OBL      city·PL:GEN·PL:GEN  
          ‘the gates of the cities’
- ii.     kar·ta                      kalak·ta  
          door·PL:OBL      city·PL:GEN  
          ‘the gates of the cities’

Haplology is also documented as occurring across word boundaries. Bolling (1948) cites examples from Archaic Greek poetry, such as the following from Hesiod, where the ‘on of ball·on·onykhas is haplologized as in ball’·onykhas (Hesiod, Aspis 254).

- (92)    « βαλλ’ ονυχας μεγάλους »  
 ball’      onykh·a·s      megal·ou·s  
 throw(ing) claws·♀·ACC large·♀·ACC  
 ‘throwing large claws’

Similarly, he shows in a passage from Homer how Êtiôn·os·hos is haplologized as Êtiôn’·hos (Iliad 7:396).

- (93) « Ἐετιῶν' οὗ ἐναιεν ὑπο Πλακῷ ὑληεσση »  
 Êëtiôn' h[os] enaien hypo Plakô hylêessê  
 Êëtïon who lived below Plako woody  
 'Êëtïon had lived below the forests on Mount Placus'

Similarly, in Apollonius Rhodius, *êrêrein* [to] [to] is haplogized as *êrêrein* ' [to]

(Apollonius Rhodius 4.947).

- (94) « ἡρηρεῖν, τὸ δὲ πολλὸν ὑπεῖρεχεν ἀγρίον οἶδμα »  
 êrêrein' [to]•de pollon hypeirekhen agrion oidma  
 be:fixed:fast:PST:3PL the•and much pour:PST:3 wild squall  
 'were fixed fast, and the fierce waves poured over them'

In the Sanskrit *Mahābhārata*, *cāvay* [or] [Ar] *junah* is haplogized as *cāvay* [or] *'junah*

(*Mahabhārata* 2.18.3b).

- (95) « रक्षिता चावयोर्जुनः »  
 rakṣitā cāvay [or] 'junah  
 protection may:need.Arjun·NOM  
 'Arjunah may need your help'

Surveying the findings of Lüdtke (1980; 1985), Haspelmath (1999) notes that the word reduction seen in language change characteristically comes by way of speakers reducing their utterances phonetically, not morphosyntactically (p. 238). As such, even when it appears that an entire morpheme is lost, as in the case of (90), it is when the entire morpheme's loss corresponds, in one or many steps, with the loss of a targeted phonological segment.

Raising the question of whether there is a physical motivation for haplogy, Sigurd (1973) tests speakers with repeated syllables such as [tatata...], [stastasta...], & [strastrastra ...], and demonstrates that errors arise in greater numbers than they do from differentiated syllable strings. Sigurd claims that the errors arise on account of difficulties in coordinating articulatory movements as well as difficulties in the phonetic anomaly of the syllables under examination; however, the only thing anomalous about the syllables

he tests is their repetition, not the fact that they have onsets in [ta], [sta], or [stra], which have fully acceptable syllable structure in English and appear in such high-frequency words as *talk*, *stop*, and *strong*. Given that exercise physiology measures endurance by “consistent repetition duration” (Haff & Dumke 2012: 250), it could reasonably be claimed that haplology of homophonous syllables is motivated by both cognitive and physical factors. Of key importance is that any such physical motivations only compound the cognitive difficulty; they do not in any way counterbalance them.

The data suggests that the limitations on repeated homophonous morphemes represent a hard constraint, in that no reliable data shows more than three levels (and rarely even more than two levels) of interdependent variables produced or processed in natural language usage. The persistent phenomenon of haplology across millennia and across language families suggests that the uttering of identical syllables creates a burden on either or both of the interlocutors to the extent that it is often preferable to lose a unit of meaning than to risk losing one’s bearings while counting through a stream of syllables with no road signs as to which syllable belongs to which morpheme.

## **5.2. Lexical Choice as a Strategy for Avoiding Similar Syllables**

Besides haplology, other ways to avoid like-syllable repetition exist, such as simply choosing alternative wording. Consider the identical verbs from different clauses which appear alongside each other, as in the so-called cleft construction of (96). Since haplology, as in (97)a (Lambrecht & Ross-Hagebaum 2006), is not a grammatically viable option, one remaining strategy is to separate them with such elements as a

resumptive pronoun, as in (97)b. In contrast, a different verb creates no such problems, as in (98)a and (98)b.<sup>24</sup>

- (96) # [What Mars is] is cold and dry.
- (97) a. \* [What Mars is] Ø cold and dry.  
 b. # [What Mars is] it's cold and dry.
- (98) a. [What Mars appears to be] is cold and dry.  
 b. [What we have with Mars] is a cold and dry planet.

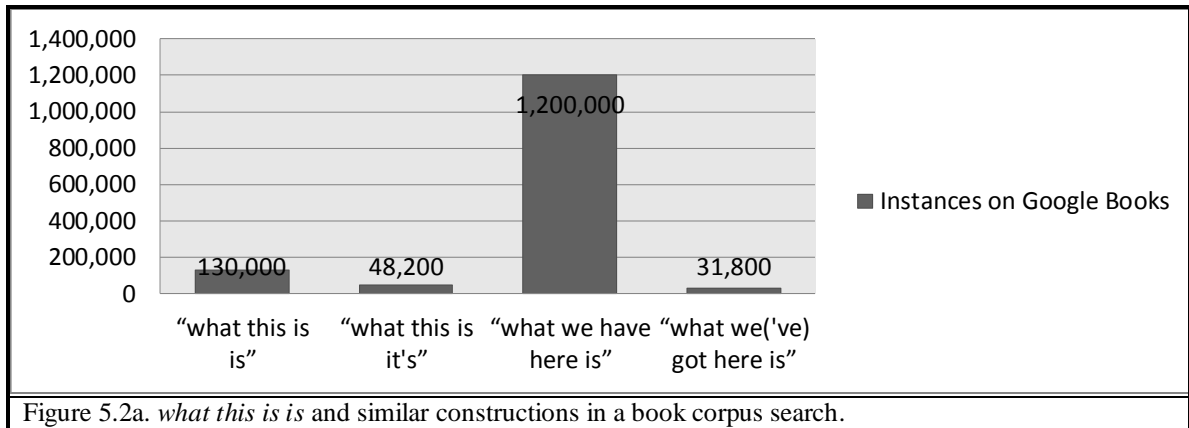
While the substitution in (97)b appears to be the most straightforward, it does not appear the most in a book corpus search, including in novels with colloquial dialog.

Performing a corpus search of published sources on *Google Books* (on December 21, 2013) for the repetitive *what this is is* string resulted in ≈130,000 hits, as seen in Figure 5.2a. The results of constructions serving the same function were revealing. The substitute *what this is it's* string resulted in ≈48,000, thus not outnumbering it, but another substitute, the *what we have here is* string, was nearly ten times more common at ≈1,200,000, and the synonymous strings *what we've got here is* and *what we got here is* were also common, at a combined ≈31,800.

The clear majority is *what he have here is* strings, as seen in (99), with a notable minority of *what this is is* strings, as seen in (100). The semantic equivalent of *what we have here is* strings, the *what we('ve) got here* strings, as seen in (101), were less common than *what this is is* strings, yet still having a notable presence in the results.

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<sup>24</sup> Far from being a construction eliciting avoidance, Liberman (2004) argues colloquial uses of the “double-is construction” without *what* at the beginning have “a plausible (fully grammatical) alternate with an overt wh-word” (par. 8). And this correspondence suggests that one subclass of *What this is is* construction has given rise to an analogous *This is is* construction in what Liberman calls a “a non-standard grammar” (par. 2).



- (99) What we have<sub>x</sub> here is<sub>y</sub> a clear example of the importance of the children learning the hidden curriculum of classrooms. (Cohen, Manion, & Morrison 2011: 580)
- (100) Certainly what this is<sub>x</sub>, is<sub>y</sub> a deep problem for everybody. (Gibson 2007: 215)
- (101) What we've got<sub>x</sub> here is<sub>y</sub> an irresistible force meeting an immovable object. (Klein 2002: 173-174)

The *what we've got here* construction of (101) is has been immortalized in a sentence ranked number 11 by the American Film Institute in their list of the 100 most memorable quotes. The line in question, from *Cool Hand Luke* (Rosenberg 1967), is most commonly misquoted in published works with the *what we have here* construction (Dirks, n.d.), as seen (99), with 9,630 hits on a *Google Books* search performed on December 12, 2013, as seen in (102); it is far less often accurately quoted word for word in published works, as seen in (103), with only 835 hits on a *Google Books* search performed on the same date—the misquote thus appears more than the correct quote at a 23 to 2 ratio. Ironically, in a regular *Google* search comprising both published and unpublished sources, the correct wording outnumbered the common misquoted phrase—the correct quote thus appears more than the misquote at a 109 to 78 ratio, though perhaps this has more to do with the fact-checking prowess of the online publications included in general *Google* searches than with the amateur element. The line is also occasionally misquoted with the

construction of the *what this is is* construction (99), with 7 hits on a general *Google* search performed on the same date, as seen in (104), a relatively small number but still in line with the analysis herein that these forms serve the same function.

(102) What we have here is a failure to communicate.

(103) What we've got here is failure to communicate.

(104) What this is is a failure to communicate.

The second most common hit seems to be the *what this is it's* construction; however, none of the first hundred previews of this search gave the construction presented by Lambrecht & Ross-Hagebaum in (97)b; all such strings of *is* and *it's* are distributed across clauses with the *it's* being the subject and verb of the second clause, as seen in (105) and (106).

(105) You know what this is? It's clichéd rebellion. (Dunn 2009: 191)

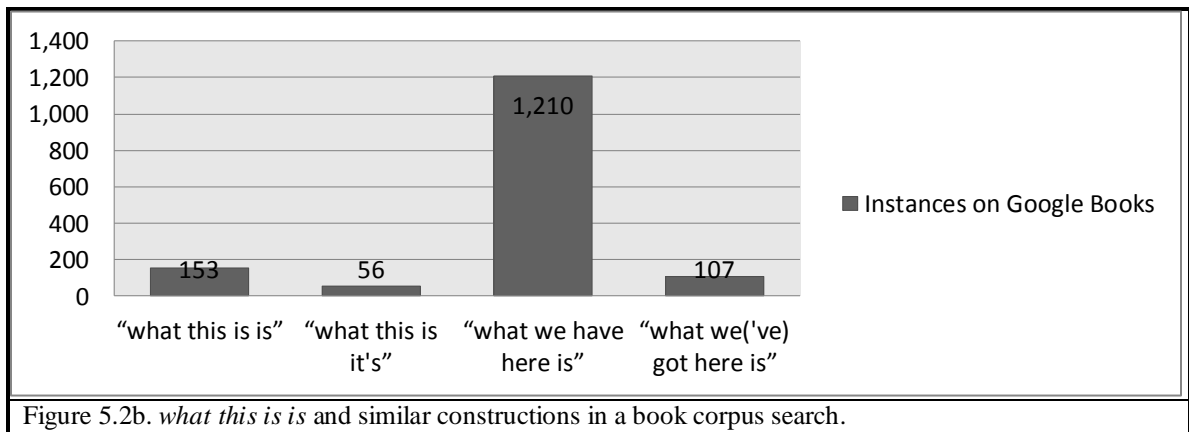
(106) If that is what this is, it's very treatable with medicine. (Wilde 2011: 19)

The fact that zero of the first hundred *Google Books* results for the searched string *what this is it's* have the construction seen in (97)b strongly suggests that such a construction, at best, constitutes only a minimal percentage of the 48,200 hits for the *this* string, while all of the other searched-for constructions on *Google Books* revealed the target construction in at least the first five hits, and with sporadic exceptions after that, apparently brought about, for the most part, by faulty OCR readings of the books scanned into the database.

Performing an analogous corpus search of news sources on *Google News* (on December 23, 2013) for the repetitive string *what this is is* resulted in 153 hits, as seen in Figure 5.2b. Again, the findings of constructions serving the same function were

revealing. The substitute string *what this is it's* resulted in 56, thus not outnumbering it, but another substitute string *what we have here is* was more than eight times more common at 1,210, and the synonymous strings *what we've got here is* and *what we got here is* were also common, at a combined 107.

As with the book corpus search above, no instances of the previewed string *what this is it's* have the construction seen in (97)b, again strongly suggesting that this is not the optimal substitution for the *what this is is* construction.



