Pragmatic Information

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Abstract

The goal of this paper is to define *pragmatic information* with a view toward measuring it. Here, *pragmatic information* means the content of valid signs — the key that unlocks language acquisition by babies and to human communication through language — also the content that enables biological "codes" in genetics, embryology, and immunology to work. In such systems, the inter-related layers appear to be ranked as in a hierarchy. Sounds are outranked by syllables, in turn outranked by words, and so on. In DNA, nucleotide pairs are outranked by codons, which are outranked by genes, and so on. As signs of lower rank combine to form signs of any higher rank, combinatorial "explosions" occur. With each increase in rank, the number of possible combinations grows exponentially, but the constraints on valid strings and, thus, their pragmatic value, sharpens their focus. As a result with each explosive increase in the number of possible combinations the relative proportion of meaningful ones diminishes. Consequently, random processes of forming strings or changing them must tend increasingly toward meaninglessness (invalid and nonviable) strings. The consequent outcome of random mutations is mortality of individuals and in deep time an increasing number of disorders, diseases, and the eventual extinction of populations.

Key words: communication disorders, combinatorial explosion, pragmatic information, child language acquisition, biomolecular cryptology, pragmatic mapping, true narrative representations

Introduction

To show that sign systems are ranked and layered, consider that this is obviously true of the highest cortical functions of human beings. Layering and ranking can be demonstrated easily for our brains and are also found in biological systems. Combinatorial explosions occur as signs of lower rank are combined to form signs and strings of the next higher level up. As the complexity and number of possible strings increases along with the constraints on valid sequences at each higher level, the likelihood of generating them by random processes diminishes toward a vanishing point. As a result, random mutations (or injuries) in sign systems tend to produce disorders, genetic diseases, death, and, eventually, the extinction of populations. In this paper, I limit myself to explaining what pragmatic information is and how it increases with each combinatorial explosion in child language development and in genetic systems. The larger goal is to work toward an empirical measure of pragmatic information in the future.

Ranking in Sign Systems

At the Cornell symposium, since my starting time was an hour after lunch, to get the blood flowing and to give folks a chance to make it to our next coffee break, I asked the audience please to stand. I asked them to perform a few simple movements: a right handed thumbs up; then, a left; then, with both hands. I demonstrated and the audience followed along. Next, we wrote our names in bold strokes in the air with the dominant hand. I demonstrated writing "John" with my right hand. Then, we tried it with both hands. First, we allowed the subordinate hand, the left for most of us, to write the mirror image; then, using both hands in parallel, we wrote our respective names simultaneously with both hands. The reader may easily repeat the experiment and show that it is possible to do something with the subordinate hand that hardly anyone, apart from this sort of experiment, can do with the subordinate hand. For instance, I cannot fluently write the mirror image of my name with my left hand. However, when the subordinate hemisphere of the brain is slaved to the dominant linguistic hemisphere, the subordinate hand can easily do something it has never practiced — fluently writing the mirror image of a sequence of letters. How is this possible?

The actions just described provide a pragmatic (active and dynamic, real) demonstration of the ranking and layering of biocontrol systems at the highest cortical level in human beings. The ranking is shown in the exercises just described in three ways: For one, each compliant member of the audience subordinated himself or herself, to the whole group as led by the speaker. They subordinated their actions to my words. For another evidence of ranking, the speaker, in turn, subordinated himself to the organizers of the conference. The object of all this subordination was to make the ranking of biocontrol systems, combinatory explosions, and their consequences for pragmatic information, as intelligible, relevant, and memorable as possible to the participants at the symposium. For yet another, the slaving of the subordinate hand and the subordinate "mute" hemisphere of the brain to the dominant "talking" hemisphere of the brain — in the parallel and mirror-image writing by the subordinate hemisphere — also shows that linguistic signs at the highest cortical level are dominant.

Every person who performed the requested actions demonstrated the ranking summed up in Figure 1. In that diagram, let S represent the conventional signs (the words) of any natural language; let π represent acts of mapping those signs onto

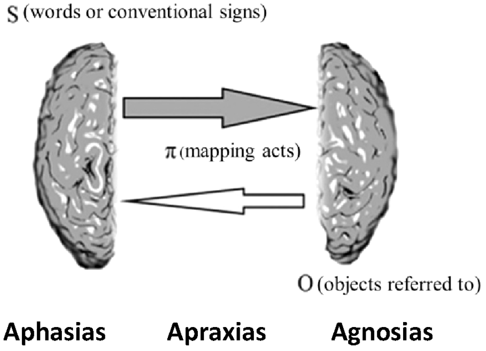

Fig. 1. Pragmatic mapping in the brain.

whatever they are about; and let O represent the logical object(s) referred to. The O may consist of an event or sequence — say, writing the mirror image of a name, or, attending the Cornell symposium, or the exchanges and acts leading to this paper, or the book in which it appears, or the whole network of connections through its cited references.

Keeping in mind that the motor and sensory functions of each side of the body are mapped to the opposite hemisphere in the brain, the physical acts of the exercises, show that the symbolic (word producing and arranging) hemisphere is dominant. It can take nearly complete control of the subordinate hemisphere. The dominant system can "slave" the subordinate one. In between the hemispheres is the corpus callosum (190 million fibers connecting them) — not shown in Figure 1, but implied in the arrows between the hemispheres. Interestingly, random mutations (by disease or accident) or selective ones (by surgery) of the brain often result in disorders. If they impact the dominant hemisphere they commonly produce disorders of language, *aphasias*; damage to the subordinate hemisphere generally results in disorders of recognition, holistic knowledge, and feelings about things, persons, and events, *agnosias*; and damage to the corpus callosum disrupts knowledge and control of action sequences which yields *apraxias*.

