Silent Utterances and Linearization: An Evolutionary Perspective

Patricia Schneider-Zioga

1. The Irreflexivity Problem and Private Utterances

One concern of Minimalist theorizing has been the issue of linearization of the computation, and, in particular, the linearization of non-simplex chains. Linear order is understood not to be a property of the computation itself, which produces hierarchical structure; rather linear order is forced by the mapping of the hierarchically structured computations to the Sensorimotor (SM) interface. At that point, the lexical items involved in the computation must be pronounced in an ordered manner, given the fact that only one word at a time can be uttered. A particular problem for linearization has been how to proceed when two identical objects need to be linearized as is always the case when internal merge has taken place. The irreflexivity problem, that is, the problem of how to prevent an object from both preceding and following itself, can be solved if only one copy of the complex object is pronounced and all other copies of it are silent (see, e.g., Nunes 2004).

(1) What did Eleni buy ~~what~~?

However, if irreflexivity is a problem for the externalization of language via the SM interface, why, asks J-R Vergnaud (p.c. 2010), must all but one copy still be silent when language is used privately, in silent, internal monologues where linearization should be irrelevant? For example, why in our private utterances, would a sentence which involves internal merge, still need a silent copy? Linearization should not be required if an utterance is wholly silent. If linearization does not take place, there should be no irreflexivity problem and hence no silent copies. Nonetheless, silent, privately uttered sentences still seem to require linear order.

In this paper, following a suggestion of D. Hoffman (p.c. 2010), I argue that linearization is forced by a physical brain internal condition, namely, the narrow bandwidth of the corpus callosum, which regulates the exchange of information between the two hemispheres. Computations which are serialized would require far less bandwidth than computations that proceed in parallel. This solution to

The uniquely creative questions and insights Jean-Roger Vergnaud generously shared with his friends and colleagues have influenced every page of this paper. I have also benefitted from the responses and discussion of participants at the USC Parallel Domains Workshop, organized in honor of and in memory of Jean Roger-Vergnaud and from discussion with Lisa Pearl. All errors are mine.

the silent irreflexivity problem also offers a unique perspective for the literature concerned with the evolution of language. Namely, it provides a brain-internal reason for linearization and thereby provides a conceptual argument against Pinker & Jackendoff's (2005) assertion that the phonological component cannot be motivated given the view of Hauser, Chomsky, & Fitch (2002). Hauser, Chomsky, & Fitch (2002) argue that language originated as a vehicle for thought rather than as a vehicle for communication. Pinker & Jackendoff's concept of communication involve exchanges of information between distinct human beings.

2. Narrow Bandwidth, Thought, & Communication

2.1. The Corpus Callosum and the Hemispheres

The corpus callosum, a thick band of 200-250 million nerve fibers, mediates the neuronal communication between the two hemispheres of the brain. Lateralized testing in split-brain studies establishes that each hemisphere has its own perceptual, learning and memory systems (Zaidel, Zaidel, & Bogen 1999). Indeed, each disconnected hemisphere has its own distinct personality (D. Zaidel 1994). Because the corpus callosum mediates communication between the two personalities within the cranium, patients who have undergone a commissurotomy of the brain (i.e., split brain surgery) must rely on other means of communication with the separated hemisphere. Externalized language can play this role as when the right hand picks up an object which is presented exclusively to the left hemisphere and can communicate to the right hemisphere which object is involved by naming the object aloud. The left hemisphere cannot simply think about the information that it desires to convey to the right hemisphere and successfully convey it through inner speech if the corpus callosum is severed. Therefore, there are two paths for linguistic communication between the hemispheres: the corpus callosum and externalized communication, one possibility of externalized communication being externalized language.