Cleft constructions are not the only relative clauses which offer the possibility of identical verbs from different clauses appearing alongside each other. Bolinger (1971) points out similar problems with subject-modifying relative clauses, as in (107), and notes the strategy of writing in a comma to represent “disjunctive” and “contrastive accent,” as in (108), which he claims raises the acceptability (p. 30).

(107) # The boy [that the girl saw] saw her.

(108) The boy [that the girl saw], saw her.

Coping strategies are common not only with recurring morphemes but also with consecutive homophonous morphemes. Masica (1991) translates the Hindi-Urdu

conjunctive participle  $\bullet\boxed{kar}$  as ‘having... ed’ (pp. 323-324), as seen in (109) (Sharma 2006: 148).

- (109) « सभी खाना खाकर चले गए »  
sab<sup>h</sup>ī k<sup>h</sup>ānā k<sup>h</sup>ā• $\boxed{kar}$ , čalē gayē  
all food eat•upon, moved went  
‘They left upon/after eating all the food.’

Snell & Weightman (1989) note that, in Hindi-Urdu,  $\bullet ke$  can be used as a substitute for  $\bullet\boxed{kar}$  (149), as seen in (110) (Nagar 2007: 53).

- (110) « खाके चला गया था »  
k<sup>h</sup>ā•ke, čalā gayā thā  
eat•upon, moved went had  
‘They had left upon/after eating.’

However, following the verb stem *kar* ‘do’, only the non-homophonous  $\bullet\boxed{ke}$  can be used to make the conjunctive construction *kar• $\boxed{ke}$*  (Snell & Weightman 1989: 149), as in (111) (Bharathi 2001: 89);  $\bullet\boxed{kar}$  cannot be used to form *\*kar• $\boxed{kar}$*  (Snell & Weightman 1989: 149), as in (112).

- (111) « अपना काम करके चले जाते हैं »  
apnā kām kar•ke, čalē jātē haĩ  
own work do•upon, move go are  
‘They leave upon/after doing their own work.’

- (112) # « अपना काम करकर चले जाते हैं »  
apnā kām kar•kar, čalē jātē haĩ  
own work do•upon, move go are  
‘They leave upon/after doing their own work.’

Similar problems in English with the consecutive homophonous morphemes *·ly* (adjectival and adverbial) are handled not by substituting synonymous morphemes but instead by substituting synonymous roots. For example, while adjectives like *sad* and *happy* take the derivative suffix *·ly* to become the adverbs *sadly* and *happily*, adjectives

already ending in a homophonous *·ly* suffix like *likely* and *friendly* do not standardly take the derivative suffix *·ly* to become the adverbs *\*likelily* and *\*friendlily*. Instead, they can be substituted with synonymous roots such as *probably* and *amicably* or be expressed periphrastically, e.g. *in all likelihood*, *in a friendly manner*, etc.

Problems with consecutive homophonous morphemes in English also arise with the morpheme *that*. Consider the two sentences in (113) which convey the same truth value. In (113)a, the complementizer, determiner, quoted word and relative pronoun are all expressed with distinct uses of the homophone *that*,<sup>25</sup> thus severely complicating the task of an interlocutor in either producing or processing the initial word string, while in (113)b, they are all phonologically distinct.

- (113) a. \*That<sub>w</sub> that<sub>x</sub> “that”<sub>y</sub> that<sub>z</sub> I wrote is misleading is notable.  
 b. ?The fact (that)<sub>w</sub> the<sub>x</sub> “that”<sub>y</sub> (which)<sub>z</sub> I wrote is misleading is notable.

While (113)b is still complicated by the fact that it contains embedded clauses requiring that the interlocutor keep track of three syntactic variables, the task is not further complicated by the track-keeping task at the phonological level which (113)a requires of interlocutors.

- (114) a'. \*That<sub>x</sub> [that “that”<sub>y</sub> [that I<sub>z</sub> wrote<sub>z</sub>] is<sub>y</sub> misleading] is<sub>x</sub> notable.  
 b'. ?The fact<sub>x</sub> (that) [the “that”<sub>y</sub> [(which) I<sub>z</sub> wrote<sub>z</sub>] is<sub>y</sub> misleading] is<sub>x</sub> notable.

Recurring morphemes do not have to be consecutive to elicit avoidance. Even appearing suffixed to distinct roots is enough in the case of English constructions with homophonous *·ing* constructions. Breva-Claramonte (1990) discusses this avoidance of constructions with two consecutive *·ing* inflections. As seen in (115)a and (115)b, the

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<sup>25</sup> While all uses of “that” can optionally be pronounced as [ðæt], it is also possible to pronounce the relative use of “that” with a schwa, i.e. as [ðət]. The same is true of the complementizer use of “that,” when not at the beginning of a sentence, as it is above. British speakers moreover can pronounce the demonstrative “that” with a schwa (Ian Maddieson, personal correspondence).

auxiliary *stop* regularly precedes participial constructions in *·ing*; however, when *stop* itself is marked with *·ing*, as in (115)c, the acceptability drops off significantly, often eliciting a construction with a different root, as in (115)d.

- (115) a. Stop do<sup>ing</sup> this.  
 b. It's a good idea to stop do<sup>ing</sup> this.  
 c. # Stopp<sup>ing</sup> do<sup>ing</sup> this is a bad idea.  
 d. Ceas<sup>ing</sup> to do this is a bad idea.

Normally, expressions with strings with the semantically broader *stop V·ing* are far more common than strings with the semantically narrower *give up V·ing*. Performing a search of published sources through *Google Books* (on December 9, 2012) for the strings seen in Figure 5.2c, with the high frequency verbs *be*, *have*, and *do* as complements, clearly showed that *stop V·ing* is the more common of the two constructions, with a 131 to 25 ratio for the complement *being*, a 105 to 23 ratio for the complement *having*, and a 563 to 36 ratio for the complement *doing*.

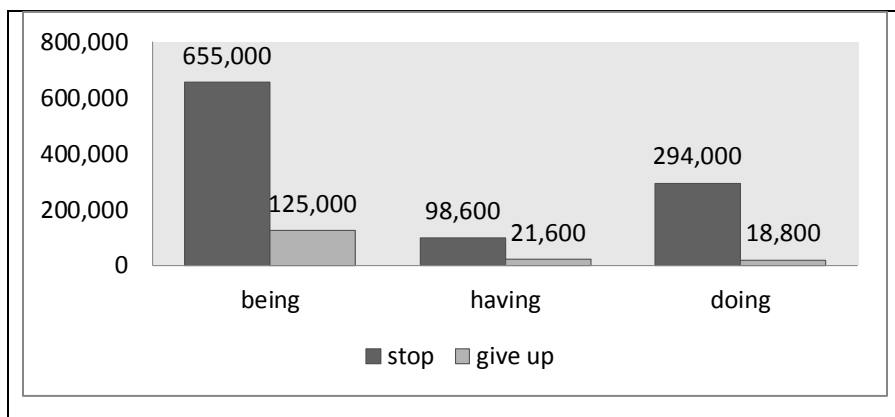


Figure 5.2c. Frequency of *stop* and *give up* before the three common complements *being*, *having*, and *doing*.

Significantly, when the construction requires that the auxiliary *stop* or *give up* take *·ing*, thus creating two consecutive verbs with *·ing*, the trend reverses. Despite being semantically broader, strings with *stopping V·ing* are far less common than strings with the semantically narrower *giving up V·ing*. Even though both constructions involve two

consecutive verbs with identical suffixes, *giving up V-ing* breaks the sequence up with the adverbial formative *up*, whereas the construction with *stopping V-ing* places the two verbs in direct sequence with no intermediary word.

Performing a search of published sources through *Google Books* (on December 9, 2012) for the strings seen in Figure 5.2d, with the high frequency verbs *be*, *have*, and *do* as complements, clearly showed that *stop V-ing* is the less common of the two constructions, with a 8 to 29 ratio for the complement *being*, a 13 to 32 ratio for the complement *having*, and a 41 to 49 ratio for the complement *doing*.

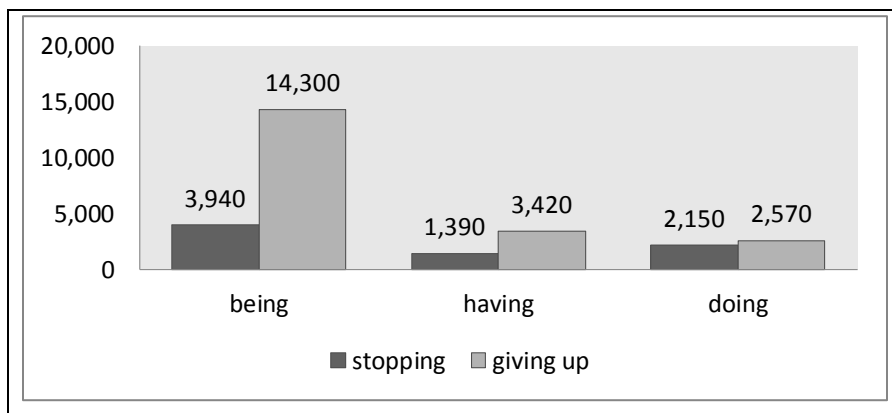


Figure 5.2d. Frequency of *stopping* and *giving up* before the three common complements *being*, *having*, and *doing*.

Breva-Claramonte (1990) discusses cases such as in (116)a and (117)a, where two deverbal nouns ending in *-ing* are compounded. In such cases as these, one or the other is substituted with a synonym or near-synonym, which might be a cognate as is the first noun in (116)b & (117)b, or might not be a cognate as is the second noun in (116)c & (117)c (pp. 17-18).<sup>26</sup>

- (116) a. \* exercising training  
 b. exercise training

<sup>26</sup> It should be noted that when no other deverbal nominal exists (in common usage) for either word, such as with *acting training* and *pitching training*, simply choosing a non-*ing* derivation for one word isn't possible. In these cases, there appears to be greater acceptability, although periphrasis also remains a competing strategy, e.g. *training for actors/acting*.

- c. exercising drill
- (117)
- a. # ski jumping standings
  - b. ski jumping scores
  - c. ski jump standings

Despite the hard constraint on repeated homophonous morphemes, the data suggests that the limitations on distinct words with identical affixation represent a soft constraint rather than a hard one since speakers involved in dialog with each other can transgress this limit (even without pen and paper); however, the fact that corpora show this pattern to numerically correlate with the hard constraints constituting the bulk of the present work makes it merit inclusion in this discussion. As with the haplology discussed in §5.1, avoidance of consecutive lexemes with identical morphology across millennia and across language families suggests that uttering strings with identical syllables creates a burden on either or both of the interlocutors to the extent that it is often preferable to avoid the construction altogether in favor of another than to risk losing one's bearings while counting through a string of prosodically similar words with no distinct road signs as to which role each lexeme plays.

### 5.3. Metathesis as a Strategy for Avoiding Similar Syllables

In Arabic, when identical-onset syllables with short vowels appear in a single lexeme the consonant and vowel of the first such syllable are metathesized, thus rendering the onset of the first syllable a coda. In doing this, the number of vowels remains constant; only, the place of the vowel changes, and as such, any derivational or inflectional information encoded in the vowel is preserved.

From the common pattern of adjective formation in (118) (*Qur'ān* 2:217), the shift of infixing vowel pattern from  $\text{[·a·]·[ī]}$  to  $a\text{·[·]·}a\text{·}$  derives the comparative adjective

in (119) (*Qur'ān* 2:217)—the *u* suffix common to both of them is the nominative marker; the *n* following the *u* in (118) is the indefinite marker.

(118) «كبير»

kabīr·u·n  
'great'

f(ADJ)		·a·		·ī·		·u
ROOT	<b>k</b>	—	<b>b</b>	—	<b>r</b>	—

(119) «أكبر»

ʔakbar·u  
'greater'

f(CMPR)	ʔa·			·a·		·u
ROOT	—	<b>k</b>	<b>b</b>	—	<b>r</b>	—

However, the same pattern of adjective formation in (120) (*Qur'ān* 2:165), the shift of infixing vowel pattern from [·a·]·[ī·] to a·[·]·a· cannot derive the comparative adjective seen in (121) (*Qur'ān* 2:191), since it creates identical-onset syllables with short vowels in a single lexeme. Instead, the consonant and vowel of the first identical-onset syllable must be metathesized, as in (121)', thus realizing the onset of the first identical syllable as a coda.