The simplest of the valid representations produced when all of our faculties are working well and when we merely report faithfully on actual experience are true narrative representations (TNRs). For instance, if I say truthfully, "I had lunch with Berkley Gryder, Robert Carter, and John K. Park on the second day of the Cornell symposium," I illustrate the sort of valid pragmatic mapping that is required in order to explain pragmatic information. A simpler instance of such a valid mapping can be found in a proper name applied correctly to the person who goes by that name. Analogous to the macro-cortical level seen in Figure 1, in Figure 2 — at a much more focused level — the name can be construed as a

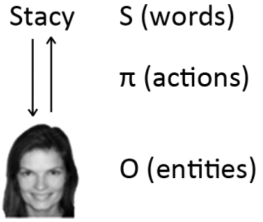

Fig. 2. Naming as a pragmatic mapping of S through π onto O.

symbol, S; the person named as its logical object, O; and the mapping of the name to the person named as an action, π. If the name is applied to the person who actually goes by that name, this sort of mapping captures the essence of all TNRs. It expresses their common form in a simplest instance. The action in validly referring to some logical object as shown in Figure 2, sums up the sort of things we do in giving any valid report. Consider my statement mentioning the persons with whom I had lunch on the second day of the symposium. Biological examples of such valid acts of reference would include complex mappings such as the recognition (or production) of the major histocompatibility complex (MHC) on the surface of a bodily cell enabling the body's own immune systems to identify the marked cell as one of its own — that is, as "self" as contrasted with a "non-self" cell or some foreign entity to be attacked, killed, and dismantled, or merely to be transported to a detention center for interrogation and further identification before it is taken apart piece by piece [1]. The SπO relation of Figure 2 would also include something as simple as the correct rendering of a UUU codon in a gene into the amino acid phenylalanine in a corresponding protein sequence. These and countless other examples, are special instances of the general SπO relation.

In natural human languages (as suggested by Figure 2), the mapping from S to O shows linguistic comprehension while mapping from O to S, shows linguistic production. What may not be so obvious, but must be taken into account, is that the name, or any referring sequence of symbols, S, is inherently abstract and general with respect to its generalized *semantic meaning*, but it is both arbitrary and conventional with respect to its surface form (its sounds, syllables, and syntax — that is the spatio-temporal arrangement of its components). By contrast the logical object O of the S in an ordinary naming relation, for instance, is concrete, particular, and actual. We may say that the *pragmatic meaning* of the S is materially instantiated in its particular logical object, O. In the case of ordinary proper names, we may say that the O involves a unique identity — as it also evidently does in the case of any MHC in the cells of a given individual. Abstracting from all of this, by the term *pragmatic information* I mean the useful content of TNRs, that is, reports or narrative-like representations that involve valid SπO relations.

The pragmatic mapping process, illustrated in naming, is considerably more complex than it might seem on the surface, and, as argued in a series of papers and books elsewhere [2–6], it forms the foundation for valid referring relations — which are invariably embedded in true narrative representations (TNRs). Valid referring relations, SπO, and all TNRs are true in the ordinary sense of "truth" because they conform to the normal conventional applications of their signs, S; they are narratives in all cases because it is impossible to refer to any particular material entity whatsoever apart from some context of experience that involves events unfolding over time; and they are representations because the S in each case invariably stands for something other than itself. It has been argued that TNRs are crucial to the discovery of pragmatic information in sign systems in general [7–9]. Because our world is so pervaded by valid SπO representations from the highest cortical processes downward, their very familiarity makes the pragmatic mapping of a name onto a certain person seem much simpler than it is. Also, many philosophers have been lured into the false notion that names (or referring terms) are non-essential elements on account of the ubiquitous fact that not all signs are names; added to the fact that fictional, erroneous, and deliberately deceptive uses along with nonsensical ones are also possible. A few lines from Shakespeare serve to remind us of the tendency to regard some exceedingly complex relations as simple:

> But man, proud man,
> Drest in a little brief authority,
> Most ignorant of what he's most assured,
> His glassy essence, like an angry ape,
> Plays such fantastic tricks before high heaven
> As make the angels weep [10].

Tampering with the Sign Architecture

Among the "tricks" done on human beings that have certainly made some humans weep are "split-brain" surgeries where the corpus callosum — the bundle of about 190 million fibers [11] enabling the left hemisphere to communicate with the right and vice versa — was cut on the theory that doing so would prevent the spreading of an epileptic event between the hemispheres. The justification has been the claim that in a substantial majority of surviving patients the surgery would prevent full blown life-threatening seizures. Such surgeries and other sources of disease and injury to the brain demonstrate the foundational division of labor, and the ranking of major classes of signs, in the highest cortical functions of human beings as summed up in Figure 1 above. In fact, at Glenn Fulcher's web site on language testing, I have explained the pragmatic mapping process and there I illustrate it with video clips some of which were also presented at the Cornell symposium [12].

At the language testing site, thanks to Fulcher and the BBC in sharing materials from the educational series entitled "The Brain: A Secret History" [12], it is possible to see an extreme instance of what is known as *alien hand syndrome* in which the normal controlling role of the dominant hemisphere is disrupted by severing of the corpus callosum. The alien hand result offers straightforward evidence both of the normal ranking of sign systems in the human brain (as described above in Figures 1 and 2) and also of the fact that things can go very wrong when the normal ranking is disrupted by surgery, disease, or mutation.

After her surgery, Karen Burns discovered to everyone's dismay that her left hand (under the control of her subordinate, right hemisphere) suddenly had a mind of its own, producing a strange conflict with her right hand (under the control of her dominant, left hemisphere). After the surgery, her left hand would disconnect the phone by depressing the "clicker" just after she answered a call with her right hand. Her left hand would put out the cigarette she had just lit with her right hand. Her left hand would unbutton her blouse while her right was trying to button it again. After her surgery, when Karen began to regain consciousness, the attending personnel in recovery, immediately called for the doctor. The neurosurgeon arrived minutes later and found Karen's left hand beating her face black and blue. He asked her to give him a thumbs up. She did so with her right hand but her left hand was unresponsive to the linguistic request. Karen's difficulty was focused specifically in the inability of the dominant hemisphere to take charge of the subordinate hemisphere through the corpus callosum. Karen would have been unable to slave her subordinate hemisphere to perform the mirror writing that the audience at Cornell was able to do easily as described earlier in this paper.