(120) «شديد»

šadīd·u  
'forceful'

f(ADJ)		·a·		·ī·		·u
ROOT	<b>š</b>	—	<b>d</b>	—	<b>d</b>	—

(121) \* «اشدد»

ʔašda·d·u  
'more forceful'

f(CMPR)	ʔa·			·a·		·u
ROOT	—	<b>š</b>	<b>d</b>	—	<b>d</b>	—

→

(121)' «اشد»

ʔašad·u  
'more forceful'

f(CMPR)	ʔa·			·a·		·u
ROOT	—	<b>š</b>	<b>d</b>	—	<b>d</b>	—

From the standard pattern of jussive verb conjugation in (122) (*Qur'ān* 6:95), the addition of a suffix derives the indicative verb conjugation in (122)' (*Qur'ān* 2:61).

(122) « يُخْرِجُ »  
yuxrij·∅  
'May he bring forth'.

f(IMP <sup>IV</sup> )	yu·			·i·		·∅
ROOT	—	<b>x</b>	<b>r</b>	—	<b>j</b>	—

(123) « يُخْرِجُ »  
yuxrij·u  
'He brings forth'.

f(IMP <sup>IV</sup> )	yu·			·i·		·u
ROOT	—	<b>x</b>	<b>r</b>	—	<b>j</b>	—

However, from the same pattern of jussive verb conjugation in (124) (*Qur'ān* 4:88), the shift in vowel pattern cannot derive the indicative verb conjugation in (124)', since it creates identical-onset syllables with short vowels in a single lexeme. Instead, the consonant and vowel of the first identical-onset syllable must be metathesized, as in (124)" (*Qur'ān* 2:26), thus rendering the onset of the first syllable a coda.

(124) « يُضِلُّ »  
yudlil·∅  
'May he mislead'

f(IMP <sup>IV</sup> )	yu·			·i·		·u
ROOT	—	<b>ḍ</b>	<b>l</b>	—	<b>l</b>	—

(125) \* « يُضِلُّ »  
yudlil·u  
'He misleads'.

f(IMP <sup>IV</sup> )	yu·			·i·		·u
ROOT	—	<b>ḍ</b>	<b>l</b>	—	<b>l</b>	—

(125)' « يُضِلُّ »  
yudlil·u  
'He misleads'.

f(IMP <sup>IV</sup> )	yu·			·i·		·u
ROOT	—	<b>ḍ</b>	—	<b>l</b>	—	<b>l</b>

By relocating the inflectional vowel, Arabic appears to prefer disrupting its otherwise pristine infixing patterns over allowing for the repetition of identical onsets

(between short vowels). However, the displacement of these vowels is such a common phenomenon that it is simply recognizable as part of a sub-paradigm.

The data suggests that the limitations on identical-onset syllables represent a soft constraint rather than a hard one since it is more prominent in some languages than others; however, the fact that tongue twisters are difficult across languages makes it worthy of inclusion in this discussion (Goldrick & Larson 2010; McMillan & Corley 2010)—see §5.4 below for further development of this point.

#### 5.4. Dissimilation as a Strategy for Avoiding Similar Syllables

Just as haplology limits recursion by reducing entire syllables, dissimilation limits recursion by modifying the sounds within identical (or highly similar) syllables.

Arabic imperfect verb conjugations are prefixed by *n*· in first-person plural, as seen in (126) (*Qur'ān* 6:22), and prefixed by *ʔ*· in first-person singular, as seen in (127) (*Qur'ān* 6:50). However, when the verb is glottal-stop initial, non-glottal prefixes like the first-person plural *n*· act no differently than they otherwise would, as in (128) (Al-Shāfiʿī 2009: para. 2), while glottal prefixes like the first-person singular *ʔ*· are not acceptable before a root-initial glottal, as in (129), and as such, they force the following glottal stop to dissimilate and become realized as an extension of the preceding vowel segment, thus maintaining the syllable length, as in (129)' (*Qur'ān* 12:32).

(126)	« تقول »	(127)	« أقول »
	n·aqūl		ʔ·aqūl
	1PL·say		1SG·say
	‘we say’		‘I say’

(128)	« نَأْمُر » n·aʔmur 1PL·command 'we command'	(129)	*« أَمْر » ʔ·aʔmur 1SG·command 'I command'	→	(129)'	« آمْر » ʔ·a·mur 1SG·command 'I command'
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Similarly, Latin has an aversion to suffix laterals following word roots with laterals, which is why the adjectival suffix *·al*, as seen in (130)a, becomes *·ar* following a root with [l], as seen in (130)b. However, when an [r] follows the [l] of the word root, the suffix *·al* now preserves a distinction between itself and the preceding [r], giving a dissimilar pattern of [l]... [r]... [l], as seen in (130)c (Calabrese 2005: 357-358).

(130)	nav·aḷ· boat·ADJ· 'naval'	(130)b	sol·aṛ· sun·ADJ· 'solar'	(130)c	fḷor·aḷ· flower·ADJ· 'floral'
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In a similar fashion, Greek roots with two aspirate consonants, such as *\*t<sup>h</sup>rik<sup>h</sup>* 'hair' and *\*t<sup>h</sup>rep<sup>h</sup>* 'to rear', appear with a deaspirated final aspirate when followed by [s], such that *\*t<sup>h</sup>rik<sup>h</sup>·s* is realized as *t<sup>h</sup>rik·s*, as in (131), and *\*t<sup>h</sup>rep<sup>h</sup>·s·ō* is realized as *t<sup>h</sup>rep·s·ō*, as in (132). However, when the final aspirate is not deaspirated by an [s] suffix, the first aspirate consonant is deaspirated, according to Grassmann's Law, such that *\*t<sup>h</sup>rik<sup>h</sup>·os* is realized as *trik<sup>h</sup>·os*, as in (131)b, and *\*t<sup>h</sup>rep<sup>h</sup>·ō* is realized as *trep<sup>h</sup>·ō*, as in (132)' (Campbell 1998: 31).

(131)	*« θρίχς » [t <sup>h</sup> rik <sup>h</sup> ]·s hair·NOM 'hair'	→	« θρίξ » [t <sup>h</sup> rik]·s hair·NOM 'hair'
(131)b	*« θρίχος » [t <sup>h</sup> rik <sup>h</sup> ]·os hair·GEN 'of hair'	→	« τρίχος » [trik <sup>h</sup> ]·os hair·GEN 'of hair'

- (132) \*« θρέψω »      « θρέψω »  
 [tʰreɸˈšo]      [tʰreɸˈšo]  
 rear·FUT·1SG      rear·FUT·1SG  
 ‘I will rear’      ‘I will rear’
- (132)b \*« θρέφω »      « τρέφω »  
 [tʰreɸˈo]      [treɸˈo]  
 rear·1SG      rear·1SG  
 ‘I rear’      ‘I rear’

MacEachern (1997) performs a systematic study of this aversion to common features in consonants, in which she uses extensive samples from eleven languages to draw up a hierarchy of restrictions on multiple occurrences within words or word roots. What she finds is that the restrictions are gradient (pp. 3, 10, 97), with some languages restricting repetition of consonants with the exact same feature matrix, while others restrict any combination of consonants with a single shared feature.

In some languages, like Tzutujil and Shuswap, a root merely cannot contain two homorganic stops with the same voicing or any two stops from the ejective series (p. 25). In more restrictive languages, like Bolivian Aymara and Hausa, a root cannot contain any of the foregoing or contain any combination of ejective, implosive, and glottal stop (p. 42). In yet more restrictive languages, like Peruvian Aymara and Gojri, a root cannot contain any of the foregoing or any combination of aspirate and ejective or aspirate and glottal fricative (p. 61). And in the most restrictive languages, like Cuzco Quechua and Sanskrit, a root additionally cannot contain any of the foregoing or any combination of aspirate, ejective, implosive and glottal consonant (p. 86).

The simple fact that similar features complicate articulation and perception explains why tongue twisters are so difficult. Despite the fact that they do not require repetition of the exact same syllable, tongue twisters do require syllables with similar

enough features in immediate proximity to necessitate a multi-variable tracking task on the part of the interlocutor.

Goldrick & Larson (2010) performed tests with tongue twisters to demonstrate that phonotactic probability influences speech production independent of phonetic complexity. Accordingly, since similar strings of syllables are less likely to occur, they are more difficult to utter than are distinct strings of syllables with equal phonetic complexity.

However, their findings could also be used to claim the opposite, namely that, since repeated syllables are more difficult to utter than are distinct strings of syllables with equal phonetic complexity, they are less likely to be repeated. This is, in fact, the claim made by McMillan & Corley (2010), who employ VOT experiments to demonstrate that common-feature syllables in tongue twisters create more articulatory perturbation than do non-tongue-twister syllables.

Merely claiming that dissimilation eases articulation, of course, fails to address the competing motivation of assimilation easing articulation. It is important to note, however, that, although the two phenomena are not in complementary distribution, their distribution does not completely overlap either. Indeed, while assimilation is a process more typical of directly adjoined phonemes (Sihler 2000: 20), dissimilation is a process more typical of neighboring syllables (p. 23), and, of primary importance in the cases above, the onsets of neighboring syllables. Keeping in mind that exercise physiology measures endurance by “consistent repetition duration” (Haff & Dumke 2012: 250), it could reasonably be claimed that dissimilation of common-feature syllables (like the haplology discussed in §5.1 above) is motivated by both physical and cognitive factors.

The data suggests that the limitations on adjacent syllables with similar features represent a soft constraint rather than a hard one since it is more prominent in some languages than others; again, however, the data from tongue-twister studies across languages makes it merit inclusion in this discussion.

## 5.5. Defying the Limits with Artifice

### *Pen & Paper*

Even without keeping track of the various levels of embedding in fictional words like *anti<sub>w</sub>-[anti<sub>x</sub>-[anti<sub>y</sub>-[missile<sub>z</sub>]-missile<sub>y</sub>]-missile<sub>x</sub>]-missile<sub>w</sub>*, the string of identical morphemes can only be processed as a counting game at the meta-linguistic level of writing by the characters of a story who use each *anti<sub>n</sub>-* to refer to a technology which cancels out that of one *anti<sub>n</sub>-* lower than his own and refer to them with specific numbers, such as one's "six antis" vs. another's five (Buchwald 1966: para. 9). The recourse to writing here is evident since this scenario, with its reference to counted affixes, only takes place in the world of a written story.

### *Musical Scaffolding*

Just as the three-dimensional cap on human cognition can be manipulated and overridden by the literary artist, the cognitive limits on phonological variable tracking can be flouted, as is often done in poetry and lyrics, like those of David Bowie's "Changes" (1971), as seen in (133).

- (133) Ch-ch-ch-ch-changes:  
       Turn and face the strange.  
       Ch-ch-changes:  
       Don't want to be a richer man.

The repetition of the [tʰə] sequence in (133) has no linguistic value, but is merely a device of musical rhythm. Like the completely meaningless *na-na-na-na* sequence in the theme song of the 1960's Batman series (Hefti 1966), it is simply a type of instrumental timbre. Horowitz (2012) mentions that the memorability factor of such a theme “is based on the limited number of sounds, the relative simplicity of the interval arrangement, the consistency of presentation, and the proper use of repetition” (p. 166).

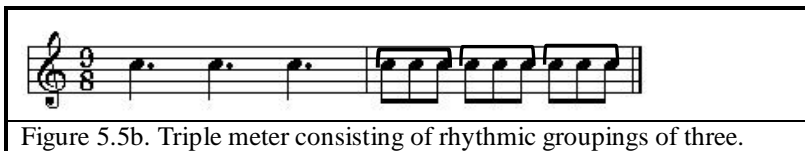
Even when meaningfully repeatable words are iterated for emphasis, they can lose their contrastive significance after a small number of iterations and degenerate into hyperbole (Nemesi 2010: 385), as in the case of *very* in (10)', repeated here for convenience (Edwards 2007: 63).

(10)' The relationship a person has with their friends or so-called friends is very important. No, I rephrase that: “it's very, very, very, very, very important,” and that is no exaggeration.