At the symposium, I also gave an example of aphasia owing to damage to the left hemisphere of trilingual Julia Sedera. The relevant video clip can also be found in my feature presentation on the Fulcher site [12]. Julia's injury was owed to a stroke leaving her with a surprising inability to name an object, such as a "pineapple," for instance, though she knew well what the object was (via her relatively intact right hemisphere). Even when the neurologist modeled the first syllable of the word "pineapple" Julia was still unable to say the word.

Looking to the subordinate hemisphere that specializes in handling whole scenes, entities, faces, and in generating the feelings that are ordinarily associated with a sequence of events — the famed psychiatrist and author, Oliver Sacks, describes his special agnosia. He has prosopagnosia — difficulty recognizing faces and places — even his own face or the house where he lives. In the video clip of Sacks [12], he describes how he is apt to mistake an image of himself in a mirror or plate glass window for someone else. Or, when seeing a large bearded man on the opposite side of a window, the reverse has also occurred, where he finds himself preening what he takes for his own reflection only to discover that the bearded man on the other side of the glass is not preening his beard, but is looking rather strangely at Dr. Sacks.

In studies of split-brain patients that won him a Nobel Prize in 1981, neurologist Roger Sperry wrote: “The [dominant] speaking hemisphere in these patients could tell us directly in its own words that it knew nothing of the inner experience involved in test performances correctly carried out by the [subordinate] mute partner hemisphere” [13]. Again, there is video footage from Sperry’s studies of such split-brain patients [12]. The relevant video clip reveals that split-brain patients can produce and comprehend language with the dominant hemisphere but are unable to do so with the subordinate hemisphere. Similarly, the subordinate hemisphere can reconstruct a pattern with blocks while the dominant hemisphere makes a hash of the same task.

Not only does the subordinate hemisphere excel at handling holistic scenes, patterns, and images, but it is also evidently in charge of producing feelings about whole patterns and sequences of events. In the BBC footage, a man named Dave, who lost a significant portion of the frontal lobe of his right hemisphere when a tumor was removed, also lost the ability to generate feelings toward the persons and events of his own experience. His wife commented that after the surgery he was not the same. Beforehand he used to do “nice things” to make her feel more comfortable, but afterward, he was no longer able to have normal feelings. They were divorced but she still takes him to his neurological appointments. Dave himself describes how he can remember feelings but no longer generates them. At the end of his post-surgery narrative he says in a near monotone, “The longer I go basing what I should feel on memory, I’m kinda nervous that eventually the memory will fade and then trying to remember what the actual emotion felt like will be more mysterious. At least now I have the memory so I can at least go through life with that understanding. . . if I didn’t have that memory, I . . . I guess it would be a lonely . . . lonely existence” [12].

In another segment, Dr. Michael Mosely, who narrates the BBC series [14], talks through his own experience in confronting his fear of being closed in. He does so by going down into a very dark and small cave. Before starting out he is equipped with gloves to stop him from “ripping his fingernails off” if and when he gets stuck and panics. On seeing the entrance to the cave he sighs, “Gosh, well, that’s small, isn’t it. I was imagining something large,” and then he sighs loudly, “Haaaahhhh!” Later, in the video clip [12], he gets stuck in a passageway with one arm pinned beneath him in a prone position. He is barely able to move enough to breathe and the fear momentarily takes over.

Undoubtedly, it is Mosely's right hemisphere (and that of anyone who empathizes with him) that generates the feeling associated with the whole sequence of events leading up to and including Mosely's predicament in the cave. The feeling remains intense for him (and for me as a viewer) even after he is extricated by somehow wriggling out or being helped out of the tight spot by the BBC camera crew. The video does not show how he gets out, only him gasping head in hands afterward, still in the cave saying, "That was bloody awful." Presumably, he would scarcely have put himself in such a situation if it were not for a linguistically guided decision — a dominant hemisphere commitment — to enter the cave despite his fear. Clearly the dominant hemisphere can over-rule the protesting subordinate hemisphere. Would he experience the same sort of fear if he had the sort of brain injury that Dave experienced to his subordinate hemisphere? Probably not. Could Mosely have the same fear if he were anesthetized and then placed in exactly the same posture in the narrow passageway? Again, probably not, as the pragmatic information about the sequence of events would be unavailable to him. But the point is, in ordinary conscious experience, there is a division of labor involving a ranking of the highest sign systems of human cortical functions. Even something as overwhelming as near complete terror (a subordinate hemisphere function) can be dominated by the rational power of the linguistic, speaking hemisphere.

Next, it is useful to note that the ranking of distinct layers of sign systems just demonstrated for the highest cortical functions can also be found in biocontrol systems right down to the molecular levels of DNA, RNA, and proteins. Figure 3

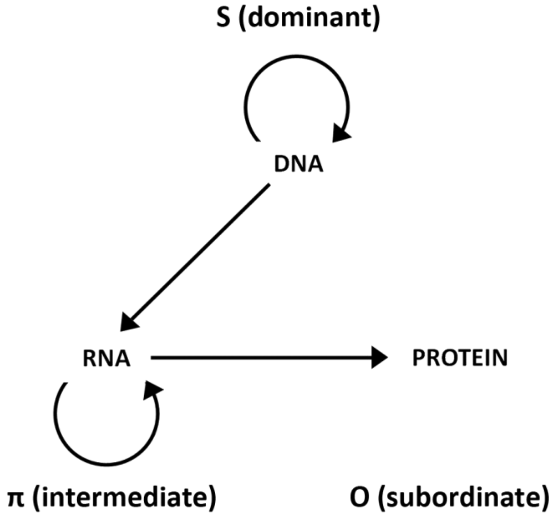

Fig. 3. Crick's dogma and the ranking of biological signs.

shows how Francis Crick's famous dogma [15,16] — though we now know it needs modification to take account of epigenetic interactions between RNAs and DNA (and no doubt other interactions beyond these) — reflected the same sort of ranking of genetic sign systems as we have seen in the highest human cortical functions (Figure 1) and in the linguistic process of pragmatic mapping as summed up in the naming relation (Figure 2). Although Crick's dogma is still defended as standard doctrine in many current biology texts, the interactions between the named systems are more complex, more constrained, and more deeply layered than the dogma suggested. Nevertheless, the point here is merely that the valid ranking proposed in Crick's dogma is consistent with that in the human neuro-architecture and in pragmatic mapping in general.