While the five instances in *very<sub>v</sub> very<sub>w</sub> very<sub>x</sub> very<sub>y</sub> very<sub>z</sub> important* are notably more emphatic than the single instance of *very important*, they are not literally intended to signal a greater degree than the four instances of *very<sub>w</sub> very<sub>x</sub> very<sub>y</sub> very<sub>z</sub> important* or a lesser degree than the six instances of *very<sub>u</sub> very<sub>v</sub> very<sub>w</sub> very<sub>x</sub> very<sub>y</sub> very<sub>z</sub> important*. Instead, the composite meaning of each individual recursion beyond three is lost, and the rhythmic string serves only to convey hyperbole (Nemesi 2010: 385) or even “triviality” (Hitchings 2011: 277). Edwards (2007) apparently even acknowledges this sense of triviality in (10) and thus calls attention to it by adding “and that is no exaggeration” (p. 63). Such repetitions are not intended to be processed for their cumulative value but defy literal meaning in the same way that repeating a syllable in the song verse in (133) does.

The interface with rhythm, both in music and in hyperbolic repetition, can indeed flout the limits of human language, but when this happens, the composite meaning of the morphemes in question is compromised, and even in instances when a single repetition contrasts with no repetition, there is no apparent instance of degrees beyond three contrasting with each other, as the repetition beyond three constitutes a mass of hyperbolic utterance.

The production and perception of rhythmic meter is a multi-variable tracking task of interdependent variables, which humans universally develop within the limitations of three variables. At the age of three, children typically develop an imitative sense of musical rhythm (Winner 2008: 347). Yet, even at 7-9 months old, children recognize rhythm despite variation in tempo (p. 342).<sup>27</sup>

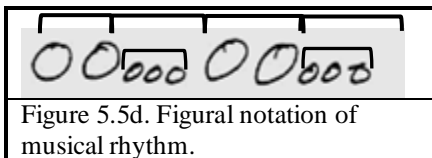
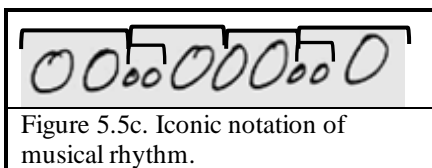


Since rhythmic beats, at their most fundamental form (free of tone and timbre) are only distinct from each other in terms of the order in which they occur, the mind of the perceiver must keep track of these segments with reference to each other. Given that musical rhythms are either duple, triple, or a combination of both, the process is limited to a balancing of two or three variables at a time. For example, 4/4 timing, and 6/3 timing

<sup>27</sup> The babbling which serves as a precursor to (and apparently as a preparation for) speech is also rhythmic in nature (Lalevee & Vilain 2008: 70-72).

are merely multiples of duple and triple meters respectively, grouped together in constructions, as seen in Figures 5.5a & 5.5b (Houle 1999: 47).

When non-trained eight- and nine-year olds were asked to replicate the duple-meter rhythm of “three, four, shut the door; five, six, pick up sticks; seven, eight, shut the gate,” they reproduced patterns like those of Figures 5.5c & 5.5d, which encode the duple and triple nature of what they heard. Note that some children produced metric notation which accounts for the longer notes and the shorter notes iconically, as seen in Figure 5.5c. Others produced figural notation which conceptualizes the faster successive notes as occurring in a triplet, after which there is a space before the next cycle, as seen in Figure 5.5d (Bamberger 1995: 25, 46). In metric notation, this would actually be proportionate to two eighth notes followed by a quarter note, but given their equidistant succession, the figurative conceptualization of them as triplets is no less reasonable, despite the fact that the differing groups of children could not see the reason in each other’s group’s notation (Damon, Lerner, Kuhn, & Siegler 2006: 894-895).



Even the meters which appear to not consist of multiples of duple or triple meter are combinations of both duple and triple. For example, the Eastern European folk music which inspired the exotic meters of Bela Bartok’s music, such as 5/8 timing and 7/8

timing, consist of merely alternating combinations of duplets and triplets, such as 3/8+2/8 and 3/8+2/8+2/8 respectively (Rice 2000: 198), as seen in Figure 5.5e.



Figure 5.5e. Complex meter consisting of mixed rhythmic groupings of two and three.

While it is tempting to think that such divisions of two and three are imposed by culture and convention, this claim of their universality is consistent with meter as found across language families. For example, a number of languages exhibit a limitation constraining stress to the last foot of a word, be it an iambic or dactylic foot. For example, in both Latin and Classical Arabic, the possible range of a word's stress appears only within the last three syllables. By default, it appears on the third-to-last (antepenultimate) syllable, as in (134) & (135).

- |   |  |
|---|--|
| <p>(134) « فَأَخَذَهُمْ »<br/> fa:ʔaxáðahum (<i>Qur'ān</i> 3:11)<br/> 'and so he took them'</p> | <p>(135) hōmínibus (Galatians 1:1)<br/> 'to men'</p> |
|---|--|

The stress can instead appear on the second-to-last (penultimate) syllable when it is heavy, i.e. containing either a long vowel, as in (136) & (137), or a coda consonant, as in (138) & (139).

- |   |   |
|---|---|
| <p>(136) « فَأَحْيَاكُمْ »<br/> fa:ʔahyákum (<i>Qur'ān</i> 2:28)<br/> 'and so he gave you all life'</p> | <p>(137) vidére (John 3:3)<br/> 'to see'</p>            |
| <p>(138) « فَأَخَذَاتْكُمْ »<br/> fa:ʔaxaðátkum (<i>Qur'ān</i> 2:55)<br/> 'and so it took you all'</p>  | <p>(139) secúndo (Genesis 2:13)<br/> 'according to'</p> |

However, as seen in (134) & (135) above, even when a word has more than three syllables in languages like Latin and Arabic, the stress does not appear on the fourth-to-

last syllable, despite the absence of heavy syllables impeding stress migration deeper than the final triplet foot of the word.

In contrast to languages like Classical Arabic and Latin, others like English and Polish do permit the stress to penetrate the word beyond the third-to-last syllable; however, it does so in successive duplets or triplets, with the main stress on an internal foot and secondary stress on the final foot. For example, in the English word *difficulty* (140), the main stress appears four syllables back in the first duplex foot, while a secondary stress appears two syllables back in the final duplex foot.

(140) dífífcùlty

Hayes and Puppel (1985) demonstrate how entire phrases and sentences work within the metrics of such duplets and triplets. For example in the word *Mississíppi* in (141), the primary stress appears two syllables back in the final duplex foot, while secondary stress appears four syllables back in the first duplex foot; however, in the phrase *Míssissíppi múd* in (142), the primary stress of *Mississippi* appears four syllables back in the first duplex foot, while secondary stress appears two syllables back in the final duplex foot (p. 60).

(141) Míssissíppi

(142) Míssissíppi → Míssissíppi múd<sup>28</sup>

Hayes and Puppel duplicate this finding with Polish phrase *prezydènta żóna* ‘the president’s wife’, where the primary stress of *prezydènta* ‘the president’s’ shifts from the final duplex to the first duplex (p. 60).

(143) prèzydènta żóna → prezydènta żóna

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<sup>28</sup> The name of a both a standard song (Barris 1922) and a number of popular desserts (Puckett 2013: 186) and beverages (Heatter 2010: 236).



The data suggests that the limitations on rhythmic scaffolding represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in rhythmic overlays on language.

## 5.6. Assimilation, Reduplication and Onomatopoeia

Recall from §5.4 that that assimilation operates in conflict with dissimilation by pitting its ease-of-articulation motivation against dissimilation's ease-of-processing motivation. In a similar fashion, reduplication operates in conflict with dissimilation motivation by pitting its iconicity motivation against dissimilation's ease-of-processing motivation.

Reduplication routinely occurs only once, thus creating two adjacent identical (or at least similar) syllables. Examples abound in Indo-European languages, such as Latin where from the base of the present tense *currit* 'run' (*Vulgate*: Psalms 147:4), in (146), derives the past tense *cucurrit* 'ran' (*Vulgate*: Numbers 11:27), in (147).

(146)	velociter	<u>curr·it</u>	sermo eius	(147)	<u>cu·curr·it</u>	puer	et	nuntiavit	Mosi
	swiftly	<u>run·3SG</u>	speech his		<u>PERF·run·3SG</u>	youth♂	and	told	Moses
	'his word runs swiftly'					'A young man ran and told Moses'			

In a number of languages, including Salish (Haeberlin 1918: 171) and Tsishaath Nootka (Stonham 2003: 243) reduplication can occur twice, thus creating three phonologically identical (or at least similar) syllables encoding distinct meanings. In these respective languages the monomorphemic roots of (148) & (150) undergo double reduplication in (149) & (151).

(148)	mūs	(149)	mus·mū's·must
	four:INAN		DISTR·four·ANIM
	'four'		'four (people) at a time'

(150)	q <sup>w</sup> aa thus 'thus'	(151)	q <sup>w</sup> a·q <sup>w</sup> a·q <sup>w</sup> a·rh·asči DISTR·SUF·thus·as·far·as·in·one·group 'half of the young men to a side'	haawiihał young:men <sup>29</sup>
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The data suggests that the limitations on morphologically distinct reduplicative morphemes represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in natural language usage. In contrast, the unlimited nature of onomatopoetic homophonous morphemes appears to represent a lack of constraint of the sort seen with the foregoing phenomena. It is generally understood that reduplication where each reduplication serves a unique function, does not occur three times, which would thus create four phonologically identical (or at least similar) syllables encoding distinct meanings (Ekanjume-Ilongo 2013: 28). However, as Dressler (1995) notes, onomatopoetic reduplication can surpass this limit (p. 27), suggesting a rhythmic element is at work rather than a semantic one with phonologically identical (or at least similar) syllables encoding distinct meanings.

## 5.7. Relevant Connectionist Models

Appropriate to the types of phonological variable balancing surveyed in this chapter are connectionist models which measure the limitations on repeating homophonous morphological segments (§5.1). The next logical step is to incorporate into these models the aforementioned strategies for alleviating the processing burden of repetition (§5.1-5.5).

McClelland and Elman's (1986) TRACE model shares connectionist traits with SRN models but is specialized for phonetic features and phonemic elements. Its cyclical loop with a "memory network" for past inputs integrates sequences of successive inputs,

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<sup>29</sup> The abbreviation SUF in this literature refers to suffix-triggered reduplication.

such as the phonological variable-tracking task. If the TRACE model is given the task of parsing homophonous morphemes in sequence, it would reveal a degradation pattern, as it would have a problem aligning them unambiguously with a template stored for recall.

Ultimately, in phonology, there is not so much a dearth of applicable connectionist models as there is an absence of a single model which captures the analogy between the processing limitations of phonological sequences of successive inputs and other types of limitation patterns in human language, as well as other types of limitation patterns in general human cognition.

## 5.8. Concluding Remarks on Phonology

As with the recursive limits on reference, syntax, and morphology seen in the previous chapters, the simplest explanation is the easiest to quantify and corroborate with various other forms of typological phenomena. What the foregoing discussion demonstrates is that articulation of identical elements is not a linear task so much as it is a multi-variable tracking task, and no such variable acrobatics can surpass a three-dimensional calculus function.

Various factors can conspire to further complicate variable-balancing tasks in phonology, such as the task of processing homophonous strings in (152) being additionally burdened by the interference of syntactic center embedding—see §3.1 above for a full discussion of this phenomenon and the processing burdens it entails. For example, the construction in (152) tasks the mind with three variables of embeddedness (x, y, & z) and simultaneously with three variables of homophonous morphemes (a, b, & c).

(152) \* The machine<sub>x</sub> [that the man<sub>y</sub> [who<sub>z</sub> ran<sub>za</sub>] ran<sub>yb</sub>] ran<sub>xc</sub>.

The visually tiered analysis of (152) in Figure 5.7a illustrates the fact that the interlocutor must conceptually hop between the different sides of a three-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

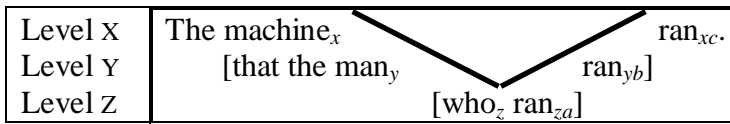


Figure 5.7a: A conceptual three-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

Even reducing this to two variables of embeddedness with two simultaneous variables of homophonous morphemes, as in (153), is burdensome enough on human cognition to be avoided.

(153) # The machine [that the man ran<sub>y</sub>] ran<sub>z</sub> well.

The visually tiered analysis of (153) in Figure 5.7b illustrates the fact that the interlocutor must conceptually hop between the different sides of a two-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

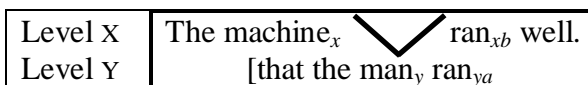


Figure 5.7b: A conceptual two-tier valley, with walls consisting of incomplete thoughts, whose complement is equi-level on the opposite side.