Pragmatic Mapping

Weinberger (2002) defined pragmatic information as the likelihood that a given message will change another person's conduct [17]. While the measure proposed by Weinberger may be relevant and suggestive, I am aiming for a more general definition of pragmatic information on which all meaningful sign systems depend for their representational power as displayed in the process known as *pragmatic mapping* [2]. Such an approach suggests the question of how pragmatic information enriches the capacity for representation in general — that is, in any representational system. I want to characterize the sort of pragmatic information that seems to be crucial not only to language acquisition, ordinary linguistic communication, and valid reasoning, but also to the biocontrol systems involved in genetics, metabolism, embryological development, immune defenses, and so on. A more recent paper (Gatherer, 2007) reported on the ongoing search for an algorithm to discover what he and others believe will turn out to be the discrete words and phrases, the meaningful/functional strings, in protein texts [18].

Gatherer points out that molecular biologists have commonly compared "genomes . . . to libraries of genetic information, with each chromosome as a book, genes as chapters, and DNA bases as the letters in which the text is written" (p. 101). With this linguistic metaphor in mind, Gatherer and others have suggested that discovering meaningful sequences in biological texts is like cryptology — with geneticists working as "biomolecular cryptologists" [19, 20] — like Jean-François Champollion seeking out the sounds, words, and meanings of Egyptian hieroglyphics [21]. In biology the units would be "nucleotides, codons, motifs, domains, exons, genes, genomes, etc... up to cells and organisms" (John Sanford, personal communication). The purpose of genetic cryptology, according to Gatherer's approach, is to devise an algorithmic discovery procedure to find the meaningful strings embedded, presumably, in the protein languages of various organisms. To test several options and combinations of rules, Gatherer tried them out not only on the deciphered proteins — the "proteomes" of various organisms — but also on various linguistic texts of which the shortest was *Alice in Wonderland*. In that text, his system found 85% of the 2,593 distinct words in the 26,587 word text.

With the cryptology metaphor in mind — as well as Shakespeare's lines about "proud man" and our "glassy essence" — a different metaphor for the difficult problem of deciphering biological language systems can be suggested. Perhaps molecular biologists could learn from normal babies acquiring any one, two, or even three at a time [22] of the 6,909 languages of the world [23]. Babies can solve them all, and as is becoming increasingly evident, biologists also, evidently, have a lot of distinct layers of language systems to decipher. In addition to the DNA codons corresponding to the amino acids of proteins, there are, of course, the RNA intermediaries and there is the protein language itself. In addition there are the partially understood "12 Trifonov codes" [24] and the codes for nucleosome building sites, cohesin protein binding, RNA transcription, splicing, RNA binding/folding, pyknons, isochores, and three dimensional nuclear architecture. According to remarks by Sanford on the paper by Montañez *et al.* (this volume [25]) there may also be codes involving triplex and quadruplex strands of DNA as well as electromagnetic coding, tandem repeat codes, and perhaps even vibrational codes as discussed by Dent (this volume [26]). Also relevant here is the paper by Dembski *et al.* (this volume [27]).

Building on the cryptology metaphor, I would like to propose that the manner in which babies solve natural language systems of the world may be relevant. If normal human babies can solve for the meanings of any unknown natural language, perhaps intelligent adults can figure out how they do it so that linguists, geneticists, and "biomolecular cryptologists" can learn why some discovery procedures for deciphering unknown languages can work where others will not. A clue concerning what advances in child language studies are teaching us about how infants decipher an unknown language can be found in Gatherer's results in trying to identify algorithmically all the meaningful words in *Alice in Wonderland*. Keeping in mind the deceptively simple $S\pi O$ relation — one exemplified in every valid use of a name or referring term — the clue I have in mind is suggested in these questions: (1) What is the most important entity referred to in the *Alice in Wonderland* text? (2) What referring terms (meaningful words) in the text refer specifically to that entity? (3) Of the 2,953 different words in the 26,587 word text, what consistent referring term occurs most frequently? What term is critical to making the story hang together? What gives the fiction its sense of continuity? Or, to connect back to the cryptology problem of Champollion, what word was crucial to his solving of the hieroglyphics in the Rosetta stone? Similarly, bearing in mind the known and suspected “codes” remaining to be deciphered in molecular biology, when Watson and Crick were solving the “genetic code” — or, at least, the part which is perhaps best understood even today — what codon of DNA were they first able to solve?

The answers to all of the questions just posed involve at their foundation the simplest sort of SπO relation. The key to unlock the door to the amazing realms within each distinct language system is to find a referring term that connects regularly and consistently to the same logical object — the same already known entity. At the symposium I asked participants, “What is the most important entity in this auditorium?” My answer was to point to them and say, “You, and you, and you.” The human participants known mainly by their names, were and remain, the most important entities at that symposium, hands down. For the normal human infant, as for the molecular biologist, the most important known entities are the named bodily objects — for the infant, the persons, organisms, places, things and so forth; and for the biologist, the differentiated cells, tissues, organs, and bodies — that populate the world of experience. As Augustine pointed out in about 401 AD, children discover the meaningful words, phrases, etc., of a language by attending to entities pointed out to them by adults [28]. They seem to assign priority to entities that talk and prefer talk directed at infants over adults [29].