Such compounding of variable tracking can complicate the task of dealing with the constraints already imposed by the cognitive limit of three dimensions; it is not a neutral addition, and it is certainly not one which alleviates the cognitive burden. What is clear is that the human mind is pushed to its limits with any individual three-dimensional juggling task, and thus working with multiple simultaneous three-dimensional juggling tasks. This might explain why humans either close their eyes or find something to focus

on during recitative processes involving intense memorization tasks, since the addition of visual stimulate has the potential of overburdening an already complicated task. The next section examines general phenomena in human cognition and examines parallels between variable-balancing tasks at that level of analysis and those explored in this and the foregoing chapters.

## 6. Beyond Language: Three-Dimensional Constraints on Interdependent Structures in General Cognition

We are three-dimensional creatures trapped in three dimensions.  
– Carl Sagan (in Sagan, Druyan, & Soter 1980)

This chapter surveys non-linguistic phenomena to examine the degree to which they share a three-dimensional constraint with the linguistic phenomena discussed in the previous chapters. The phenomena under analysis are the universal transfer of three-dimensional images onto two-dimensional surfaces, the universal distinction between the two dimensions of space which do not elicit fear (i.e. width and depth) alongside the third dimension of space which does elicit fear (i.e. height), interaction conceptualization, musical nuclei, and subitizing.

Following the survey of these non-linguistic phenomena which share variable-balancing limitations mirroring those of human language, the focus shifts to corrective mechanisms of stimulus interpretation, which parallel those discussed in the foregoing sections (such as haplology in §5.1, metathesis in §5.3, and dissimilation in §5.4).

In the area of general human cognition, such human universals as visual representations, spatial fears, interactive conceptualization, and music display a cognitive manipulation of up to but not beyond three variables. This manipulation involves an interdependent use of three variables in which one cannot be registered without

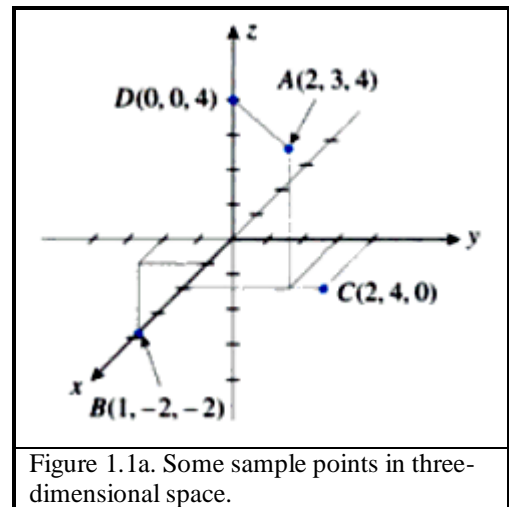


Figure 1.1a. Some sample points in three-dimensional space.

reference to the other two, as is the case with a three-dimensional calculus function of the sort illustrated above in Figure 1.1a (Tan 2006: 540) (repeated here for convenience),

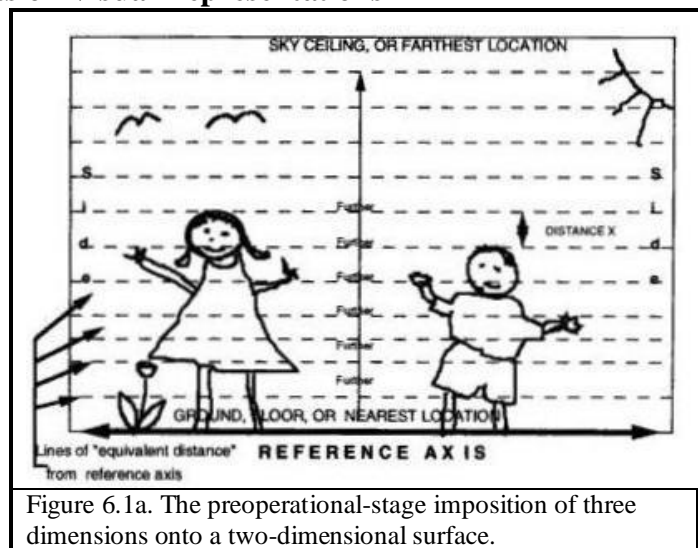
where we see that any given specific point cannot be registered without reference to all three variables in relation to each other.

What the various types of non-linguistic phenomena analyzed in this chapter all have in common is that they share the same interdependency and limitations as the linguistic phenomena of Chapters 1-5.

Skirting and transcending these recursive limits is sometimes possible in experimental and cultivated settings, and, while intellectually analyzable as concepts and even trainable as skills, they do not arise in universal human circumstances but, like the concept of the number zero, have risen independently in highly cultivated settings.

### 6.1. Three-Dimensional Constraints on Visual Representations

The universal human trait of visually representing scenes from narrations (seen in pre-historic cave-painters and pre-school level children) reveals the spontaneous ability to transfer three-dimensional images onto two



dimensional surfaces, often acknowledging an implicit depth (Case & Okamoto 2000: 14), as seen in Figure 6.1a, while no comparable tradition exists for transferring four-dimensional tesseracts onto three-dimensional sculptures.

This ability reflects two distinct three-dimensional abilities, first, the universal human ability to filter out more relevant foreground figures from a more static background, and second the universal human ability to express this perception through the display of perspective in the background.

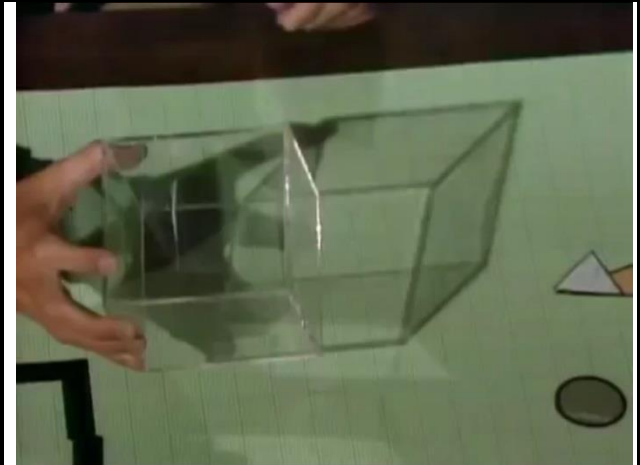


Figure 6.1b. A three-dimensional cube projected as a shadow onto a two-dimensional paper . The depth of a three-dimensional cube is represented by using two-dimensional linear elements of height and width.

Crucially, the balance of three interdependent variables is what allows humans to individuate depth with relation to height and width, even when depth must be represented using two-dimensional linear elements of height and width in what Sagan, Druyan, and Soter, (1980) calls a two-dimensional shadow of three dimensions, as seen in Figure 6.1b.

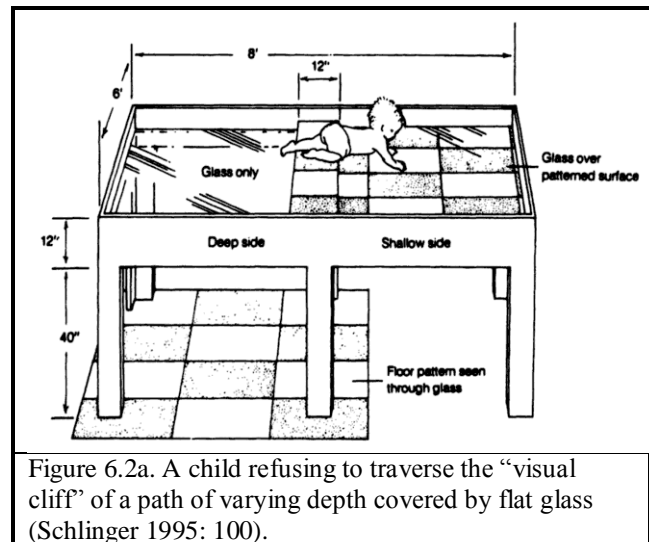
Knowledge for comprehending how tesseracts (and shapes from higher ordinal dimensions) can be shadowed onto a three dimensional “surface” is a quite recent development in human history, and even then, it is not easily comprehended, let alone experimented with, by everyone who has finished two decades’ worth of education. As such, there is a notable asymmetry between the universal human characteristic of routinely transferring three-dimensional life-scenes onto two-dimensional surfaces (with or without any training) and the exceedingly rare ability to transfer four-dimensional tesseracts onto three-dimensional sculptures (only with extensive educational preparation).

The data suggests that the limitations on transferring images from a higher dimension to the surface of a lower one represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in all but the most highly cultivated settings.

## 6.2. Three-Dimensional

### Characteristics of Spatial Fears

A similar limitation is apparent in the human sense of fear. Humans and other mammals, at the earliest stages of motility, display a full grasp of the three dimensions of height,



breadth, and depth. An acute awareness of the dimension of height in particular universally impedes certain decisions of movement. Deep glass-floor tests have demonstrated that, upon becoming motile, humans and other mammals begin to fear the visual orientation of height (Gibson & Walk 1960: 64), as seen in Figure 6.2a—accordingly, since goats and lambs can walk on day one, their fear of heights begins on day one (p. 67). As with the human understanding of depth discussed above, the balance of three interdependent variables is what allows humans to individuate depth with relation to height and width.

As with the rarity of cultivated tesseract shadowing in three dimensions, no such fear of breadth or depth is systematically accounted for, with the possible exception of relatively rare disorders, such as agoraphobia. One disorder often classified as a subclass of agoraphobia is space-phobia, which involves a fear of gravity-like forces drawing one

in non-groundward directions (Baloh & Honrubia 2001: 120; Pollard & Zuercher-White 2003: 30). Victims of this disorder do not typically suffer other psychological disorders (Baloh & Honrubia 2001: 120; Marks 1987: 319), and are aware that their fear is irrational (Pollard & Zuercher-White 2003: 30), suggesting that their problem is the result of “disturbed integration of vestibulo-ocular reflexes” creating a miscalibration of the spatial variables they balance.

Just as the cultivated knowledge of tesseract is a quite recent development in human history, an understanding of how to intentionally experiment with miscalibrations of our three special dimensions is a recent device of the most studied among the lifelong educated. M. C. Escher (1953) exploited just such a miscalibration in

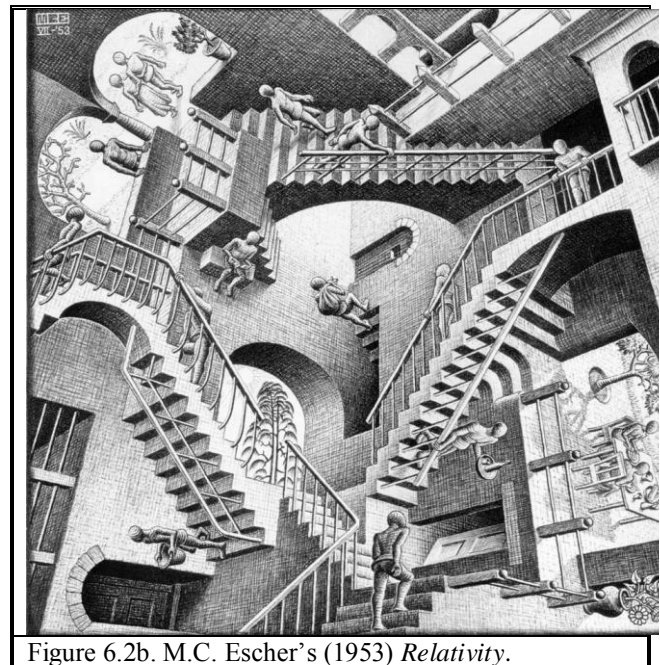


Figure 6.2b. M.C. Escher's (1953) *Relativity*.

artwork like *Relativity*, where gravity pulls equally to the side and upwards, as seen in Figure 6.2b.

Even among individuals with a strong conceptual control of the fourth dimension, there is no universally pervasive fear of width or depth, or of a fourth dimension like time (perhaps warping any of the other three dimensions) which would be comparable to our universal inborn fear of heights.

The data suggests that the limitations on dimensional distinction represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables processed even in documented cases of disorders which miscalibrate the existing three dimensions.

### **6.3. Three-Dimensional Characteristics of Interaction Conceptualization**

20th Century chess masters Russian Irving Chernev and American Fred Reinfeld, both prolific authors on mastering chess, routinely give instructions for thinking three moves ahead (1965: 150; 1960: 67; 1989: 27). It is no mistake that they coauthored a book called *Chess: How to See Three Moves Ahead* (1971).