For *Alice in Wonderland*, unsurprisingly the main character, and the most important entity, is Alice. Was the fictional Alice a creation based on the real person named Alice Liddell, or, was she a fictional composite of young girls Charles Lutwidge Dodgson alias Lewis Carroll photographed, sketched, and so forth? That unsettling question aside, Gatherer’s exhaustive count of words in the text shows that the most frequent referring terms are “she” (occurring 541 times), “I” (410 times), and “Alice” (386). Taking into account that the pronominals “she” and “I” commonly also refer to Alice, it is clear that the most common SπO relation in the whole text involves Alice as referred to by the pronouns “she” or “I” or by the name “Alice.”

Similarly, the decipherment of the Egyptian hieroglyphics by Champollion hinged on the discovery of the name “Cleopatra” from which he was able to discover by further analysis that the pictographic symbols were functionally alphabetic — letters representing sounds rather than pictures representing things. In deciphering the “genetic code” a critical SπO relation, as noted above, was found in the mapping of the DNA uracil triplet onto phenylalanine. Likewise, the “first words” produced by almost any normal child, by about the age of 12 months, are referring terms again of the familiar shape, SπO. The discovery of the meaning of the S — which is at first an unknown conventional sign — hinges on the child’s noticing the π-mapping of the S onto a familiar logical object, O. For instance, the normal child is apt to discover very early on that the word “mama” maps to the child's own mother. Thus, the normal child's "first words" often consist of "mama" or "dada" or the name of a person or pet, a salient experience — such as "hot" associated with getting burned or "no" with a slap on the hand — or even a complex sequence of events such as the marking of frequent leave-takings by someone valued by the child marked with "bye-bye" and waving of the hand.

The Vanishing Ratio of Meaningful to Random Strings

A fundamental fact easily overlooked is that valid referring expressions, all of which take the form SπO, provide the basis for what child language specialists refer to as the "vocabulary explosion" which necessarily occurs after the child's first word is uttered and which usually begins before the second birthday [30]. After the vocabulary "explosion" of distinct one-word representations, at about the age of two years, the normal child smoothly transitions to a series of advances resulting in a corresponding series of additional "combinatory explosions." Derek Gatherer [18] points to such an "explosion" in going from the "the 4-letter code in DNA" as contrasted with the "20-letter code in proteins" (p. 102).

Gatherer's point is that the number of possible strings increases with the number of elements that can be combined. Both linguistic and biological combinatory explosions can be described roughly in terms of an iterative series of steps in which the number, N, of possible strings at each step having a given length, l, is equal to the size of the vocabulary, v — the number of elements to be combined — raised to the l^{th} power, or $N = v^l$. This equation, if taken as a snapshot of any step in the series, oversimplifies and underestimates the actual number of strings that are possible for several reasons: (1) no fixed upper limit on length can be set on higher strings, say, of words, phrases, sentences, and so on; (2) as soon as we reach the level of words, and higher levels, the vocabularies are also subject to indefinite expansion; (3) additionally, the equation underestimates the total number of possible strings because it does not count strings shorter than l nor strings longer than l — both of which would have to be taken into account in a complete theory. However, we can safely set these complexities aside because incorporating them into a definition of pragmatic information would only strengthen the outcomes for natural languages and biological codes to be noted in what follows.

But, there is an additional linguistic complexity that drastically changes the dynamic of the problem faced by theoreticians trying to figure out how to generate meaningful linguistic or biological strings. The difficulty is that at the same time as the number of strings that are possible at any given level of a language (or any of the partially understood biological codes) are exploding to a growing multitude of increasingly greater multitudes, and as the length of allowable strings is increasing from word to phrase to sentence to paragraph, chapter, book, series, and so on, the constraints restricting the range of valid constructions (or meaningful continuations) in a given string are converging toward a theoretical limit of unity. Practically speaking, it is the sort of unity exemplified when folks at the Cornell symposium, for example, understood and followed the directions in the opening exercises.

To illustrate combinatorial explosions we may apply the simplified equation, $N = v^l$, to the sounds of English estimated at approximately 35 for General American English (24 distinct consonants and 11 vowels), and setting a limit of syllable length at that of the monosyllabic word "strengths" consisting of the 8 segments transcribed in the International Phonetic Alphabet as [stɹɛŋkθs] gives a possible number of 35^8 or approximately 2.25 trillion combinations (2.25×10^{12} or 2,251,875,390,625 to be exact). Of those strings, only a few thousand (estimated at about 3,000 to 4,000) are syllables actually allowed by English phonology. As a result, even if we suppose 10,000 of the possible combinations are valid syllables in English, this would mean that fewer than 1 string per $10^7$of the possible strings would be a valid syllable in English. Jumping over the levels of words and phrases and advancing to sentences, given that the *Oxford English Dictionary* lists approximately 600,000 words, even if we restrict the number of words in a sentence to 12, the number of strings of that length would be $600{,}000^{12}$ or 2.177×10^{69}. However, only a relatively small proportion of that number would form meaningful sentences of 12 words in length. Because of grammatical constraints only a tiny fraction of the strings in such a vast list would be meaningful, and if we restricted the list to just TNRs, the ratio would become vanishingly small.