Chess offers an opportunity to observe and measure controlled human interactions in a goal-driven setting. Not surprisingly, such observations reveal a human proclivity to balance up to three steps of complex interaction.

The ability for chess masters to see three moves ahead is a common topic in psychiatric and other cognitive-science literature (Cauley, Linder, & McMillan 1996: 102; Kail & Wicks-Nelson 1993: 233; Hunt 2009: 628), though the discussion is often less about why three is the cap than it is about how chess masters can think three moves ahead when doing so entails “visualizing twenty-seven thousand possibilities” (Hunt 2009: 628) (as in Figure 6.3).

This limited ability to think three moves ahead has even gained a proverbial status in literature on politics (Maraniss 2012: 15), warfare (Leonhard 2009: 22), criminology (Giacalone 2011: 63), and understandably business (Welch 2008: 117; Rice 2010: 9), with one best-selling book even bearing the title *Three Moves Ahead: What Chess Can*

*Teach You About Business* (Rice 2010). Fiction too occasionally employs this well-known motif (Natale 2009: 219).

Hastie & Dawes (2001) note in their empirical study that “the eye movement camera indicates that both experts and grand masters look ahead only two or three moves” (p. 6). Saariluoma (1995) associates this ability to think three moves ahead with three mental spaces (p. 106). What this tells us about human interaction is that those displaying ease in formal debate or informal social interactions apparently do not face impediments in working within these three interdependent mental spaces, while those who ask a single content question and then get stumped at the follow up evidently face temporary or chronic challenges in this area.

As with those able to conceptualize and work with tesseract, however, a minority of chess masters are apparently able to look ahead four or even five moves, again revealing that some highly-trained (and highly-practiced) experts can transcend the limits of three dimensions. Likewise, although such rigorous examination of mental spaces in

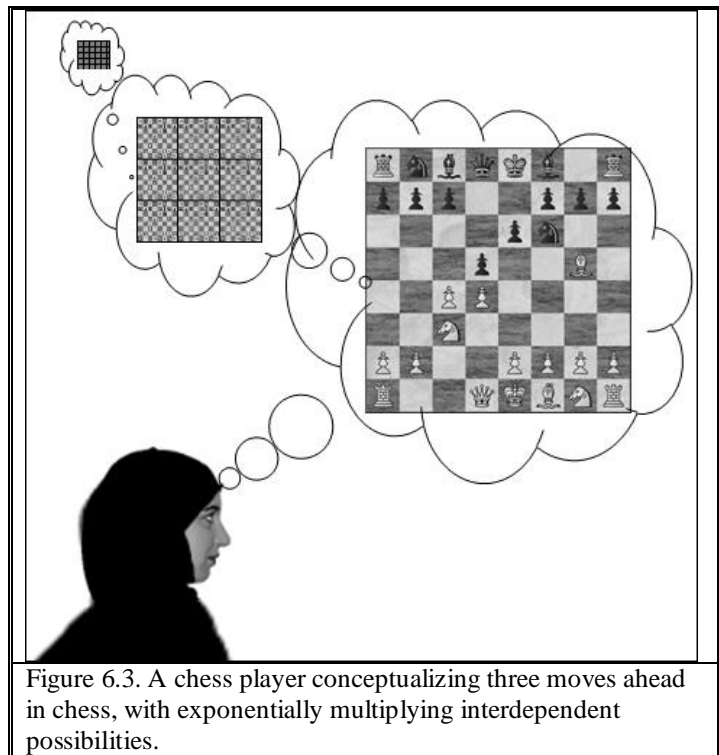


Figure 6.3. A chess player conceptualizing three moves ahead in chess, with exponentially multiplying interdependent possibilities.

formal debate is lacking, it is conceivable that a minority of those excelling at debate have the ability to not only skirt the limit of three mental spaces but to transcend it.

It is difficult to determine whether the limitations on interaction conceptualization represent a hard constraint or a soft one since the parameters of interaction as outlined in chess are subjected to a certain type of interaction; however, the fact that literature suggest that this pattern numerically correlates with the hard constraints constituting the bulk of the present work makes it merit inclusion in this discussion.

#### **6.4. Three-Dimensional Constraints on Musical Rhythm**

While visual representations, spatial fears, and certain forms of interactive conceptualization can be discussed without direct reference to language at all, everything about the linear configuration of music, from its general phrasing, to its cadences, to its meter is described in terms analogous to those of language. As such, music provides an interesting instance of a phenomenon which not only corresponds with language but even shares universally accepted analogies with it. Not surprisingly, it shares a universally accepted set of rhythmic constraints, limiting it to atomic groupings of no greater than three beats, which work in interdependent relation to each other (see §5 above).

As noted in the discussion of rhythmic universals shared by language and music above (in §5.5), children develop the ability to perceive the interdependent variables of rhythmic meter in their first year (Winner 2008: 342), and the ability to produce the interdependent variables of rhythmic meter within their first three years (p. 347). These facts along with the pervasive nature of music within all cultures of the world attest to its universality.

Moreover, the analysis of musical nuclei as being duple and triple meter segments, multiplied in meters like 4/8 and 6/8 respectively (Houle 1999: 47), and mixed in meters like 5/8 (Rice 2000: 198), is not merely a construct of music theorists but a perception

verified in tests involving children who produced their own iconic representations of the duple and triple building blocks of musical rhythm (Bamberger 1995, 25, 46; Damon, Lerner, Kuhn, & Siegler 2006: 894-895).

As with other areas constrained by three interdependent variables, highly trained musical experts cultivate skills going beyond the universal limit, such as polymetrical overlap of duple and triple meter in Bach's Goldberg Variations, BWV 998 var. 26 (Williams 2001: 94), or in Chopin's Fantasia-Impromptu in C-sharp minor, Op. posth. 66 (Niecks 1890: 274), as seen in Figure 6.4a.

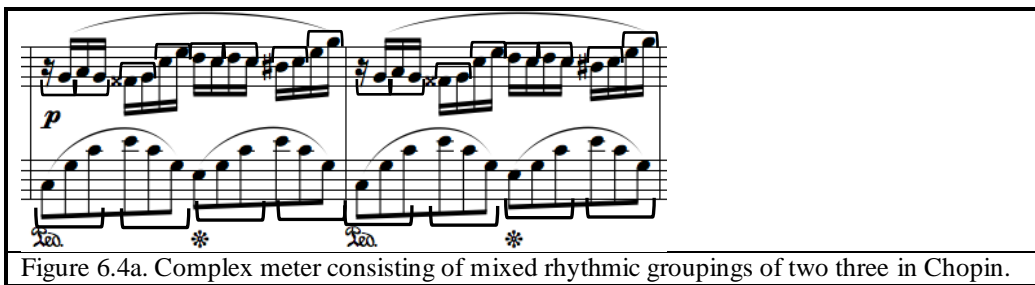


Figure 6.4a. Complex meter consisting of mixed rhythmic groupings of two three in Chopin.

More impressively, West African music maintains a rich tradition of expert musicians who combine rhythms to form two-over-three polyrhythms and even kora players who combine duple and triple rhythms on a single instrument (Hast, Cowdery, & Scott 1999: 109).

Again, however, it is an expert cultivation, the knowledge of which is passed down from generation to generation, and one which despite transcending the elements of duple and triple meter, still builds upon them as essential rhythmic elements. Thus, while musical ability appears to be universal, only a small number of traditions have cultivated polyrhythms.

The data suggests that the limitations on rhythmic scaffolding represent a hard constraint, in that no reliable data shows more than three levels of interdependent variables produced or processed in all but the most highly cultivated settings.

### **6.5. Three-Dimensional Characteristics of Subitizing**

*Subitizing* refers to the human ability to look at a set of countable items and immediately know how many of them there are. According to tests done by Pagano, Lombardi, and Mazza (2014), humans were able to subitize between one and ten items with an error rate of less than them (p. 247). However, when the number of items surpassed three, the error rate doubled at four items and quadrupled at five items. The results for other mammals are similar (p. 245).

Working with older data, relying on different criteria, Kaufman, et al. (1949) claims that the cut-off point for subitizing is seven or eight visual points on a surface, rather than three. Miller (1956), who is more often cited by linguists, claims that the same data reveal a cut-off point of seven (without mentioning the number eight). Perhaps, the distinct test criteria used in this older test do not so much signal an error in Kaufman, et al. and Miller's assessments as they point to a secondary cut-off point.

A notable trait of Miller's discussion of seven as the "magical" cut-off "number" is his discussion near the beginning of the article of the language of computer binary, where he notes that for each binary bit increase, the number of possibilities doubles. For example, a single bit can only give the two possible outcomes of 0 and 1, while a pair of bits can give the four possibilities of 00, 01, 10, and 11, and a triad of bits can give the eight possibilities of 000, 001, 010, 011, 100, 101, 110, and 111 (pp. 82-83).

In his discussion of the cut-off point being seven rather than eight, it is notable that Miller overlooked the binary correspondence between three numerals and eight outputs which he felt was worthy of bringing up earlier in his discussion, since the eight or fewer variables that humans are able to keep track of, in certain types of subitizing tasks, could result from a process analogous to the bit-to-byte-type transformation; it could also be said to result from the same recoding mechanism responsible for chunking, which might itself be a process analogous to the bit-to-byte-type transformation process. Either way, it is important that we start looking at not only variable-tracking limits in human cognition but apparent discrepancies like this, which might signal two manifestations of a single process. There is a reason why one type of subitizing test shows a limit of three (Pagano, Lombardi, & Mazza, 2014) while another shows a limit of eight (Kaufman, et al., 1949), and we should attempt to understand how they interact with each other, rather than assuming their disagreement makes one right and one wrong.

## **6.6. Corrective Mechanisms in the Interpretation of Stimuli**

Reality is merely an illusion, albeit a very persistent one.  
– Albert Einstein (Brewster 2004)

Parallels between the limitations of three interdependent variables in human language and those in general human cognition raise the question of how corrective mechanisms of stimulus interpretation in general human cognition parallel those in human language (such as haplology in §5.1, metathesis in §5.3, and dissimilation in §5.4).

The phrases in Figure 6.6a are typical of didactic exercises used for training instructors to catch typographical errors.

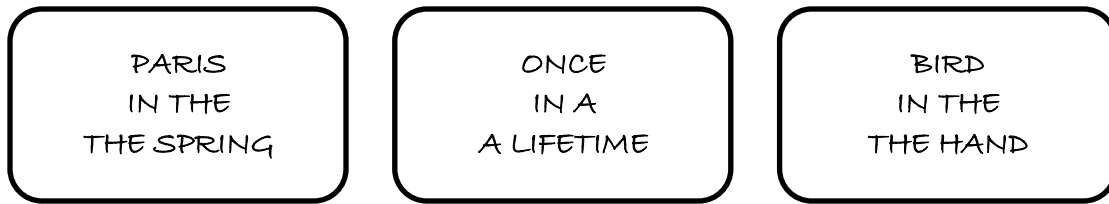


Figure 6.6a. Three common phrases used to test perception.

Figure 6.6b highlights the repetition of function words that are not easily noticed at first glance.

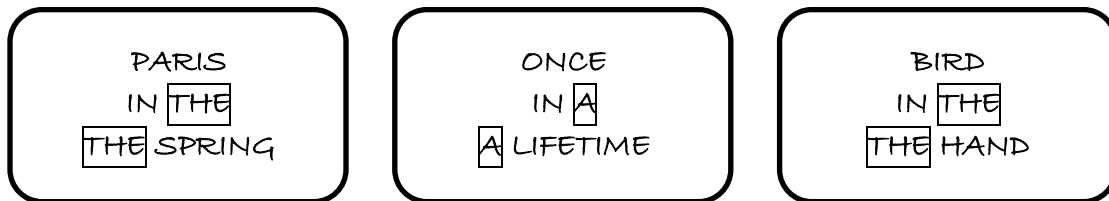


Figure 6.6b. Three common phrases used to test perception with repeated words highlighted.

According to Roser and Gazzaniga (2004), when we see illusions, our left-brain attempts to fit the image into our narrative of reality. Accordingly, since such operations take place at an automatic level, we have minimal conscious control over them: “if certain stimuli trick your visual system into constructing an illusion, knowing that you have been tricked does not mean that the illusion disappears” (p. 56).

This active attempt of our brain to correct a perceived error is particularly noticeable in pictorial illusions, such as that of Figure 6.6c (*Weldon, 2013*), which compels the viewer’s mind to harmonize two identical parallel sets of eyes. Part of the illusion arises from our natural understanding of the world (*Fish 2009: 149*), where cats have two eyes, instead of four. However, the identical patterning around both sets of eyes helps to create the illusion of a two-eyed cat that our eyes have simply not properly focused on yet.

Roser and Gazzaniga also document tests showing how the human mind inadvertently blends separate colors, as if they were “paint on an artist’s palette” (p. 57),

... often confabulate wildly in order to produce an explanation of the world that is consistent with their conscious experience. These confabulations include completely denying the existence of a deficit and probably result from interpretations of incomplete information, or a reduced range of conscious experience... Wild confabulations that seem untenable to most people, because of conscious access to information that contradicts them, probably seem completely normal to patients to whom only a subset of the elements of consciousness are available for integration. (p. 557)

the left hemisphere's attempt to reduce the parallel identical series of eyes to a single series of eyes, the mind attempts to reduce parallel identical sequences of sounds to a single instance, as with (154) in all registers of English and (155) in spoken English.<sup>30</sup>

A detailed illustration of a brown tabby cat sitting on a wooden floor. The cat is looking up with wide, yellow eyes and an open mouth, showing its teeth, giving it a surprised or excited expression. The floor is made of wooden planks arranged in a herringbone pattern. The cat's fur is brown with dark stripes, and its ears are pointed upwards. The illustration is framed by a black border.

Figure 6.6c. Cat with two identical parallel sets of eyes, which uses our understanding of the world to make our minds harmonize two unfocused eyes out of four focused eyes.

151

(155) pr**ob**ab**ly** → pr**ob**'ly

Sentences with ambiguous beginnings, moreover, tend to the simplest interpretation of the first words, even when such an interpretation is disjoint with the rest of the sentences (Croft 1995: 874), and once that faulty interpretation is internalized, it is not readily canceled out in real-time speech (Church 1980: 17).<sup>31</sup>

The corrective faculty of the left hemisphere conspires with the cognitive limitation of three interdependent variables to simplify processable input which exceeds this limit. The linguistic applications of this were taken up with more detail in the preceding chapters, especially Chapter 5 dealing with phonology; however, given the unifying theory of variable balancing herein, it is easy to hypothesize other scopes of cognition that the corrective faculty could be applied to.

## 6.7. Conclusion of this Work

As to why the third dimension plays such a crucial role in the human mind, we could simply answer that, unlike other spatial dimensions, it is the third dimension where we have made our home for as long as we have been we, and our minds are subsequently designed to work within its confines—see Figure 6.7a.

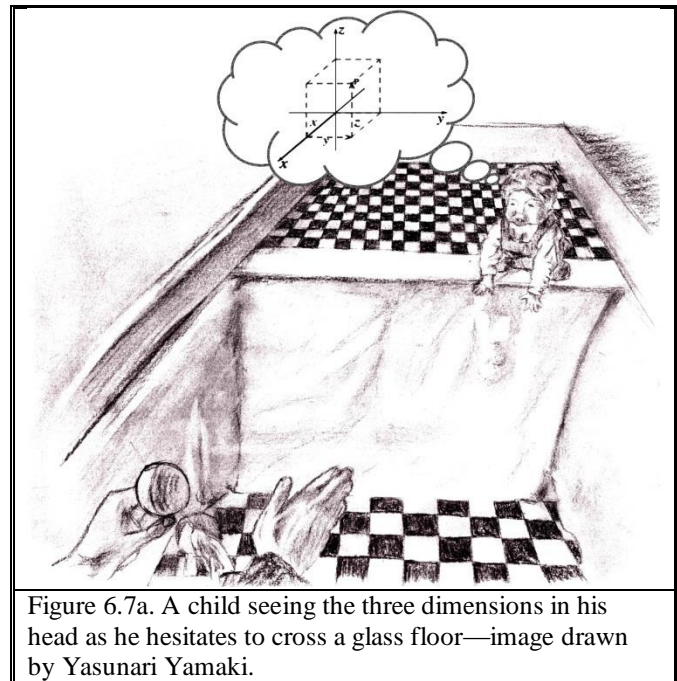


Figure 6.7a. A child seeing the three dimensions in his head as he hesitates to cross a glass floor—image drawn by Yasunari Yamaki.

<sup>31</sup> This hypothesis is summarized in greater detail in §3.5.

The ability to transfer fourth-dimensional images of tesseracts onto three-dimensional sculptures could not serve as useful art for retelling the glorious history of a pre-industrial nation, and, in such a context, the materials needed to construct a sculpture of this sort would prove an additional impediment to an already minimally desirable project.

Perhaps of more relevance to human existence throughout the centuries, such fourth-dimensional insight would prove of no use in any Darwinian sense. While fear of heights helps humans to live long enough to reproduce (Gibson & Walk 1960: 67), a fear of fourth-dimensional time-bends would not only fail to keep hunter-gatherers safer but would even provide a counterproductive phobia. Even a miscalibration of the human mind which gives one a fear of the other two familiar dimensions of breadth and depth would prove a distinct disadvantage, as agoraphobia is clearly seen to be.

Since primates share with humans the ability to distinguish musical rhythm, Ramus and coauthors believe that “rhythm may initially have served purposes other than musical or linguistic ones” (as cited in Winner 2008: 340-341). In so far as rhythms provide uses in general human life patterns, complex rhythms cannot conceivably help troops march more efficiently than the current two-steps (or any multiple thereof) which so neatly match the number of feet the average human possesses, nor do they appear to offer more useful alternatives to mammalian motile, group-migration, or mating patterns of any sort.

Not simply the wording we use to describe our asymmetrical treatment of dimensions, but even the structure of language itself reflects the same principles which bind our cognitive perception in other areas. Chomsky does not seem to recognize this

when he states that there is absolutely no connection between human language and general human cognition: “There’s just no resemblance between what a child does with blocks and the kind of knowledge he displays of English grammar at the same age” (as quoted in “Things,” 1983: para. 60). Although he does not substantiate this claim, the opposite can easily be demonstrated when we observe through data, like the foregoing, how human language reveals the same measurable limit on interdependent-variable balancing as other areas of human cognition do.

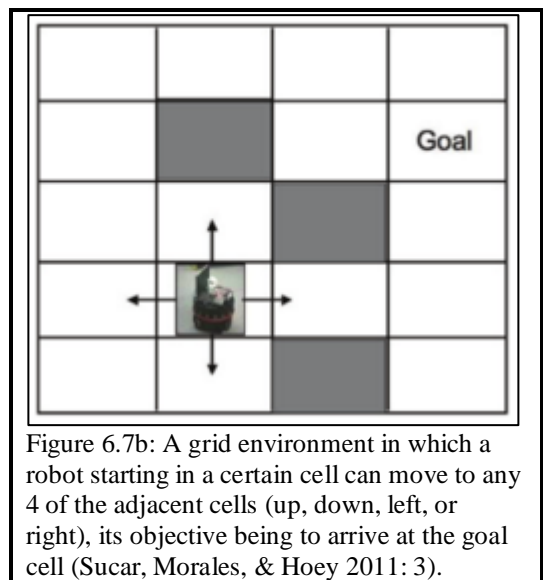
As the philosophically inclined scientist Carl Sagan once put it, “We are three-dimensional creatures trapped in three dimensions” (Sagan, Druyan, & Soter 1980). This trap on us is not one which we could simply open our minds to and escape, as the trap is built into our minds themselves. And this should not be a surprise, as the brain operates at great cost: “the brain consumes about eight times more energy than would be expected on the basis of its mass alone” (Dunbar 2000: 246), so any excess use of energy to deal with higher dimensions than we require for our basic living runs counter to the essential need for humans to survive first and hypothesize later. Keeping track of variables affects our visual perception of events, our sense of movement, our sense of fear, and our sense of pleasure. Pushed to deal with more than the accustomed three-dimensional limits we are programmed to handle, our minds find ways of simplifying the input so as to harmonize it within familiar bounds, because in the pre-industrial world, before human culture entered a phase of its development increasingly driven by modern engineering and modern science, that is all we needed to do.

The fact that language is bound by these same constraints should come as no surprise, as human language, like so many other traits of human thinking were developed

in the pre-industrial world. The ways in which language deals with the processing problems involved with keeping track of these variables and simplifying the information when it surpasses the input limit is a direct result of human language being an extension of human cognition, not an autonomous black box which transcends or falls short of the limits of general human cognition.

What this hypothesis entails is not simply an interrelation between a number of variables but also a strict limitation on which types of thoughts humans are able to process, which is the mission statement of decision theory (Bermúdez 2009; White 2009; Parmigiani & Inoue 2009), and which provides more for AI scientist to work with in the design of neural networks (De Paz 2009; Maskara & Noetzel 1992).

Decision theory can be divided into two varieties: macroscopic decisions of the philosophical sort and microscopic decisions in the realm of artificial intelligence (though various disciplines, such as economics, make use of middle grounds of analysis between these two polarities). Decision theory in philosophy is the older area of inquiry and



deals with what we traditionally understand to be decisions, such as how to most productively spend one's money or time to reach a desired goal (Peterson 2009: 1-3). The newer inquiry of decision theory in artificial intelligence deals with such minute decisions as which direction to move in, in order to reach a desired goal without hitting a

wall (Sucar, Morales, & Hoey 2011: 3), taking into account such variables as which directions best avoid circuitous routes and dead ends.

When a robot attempting to reach a physical goal, as in Figure 6.7b, hits a wall, it must decide to move in another direction. Likewise, when it takes a maze passage which at first appears to be a direct path but which progressively leads away from the goal without showing signs of change, it must decide at some point to give up on that path and make a decision to move in a different direction. Artificial intelligence tasks not involving movement are informed by the same essential mechanisms, e.g. the question of when the repetition of a process merits abandonment in favor of a new direction. For example, in language processing, the *he said, she said* mind-reading task should not be parsed in a literal sense beyond the third level, at which point a decision should be made in favor of a hyperbolic *so on and so forth* interpretation (as discussed in §2.1). Accordingly, a meaning-based parsing of repeated homophonous morphemes should be abandoned after the third iteration, in favor of pursuing the possibility of a rhythmic interpretation of the repetition (as discussed in §5.5). Understanding this cut-off point has the potential to inform artificial intelligence far beyond the scope of language alone and could indeed be the key to understanding the nature of human thought and accurately replicating it.

**An Imposing Memory Task.**

This study is part of on-going research into how people see their world. We are particularly interested in what people remember of social situations, and how they explain some of the things that happen to them. There are two parts to the study; each part has a different questionnaire. It is VERY IMPORTANT that we keep both the questionnaires together. To do this we would like you to think of any three-digit number (137, 735) and write it on the top of BOTH questionnaires. That way, if the questionnaires get separated, we can correlate the answers.

This booklet is the first questionnaire, and relates to the first task.

You will be read a set of five short stories, one at a time.  
Please listen very carefully to each one as it is read out, because you will be asked to answer questions about it later.

In this booklet are the questions about the stories. DO NOT LOOK AT THE BOOKLET UNTIL ASKED TO DO SO.

What we would like you to do is: Listen to the stories as they are being read out.  
When the first story is finished, turn over to the first page.  
Answer the questions about the first story.

Each question is composed of two [TEXT MISSING].

What you have to do is chose the correct statement of the [TEXT MISSING].

When you have finished the questions about the first story,

WAIT.

When you have listened to the second story, turn over to the second set of [TEXT MISSING].

This pattern will continue.

DON'T turn over the pages until AFTER the next story has been read out.

Thank you for your interest.

## I. WHERE'S THE POST OFFICE?

Sam wanted to find a Post Office so he could buy a Tax Disc for his car. He asked Henry if he could tell him where to get one. Henry told him that he thought there was a Post Office in Elm Street. When Sam got to Elm Street, he found it was closed. A notice on the door said that it had moved to new premises in Bold Street. So Sam went to Bold Street and found the new Post Office. When he got to the counter, he discovered that he had left his MOT certificate at home. He realized that without an MOT certificate, he could not get a Tax Disc, so he went home empty-handed.