George A. Miller estimated on the basis of empirical studies of English texts that about 10 words on the average can form an appropriate continuation at any given point in any meaningful English text [31]. Using his estimate, the number of meaningful 12 word sentences, would be about on the order of 10^{12} enabling us to estimate that the ratio of meaningful 12 word sentences in English to all the strings that could be formed from all the words in the *OED*: it comes out to be about $4.59\text{x}10^{-58}$. Finding the few meaningful strings by chance in a heap of such nonsense would be a little like trying to find some very tiny needles in a really huge haystack (a serious problem as pointed out by Dembski *et al.* this volume [27]). Consider next that if we move the combinatorial explosions up several notches to the length of a short novel, say, 30,000 words (rounding up from the length of *Alice in Wonderland*), the number of possible strings explodes to $600{,}000^{30{,}000}$ as contrasted with — again, using Miller's method of estimating the number of meaningful texts of that length — about $10^{30{,}000}$. At the level of a short novel, the ratio of meaningful strings to possible ones has diminished to a complete vanishing point for all practical purposes. Not only is there no random process that could generate one of the desired strings, neither is there any possible way to list them, much less to search through the list. The difficulty is that if each possible text could be written on something as small as an electron, the writer would run out of places to write before a measurable fraction of the task could be completed.

The Logical Sequence for Discovering Meaning

So, the question remains, how do all normal human infants routinely solve problems of such great magnitude? Normal child language development follows a strict sequence of logical steps [32]. From birth forward babies are solving for the O of SπO relations. Perhaps the most primitive solution of that type is the newborn's mapping of mom's familiar voice to her moving face as she talks. From prior experience in the womb mom's voice is a familiar vocal sign, S, and the O that moves when mom talks to the baby is marked by just that particular voice which is π-mapped onto the moving face, O. In fact, the auditory movements in the normal baby's ear are quite perfectly coordinated with the modulation of mom's voice just as movements right down to the molecular level in the baby's eyes are coordinated with movements in mom's face. These near perfect correlations converge in the understanding that the voice is coming from mom [33].

The normal baby, while paying special attention to entities that talk, also works diligently in finding the boundaries of many objects of experience. By about three months, the baby will be seen to extend the index finger as if having already understood that such a gesture is used to single out things for attention [34]. After solving a substantial repertoire of Os, the baby begins to solve π-mappings that involve significant bodily movements that accompany speech. By about 4.5 months the baby typically demonstrates interest in an often repeated S which is distinct from others — such as the baby's own name, for instance — by looking toward the adult who says it [30]. A month or two later, the baby typically begins to produce repetitive babbling, /bababa/ or /mamama/ and so on, followed by differentiated syllables, /aǰadaǰaba/ and the like [35]. By about month 6 or 7, the baby will typically display comprehension of distinct SπO mappings by looking toward or handing over an object asked for by an adult. However, it will usually take 5 or 6 more months for the child to achieve sufficient motor control of the articulators to be able to produce his or her own "first word."

If the child is learning English, for instance, adults who already know the language will be able to understand that "first word" according to the conventions of the language in use. For instance, if the child's first word is the name of the household pet (as it was for my son Stephen D. Oller), say a dog that answers to the name of "Chester," consider the constraints that must be met in order for adults to share a common understanding with the child. If the phonological target is "Chester" — phonemically /čɛstɹ/ — the utterance of it must be close enough to be recognized as that word and no other. The standard of comprehension is a convergence to the limit of unity — approximating the extreme limit of "absolute certainty" suggested by Weinberger [17]. That is, all the parties concerned think they understand and know what the child is talking about. They are so sure of this that they would consider it odd to question their belief. But the convergence and the agreement achieved is remarkable.

Considering how large the possible set of strings of that length must be — estimated at 35^5 — the target in question occupies a tiny position in a large field. It is a particular string among 52,521,875 possible strings of the 35 phonemes of English. Assisting the adult interpreter(s) in correctly understanding the S and its O is, in many instances, the bodily dog that answers to the name "Chester," the logical object itself. That is, the syntactic tree (in the shape of Figure 2 above) that π-maps the name, S, to the entity, O, assists interlocutors to achieve common understanding. They look where the child is looking, pointing, and so on. Nevertheless, considering the number of potential objects, O, that might be referred to on any given occasion, or the number of babbled strings that might be uttered naming nothing in particular, the discovery of an intended referent, a dead center hit, is much more difficult to explain than a miss.

But the correct result will subsequently be confirmed again and again as the same unity is attained repeatedly not only with the word "Chester" but as the vocabulary explosion kicks in, it will be confirmed thousands of times over with a growing repertoire of more than 50 meaningful one-word utterances. After that a series of much greater combinatorial explosions will occur as the child — now about 2 years old — progresses through the two-word stage and beyond. The key to the combinatorial progress as one of my former PhD students, Ibrahim Al-Fallay, referred to it obliquely, is the child' ability to "climb the syntactic tree." He explained why another student dropped out, "Because," Ibrahim said in his Arabic accent, "He couldn't climb the syntactic tree." So, how is it that normal 2 year olds are able to do it? The answer reveals a severe (absolute) pragmatic constraint on the syntax of abstract predicates. There must be a syntactic tree to climb. Valid signs require objects.

Plainly a name, number, or referring term, that might apply to everything, anything, or nothing at all, has no power to inform us of anything other than itself. It may be a babbled sequence of sounds or syllables, or a random cipher pulled out of the air — an S without any determinate mapping to any O. Even less informative would be something without any consistently noticeable surface form at all. It cannot qualify as an S, or any particular form of nonsense, because it has no formal resemblance to any S. If we cannot recognize the sign itself as distinct from other signs and as a particular form on different occasions, how will we be able to associate it with any language, much less with any content? Although some philosophers have claimed that predicates grounded in referring terms cannot possibly account for abstractions such as love, justice, prime numbers, matrix algebra, etc., all such arguments fail when we see how infants easily climb the syntactic tree to solve abstractions. Invariably they start with referential entities that are well-grounded in valid SπO relations.

Consider the fact that discovering the meaning of a verb such as "bark" in the sentence, "Chester is barking," is materially assisted by the barking of the dog. The action contrasts with the state of affairs when the dog is not barking, or is jumping, running, chasing his tail, or the cat, crossing the road, dreaming about chasing the cat, etc. In his "Logic of relatives" — actually the "logic of relations" generalizing the Boolean algebra from binary to all possible relations — C. S. Peirce claimed as one of his first results that there cannot be any predicates so abstract that they cannot be grounded in relations between material entities in the world of experience [7]. Peirce's proofs in that treatise and many others have stood scrutiny for more than a century. The gist of the argument is suggested by noting how difficult it would be to discover the meaning of a verb such as "dance" without a dancer, or a relation such as "greater than" or "equal to" if it were impossible to find any instantiations to illustrate their meanings. It follows that there are no pragmatically unconstrained predicates no matter how abstract they might be. With pragmatic constraints come syntactic ones and semantic ones: "Pilot the bit dog the," is syntactically disallowed, while "The pilot bit the dog" is okay syntactically (in its spatio-temporal arrangement) and semantically also in terms of its abstract meaning. However, because our pragmatic experience makes it unlikely that a pilot would bite a dog, we might infer that an error has been made, and that "The dog bit the pilot" is what was intended. Children will often correct an odd form, e.g., "Can the blindfolded dolly be seen by you?" and will answer a more sensible one, "No," the child is apt to say, "the dolly can't see me." The researcher asking the question may suppose the child has answered incorrectly, not understanding the passive voice, when, in fact, the child adjusted the question to one that makes sense. The child thinks something like: It's the dolly that is blindfolded, not me. She must mean, "Can the dolly see you?" And so forth [36].

So, again, how do normal children progress to such knowledge and what are the implications for molecular cryptologists in trying to generate viable strings in biological systems? To show how and sum up the sequence, followed by normal children, we require some additional markings on the basic SπO relation. Let $\mathrm{S}\pi\underline{\mathrm{O}}$ represent the generalized form of a hypothetical, fiction, or fantasy. At the symposium I suggested that participants imagine an elephant standing next to me on the stage. To do so, they would have to conjure the elephant, because there was none on the stage — hence, the underlined $\underline{O}$ to suggest π-mapping the conjured elephant into the blank space. Babies typically solve valid SπO mappings by about 12 months of age but require another year to distinguish a true report from a fiction, by about age 2. Just to understand the example fiction, for instance, the person doing the imagining of an elephant not present must know the meaning of the word "elephant." Thus, an SπO mapping showing what the S means must come first. Errors are more complex. Suppose someone says, "Good morning, Mimi," when Ruthie is present, not Mimi. To correct the error, my grandson not yet 3 years old, had to take the $\underline{\cancel{S}}\pi\underline{\cancel{O}}$ form and replace it with an SπO. The fictionalized and mistaken $\underline{\cancel{O}}$ which is supposed to be Mimi (his grandmother), but which is in fact Ruthie (his adult aunt), must be replaced with Ruthie, and the fictionalized and erroneous name $\underline{\cancel{S}}$ must be changed from "Mimi" to "Ruthie." Children typically can correct an error, in this way, by about age 3. Distinguishing a deliberate lie, $\underline{\underline{\cancel{S\pi O}}}$, from an unintentional error, $\underline{\cancel{S}}\pi\underline{\cancel{O}}$, takes 2 or 3 more years of development [37]. Normal children are able to do so by about age 6. In a lie all three of the underlying elements of the SπO relation are erroneous, fictionalized, and intended to cause the lie to be mistaken for a true representation. For instance, if a certain former U.S. President (notably Bill Clinton) said he didn't "have sex with that woman," but it turns out that he was lying, all the elements must be changed to truly represent the relevant facts.

Next, consider how much more degenerate the italicized string *i io mN"o "Dgmon mrgi* is than a fiction, error, or even a lie. It has the same letters, punctuation marks and spaces, as one of the degenerate representations in the preceding paragraph. Is it easy to see which one? It is a nonsensical variant, a jumble, that started as an $\underline{\cancel{S}}\pi\underline{\cancel{O}}$ (to narrow the field if the reader aims to solve the puzzle), but it is less coherent than any ordinary fiction, error, or lie. The fact is that in languages — and it seems in biological systems as well — fictions, errors, and outright lies are more coherent than scrambled versions of any of even these degenerate forms tend to be. In biology, I suppose a suppressed gene would be an example of a fictional representation; a genetic flaw resulting in, say, sickle cell anemia, or a viable cell mistaken for an invading foreign disease agent by the immune system would be examples of errors; and polyoma viruses, bacteria, or cancer cells impersonating the body's own RNA, DNA, or self cells, respectively, would be examples of biological lies. The fragments of a foreign peptide, or of a cell undergoing apoptosis, would probably qualify as some grade of biological nonsense, say, in the protein language of a given organism.

Typically, evolutionary biologists have sought to imagine ways to generate strings of meaningful signs from the bottom up. Theoreticians have often noted, as Gatherer does, that from letters to words, to phrases, to sentences, and so on (relying on the linguistic metaphor) the number of possible strings repeatedly explodes with a growing vocabulary of signs and an increasing string length at each higher rank. However, if we think from the top downward, we find that the constraints on coherence are greatest (all else being equal) at the highest rank. For instance, if we take historical biographies as an approximation to true narratives rich in pragmatic information, setting them as a kind of "gold" standard (flawed though it may be), it is possible to degenerate one or many such texts by degrees. Holding constant, say, the vocabulary of elements used to create the coherent string and the length of the string, the whole of it or some part can be chopped and scrambled stepwise at distinct ranks. Opposite the level of pragmatic information exemplified in the whole of a true biography, or in several volumes aiming to tell the history of the same person, a zero order of coherence can be found empirically at the place where the entire text is obliterated by reducing all its elements to blank spaces or mere random pixels. Between those limits it should be possible, even easy, with current technologies, to systematically sample and measure empirically the changes in coherence at distinct ranks. Empirical studies of discourse processing in natural languages show that scrambling at any rank or length of string reduces coherence and conversely that access to longer segments of a coherent text enhances comprehensibility, recall, and ability to replace missing elements (letters, words, phrases, and so on). All else being held equal, longer intact strings are increasingly constrained and therefore easier to process (comprehend, recall, and so forth) than the same elements in a cut and scrambled order [38].