## I. Where's the Post Office.

Please tick the correct answer to each question:

1. (a) Sam wanted to go to the Post Office to buy a stamp.<sup>32</sup>  
(b) Sam wanted to go to the Post Office to buy a Tax Disc.
2. (a) Henry thought Sam would find the Post Office in Elm Street. – 2 LEVELS OF EMBEDDING: 2 SEQUENTIAL  
(b) Henry thought Sam would find the Post Office in Bold Street. – 2 LEVELS OF EMBEDDING: 2 SEQUENTIAL
3. (a) The Post Office had moved from Bold Street to Elm Street.  
(b) The Post Office had moved from Elm Street to Bold Street.
4. (a) Sam thought that Henry knew the Post Office was in Bold Street. – 2 LEVELS OF EMBEDDING: 2 SEQUENTIAL  
(b) Sam thought that Henry knew the Post Office was in Elm Street. – 2 LEVELS OF EMBEDDING: 2 SEQUENTIAL
5. (a) The Post Office in Elm Street had a notice in the window saying it had moved to Bold Street.  
(b) The Post Office in Elm Street had a notice on the door saying it had moved to Bold Street.
6. (a) Sam thought that Henry believed that Sam wanted to buy a Tax Disc. – 3 LEVELS OF EMBEDDING: 3 RECURSIVE  
(b) Sam thought that Henry did not know that Sam wanted to buy a Tax Disc. – 3 LEVELS OF EMBEDDING: 3 RECURSIVE
7. (a) When Sam got to Bold Street to buy his Tax Disc, he realised that he wouldn't be able to buy it because he had forgotten his MOT certificate.  
(b) When Sam got to Bold Street to buy his Tax Disc, he realised that he wouldn't be able to buy it because he had forgotten his insurance certificate.

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<sup>32</sup> The simple memory tasks, which Kinderman et al. distinguish from interdependency (ToM) tasks, are grayed out since they are of secondary importance to the present work.

## II. JOHN'S PROBLEM.

It was nearly the end of the day; John thought it might be nice to go to the pub for a drink after work. At first, he wasn't sure whom he should ask to go with him. He very much wanted to ask Sheila, whom he fancied, but he thought that she didn't like him enough to want to give up her aerobics class to go drinking with him. He could, of course, ask Pete, his usual drinking companion. Pete was always happy to spend an hour or two in the pub before going home. Then he happened to see Penny. He knew that Penny was one of Sheila's friends. Penny might be able to help him out. She would know whether Sheila would be willing to go out for a drink rather than go to her aerobics class. "Listen Penny," he said, "I thought I might go for a drink after work. I was going to ask you and Sheila if you wanted to come. Would you ask Sheila whether she would like to come for a drink with us?" Penny looked surprised. John had never asked her to go out with him before, but she thought that he was very keen on Sheila. She began to suspect that John wanted to find out whether she knew what Sheila might want to do.

II. John's Problem - Please tick the correct answer to each question:

1. (a) The story was set in the morning.  
(b) The story was set in the afternoon.
2. (a) John wanted to go home after work.  
(b) John wanted to go to the pub after work.
3. (a) After work, Sheila was going to an aerobics class.  
(b) After work, Sheila was going home.
4. (a) [John] thought [Sheila] would not like to go to the pub with [him]. – 3 LEVELS OF EMBEDDING: 3 RECURSIVE  
(b) [John] thought [Sheila] would like to go to the pub with [him]. – 3 LEVELS OF EMBEDDING: 3 RECURSIVE
5. (a) John and Pete often went for a drink together.  
(b) John and Pete only rarely went for a drink together.
6. (a) [John] thought that [Penny] knew what [Sheila] wanted to do. – 3 LEVELS OF EMBEDDING: 3 SEQUENTIAL  
(b) [John] thought that [Penny] did not know what [Sheila] wanted to do. – 3 LEVELS OF EMBEDDING: 3 SEQUENTIAL
7. (a) John's friend, Pete, occasionally went for a drink, but never after work, always going home.  
(b) John's friend, Pete, occasionally went for a drink in the evening, after work.
8. (a) [Penny] believed that [John] thought [she] would not know what [Sheila] would want to do. – 4 LEVELS OF EMBEDDING: 3 RECURSIVE & 1 SEQUENTIAL  
(b) [Penny] believed that [John] was hoping [she] would know what [Sheila] would want to do. – 4 LEVELS OF EMBEDDING: 3 RECURSIVE & 1 SEQUENTIAL
9. (a) John spoke to Penny, but neither Sheila or Pete, about going for a drink after work.  
(b) John spoke to Penny and Pete, but not Sheila, about going for a drink after work.
10. (a) [John] thought that [Penny] thought that [John] wanted [Penny] to find out what [Sheila] wanted to do *because*<sup>33</sup> [John] wanted to go out with [Sheila] alone. – 5 LEVELS OF EMBEDDING: 4 RECURSIVE & 1 SEQUENTIAL  
(b) [John] thought that [Penny] thought that [John] wanted [Penny] to find out what [Sheila] wanted to do *because* [John] wanted to go out with them both. – 5 LEVELS OF EMBEDDING: 4 RECURSIVE & 1 SEQUENTIAL
11. (a) Penny, the woman that John spoke to about asking Sheila about going for a drink after work, after he had thought of asking Pete, was a friend of Sheila's.

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<sup>33</sup> According to the definition of interdependency in the present work, *because* constitutes a break in interdependency since the clause that it applies to is interpreted independently of the clause which governs it.

(b) Penny, the woman that John spoke to about asking Sheila about going for a drink after work, after he had thought of asking Pete, did not know Sheila.

### III. EMMA'S DILEMMA.

Emma worked in a greengrocer's. She wanted to persuade her boss to give her an increase in wages. So she asked her friend Jenny, who was still at school, what she should say to the boss. "Tell him that the chemist near where you live wants you to work in his shop." Jenny suggested. "The boss won't want to lose you, so he will give you more money" she said. So when Emma went to see her boss, that is what she told him. Her boss thought that Emma might be telling a lie, so he said he would think about it. Later, he went to the chemist's shop near Emma's house and asked the chemist whether he had offered a job to Emma. The chemist said he hadn't offered Emma a job. The next day the boss told Emma that he wouldn't give her an increase in wages, and she could take the job at the chemist's instead.

### III. Emma's Dilemma.

Please tick the correct answer to each question:

1. (a) Emma worked for a greengrocer.  
(b) Emma worked in a chemist's.
2. (a) Emma wanted more money.  
(b) Emma wanted a different job.
3. (a) Emma's friend, Jenny, was still at school.  
(b) Emma's friend, Jenny, worked in a bank.
4. (a) Jenny thought the boss would believe Emma's story. – 3 LEVELS OF EMBEDDING: 3 SEQUENTIAL  
(b) Jenny knew the boss would not believe Emma's story. – 3 LEVELS OF EMBEDDING: 3 SEQUENTIAL
5. (a) Emma told her boss, the greengrocer, that she had been offered a job in a bank.  
(b) Emma told her boss, the greengrocer, that she had been offered a job in a chemist's.
6. (a) Emma thought the boss believed that the chemist wanted her to work for him. – 5 LEVELS OF EMBEDDING: 4 RECURSIVE & 1 SEQUENTIAL  
(b) Emma thought the boss knew that the chemist had not offered her a job. – 4 LEVELS OF EMBEDDING: 3 RECURSIVE & 1 SEQUENTIAL
7. (a) Emma's boss, the greengrocer, asked the chemist if he had offered Emma a job.  
(b) Emma's boss, the greengrocer, asked Jenny if Emma had been offered a job.
8. (a) Jenny thought that Emma hoped that the boss would believe that the chemist wanted Emma to work for him. – 6 LEVELS OF EMBEDDING: 4 RECURSIVE & 2 SEQUENTIAL  
(b) Jenny thought that Emma believed that the boss knew that the chemist did not want Emma to work for him. – 6 LEVELS OF EMBEDDING: 4 RECURSIVE & 2 SEQUENTIAL
9. (a) The chemist's shop, where Jenny had suggested that Emma tell her boss that she had been offered a job, was near where Emma lived.  
(b) The chemist's shop, where Jenny had suggested that Emma tell her boss that she had been offered a job, was in a different town.

#### IV. SIMON.

Simon was 19 years old and worked as a mechanic. His cousin, Jim, was quite a lot older, and worked as a milkman. Because he got up early in the morning, he seldom went out in the evening. Jim's friend, Edward, worked in a bank, and therefore had more opportunity to go out in the evenings. Simon knew that Jim wanted to marry Susan. Simon also knew that Jim believed that Susan wanted to marry Edward. So he thought that if he could convince Jim that Susan thought that Edward wanted to marry Betty, Jim might be persuaded that Susan would say "Yes" if he asked her to marry him.

#### IV. Simon Thinks.

Please tick the correct answer to each question:

1. (a) Simon worked as a mechanic.  
(b) Simon worked in a greengrocers.
2. (a) Jim wanted to marry Susan.  
(b) Jim did not want to marry Susan.
3. (a) Jim's friend, Edward, worked in a bank.  
(b) Jim's friend, Edward, worked as a mechanic.
4. (a) [Simon] believed that [Jim] was convinced that [Susan] would not marry [him]. – 4 LEVELS OF EMBEDDING: 3 RECURSIVE & 1 SEQUENTIAL  
(b) [Simon] thought that [Jim] thought that [Susan] would marry [him]. – 4 LEVELS OF EMBEDDING: 3 RECURSIVE & 1 SEQUENTIAL
5. (a) Simon, who was 19 years old, was Jim's cousin.  
(b) Simon, who was 19 years old, was Jim's brother.
6. (a) [Jim] believed that [Susan] thought that [Edward] would like to marry [Betty]. – 4 LEVELS OF EMBEDDING: 4 SEQUENTIAL  
(b) [Jim] thought that [Susan] knew that [Edward] did not want to marry [Betty]. – 4 LEVELS OF EMBEDDING: 4 SEQUENTIAL
7. (a) Because Jim worked as a milkman, and Edward worked in a bank, neither went out very often.  
(b) Because Jim worked as a milkman, but Edward worked in a bank, Edward went out more often than Jim.
8. (a) [Simon] hoped that [Jim] would believe that [Susan] thought that [Edward] wanted to marry [Betty]. – 5 LEVELS OF EMBEDDING: 5 SEQUENTIAL  
(b) [Simon] thought that [Jim] would believe that [Susan] thought that [Edward] did not want to marry [Betty]. – 5 LEVELS OF EMBEDDING: 5 SEQUENTIAL
9. (a) Edward's friend, Jim, who was Simon's cousin, was older than Simon, who was 19.  
(b) Edward's friend, Jim, who was Simon's cousin, was younger than Simon, who was 19.

## V. A MACABRE TALE.

It was late and the old man felt sleepy. Still, he thought, he would have one last cigarette before going to bed. He lit up and puffed quietly in the half light as he watched the flickering screen of the TV. It wasn't long before he fell asleep in the chair. The cigarette he was holding fell down the side of his chair. There it smouldered until the material caught light. This in turn set fire to the foam padding. As the foam burned, it gave off poisonous fumes, which killed the old man. When the police discovered the tragedy in the morning, they called the fire-brigade fire investigation team. They found that the fire had spread to the carpet and its rubber underlay, which had burned fiercely. Examining the scene, they quickly realized where the fire had started, and what had killed the old man.

V. A Macabre Tale.

Please tick the correct answer to each question:



1. (a) The old man fell asleep in his chair.  
(b) The old man fell asleep in bed.
2. (a) The fumes from the foam padding killed the old man.  
(b) The fumes from the material of the chair killed the old man.
3. (a) When the old man fell asleep, his cigarette fell into his lap and burned a hole in his trousers.  
(b) When the old man fell asleep, his cigarette fell down the side of the chair and set light to the material.
4. (a) When the old man fell asleep, his cigarette fell down the side of the chair and set light to the material. The foam in the chair gave off poisonous fumes which killed him.  
(b) When the old man fell asleep, his cigarette fell onto the floor. It set light to the rubber underlay of the carpet which gave off poisonous fumes that killed him.

## INDEX

### Symbols and Abbreviations

I follow the abbreviations and symbols of Croft (2003) with the following

exceptions:

- Morpheme boundary—based on Huddleston & Pullum (2002). Where clitics are distinguished from affixes, a larger raised dot [ • ] is used for clitics while a smaller one [ · ] is used for affixes.
-  Emphasis
-  Intended meaning (albeit without successful realization)
- Templatic slot with the potential to accommodate an infixed element, alternatively a box is used—see above.
- | No specific order
- ♀ Feminine-Gender Marking
- ♂ Masculine-Gender Marking
- ⚥ Neuter-Gender Marking

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