Conclusions

Because of the series of combinatorial explosions that occur in progressing up the ranks in any layered hierarchy of representational systems, to find or generate any string that will qualify as a valid representation of any actual sequence of events in ordinary experience, or as a viable representation of any organism or any actual part of one, diminishes rapidly toward a vanishing point. Meanwhile, as the number of strings that are possible are exploding, the ratio of meaningful to meaningless strings at every level diminishes with each increase in the rank of signs and/or the length of allowable strings. As a consequence, the problem of finding (or generating) any valid (viable) biological strings by random processes is like the needle in a haystack problem magnified many times over. As Dembski, Ewert, and Marks [27] showed (this volume), the search for a needle presupposes a searcher. But the problem of randomly generating the searcher is vastly more difficult than any of the seemingly impossible searches we might hope for that person? robot? algorithm? to conduct.

But the difficulty does not end there. Linguistic analysis of natural language systems shows another profound problem, as was illustrated by Montañez, Marks, Fernandez and Sanford (this volume [25]). As valid (meaningful and viable) strings increase, the difficulty of generating them by stochastic processes rapidly increases. Also, as I have argued here, with each combinatorial explosion as we progress upward through sign ranks to their highest level, the ratio of valid strings to all that are possible diminishes toward a vanishing point with a numerator of unity and a divisor representing an uncountable multitude of multitudes.

In 1948, Claude Shannon proposed to measure information as the improbability of any particular message "*selected from a set* of possible [equally likely] messages" [39]. He noted that "the messages" frequently "refer to or are correlated according to some system with certain physical or conceptual entities" which he referred to as "semantic [*sic*] aspects of communication" (p. 379) and which he set aside. In doing so, he conflated the abstract and general sort of meaning properly termed "semantic" (associated with generalized conventional Ss) and also the particular and concrete "pragmatic" content (associated with particular concrete Os — the actual persons, places, events, and the "syntactic" relations between them in space and time (the π-mappings). I suppose that the crucial meaning that Shannon set aside is precisely the kind connecting intelligible signs to the facts of ordinary experience — *pragmatic information*. I agree with what I understood Baumgardner to say in one of the early discussion sessions at the Cornell symposium: When talking about information we need to work with the sort of meaning that is distinctly "linguistic in nature" (also see Baumgardner 2009 [40]). I believe that we need to consider the dynamic character of *pragmatic information* as I have described it here. It seems to be as essential in biology as it is in linguistics.

One of the reasons, I think, that we tend to over-estimate our understanding of "our glassy essence" — and to underestimate the richness of the simplest signs — is that we tend to look right through the π-mapping of any valid S to its O. As the sign systems of a child come to maturity, the generality of the S reaches out very easily to signify all possible instances of the O greatly exceeding the relatively few actual instances that have been or will ever be encountered in a life-time of experience. The agreement attained between the valid π-mapping of any S to its O in a TNR thus achieves what Peirce referred to as the "unity of coherence" [41] — like a glove perfectly fitting a hand, or the bite when the upper and lower teeth fit together. The completed, well-formed-system, is a unified triad of the SπO kind. It enables the closest we can reasonably get, I suppose, to anything like "complete certainty" in the material world. Thus every TNR, though triadic in its internal elements, as a signifying unity singles out a stream of particular facts that are both distinct from all the rest and yet, by virtue of being a part of the whole material world, are connected with the rest of it and with all the other TNRs. As a consequence, they enable, as shown in the earlier analysis of child language development, valid generalizations beyond what is experienced.

I agree with Edward T. Weinberger's comment [17] that "a theory [Shannon's] that totally ignored semantics was, in some sense, incomplete" (p. 105). Weinberger went on to urge a definition of "pragmatic information" in terms of "usefulness in making an informed decision" (p. 106). I would only want to generalize his approach to account for all intelligent judgments of any kind about the facts of experience. To me Weinberger's most intriguing claim is that "the maximal amount of pragmatic information accrues to messages that engender complete certainty" (p. 109). In my linguistic approach to pragmatic information, a maximally informative representation would be the sort found in a name mapped onto a particular identity appearing throughout a faithfully reported true narrative. With a view toward measuring pragmatic information, we can say that it varies from a limit of meaninglessness at one extreme, near 0, to a limit of what seems to be the gold standard where the unity of coherence, near 1, is commonly achieved. Simple SπO mappings, at the foundation of valid representations such as we find in ordinary TNRs and in viable biological codes, exemplify the sorts that can be used to calibrate the high end of a scale of pragmatic information, and as I suggested, we can step down from there toward the lower end by degrees.

Addendum

Due to a delay in publication of these proceedings, I wish to add the following publications which have appeared in the interim. Pertinent to the strict sequence of steps followed by infant language learning per reference [32], see Oller, J.W., Oller, S.D., Oller, S.N.: Milestones: Normal speech and language development across the life span. 2nd edition. Plural Publishing, Inc., San Diego (2014); and in addition to references [25, 26] suggesting various biocontrol systems yet to be discovered, the following entries should be added: Davidson, R.M., Seneff, S.: The initial common pathway of inflammation, disease, and sudden death. Entropy 14(8), 1399–1442 (2012); Dietert, R., Dietert, J.: The Completed self: an immunological view of the human-microbiome superorganism and risk of chronic diseases. Entropy 14(11), 2036–2065 (2012); Seneff, S., Davidson, R.M., Liu, J.J.: Is cholesterol sulfate deficiency a common factor in preeclampsia, autism, and pernicious anemia? Entropy 2012, 14(11), 2265–2290; and Gryder, B.E., Nelson, C.W., Shepard, S.S.: Biosemiotic entropy of the genome: Mutations and epigenetic imbalances resulting in cancer. Entropy 15, (2013).

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