The severed right hemisphere exhibits a fundamental linguistic asymmetry with the left hemisphere in that it is virtually silent. That is, it cannot communicate what it exclusively knows to the left hemisphere through linguistic means. However, it can benefit from linguistic information that the left hemisphere can make known to it. For example, it can process the meaning of words and sentences, although it appears to rely heavily on the meaning of words, rather than syntactic structure, in interpreting the meaning of an utterance. For example, Beeman & Chiarello (1998) in their synthesis of the contemporary literature note that left hemisphere sentence comprehension is primed by other sentences but not by a scrambled version of the target sentence. The right hemisphere, in contrast, is primed by the scrambled version of the target sentence. They interpret this to mean that the right hemisphere exhibits a processing reliance on the meaning of words as opposed to the syntax of sentences. Federmeier, Wlotko, & Meyer (2008) agree there are RH/LH processing asymmetries but note that some ERP studies indicate the right hemisphere has some access to message level (syntactic) information. In any case, the right hemisphere (RH) has some comprehension of at least words and can make use of this information. The classic example of this fact comes from cross-hemispheric verbal cuing. In verbal cross-cuing, the severed left hemisphere (LH) names an item held in the right hand (therefore, known by the LH) and the left hand (controlled by the RH) subsequently retrieves the correct object since the RH will be able to then know about it.

The previous demonstration of the benefit of externalized language in the case of the exchange of knowledge between severed hemispheres underscores that when hemispheres are connected, cross-hemispheric linguistic communication from externally silent, private utterances is highly beneficial to the "non-linguistic" hemisphere. This exchange of externally silent information is mediated by the corpus callosum, which imposes the constraint of its narrow bandwidth on the exchange between the hemispheres. One solution to the narrow bandwidth constraint is to linearize the computation, as that would require less bandwidth than a parallel hierarchically structured computation.

2.2. *Bandwidth and Disrupted Linearization in Phonology*

In this section, I note that impacted linearization of language co-occurs with a corpus callosum that is smaller than what is typical, and hence one that provides an even more constrained bandwidth than usual. A disruption to linearization when bandwidth is atypically constrained is consistent with the proposal that the already narrow bandwidth of the corpus callosum is relevant to linearization (phonological expression of language).

The linearization of language is often disrupted in people who have developmental dyslexia. Specifically, people with dyslexia often have problems with the ordering of phonemes or syllables within a word, and with the ordering of words in a sentence. In addition, von Plessen et al. (2002) find that there is a shorter corpus callosum shape amongst people with dyslexia.

An example of the linearization problem observed in dyslexia is discussed in detail in Schneider-Zioga 2012. Schneider-Zioga presents a case study where the reading of the case (Tara, a pseudonym) is marked by an overproduction of CV units and a relative absence of VC units. The phonology of Tara's inaccurately read words could be described as a conspiracy against codas. A high percentage of the time codas in the target words or pseudo-words are pronounced as onsets through one phonological strategy or the other, or are deleted. The end result of the misreading produces a CV syllable. The following chart provides typical examples of Tara's misread words[1] and illustrates some strategies she follows to avoid (C)VC units:

[1] By *words* here, I mean existing lexical items as well as pseudo-words.

(2) **Misread Words and Pseudo-words & the Anti-Coda Conspiracy**

Target word:	**Read as:**	**strategy**
a. besaub.gant	[bi.ˈsɑ.bɪ.gænt]	epenthesis b.g → bɪ.g
b. rhap.sody	[ræpəsɑdi]	epenthesis p.s→ pə.s
c. noc.febatious	[nɛkɑfɪˈbeɪʃəs]	metathesis ɑk.f → kɑ.f
d. vez.getac	[ˈvɛzɛgæt]	metathesis z.gɛ → zɛ.g
e. skid.more	[ˈski.moro]	deletion of coda ɪd.m → i.m
f. rim.besation	[ribɛˈseɪʃɛnə]	deletion of coda ɪm.b → i.b

In (2a), for example, a vowel is inserted at the point of syllable contact between a coda and onset. Due to this epenthesis, Tara reads the coda in the target word as an onset followed by the epenthesized vowel as nucleus. In (2d), at the point of syllable contact between *z* and *g*, the vowel from the nucleus of the second syllable in the target word metathesizes with its onset *g*. This results in *z*, the coda of the first syllable being read as an onset. In (2e), *d* the coda of the first syllable is deleted, resulting in an open syllable. In addition, the vowel from the second syllable is copied and what would be the coda of the second syllable, if the target were read accurately, is read as the onset of a third syllable.

In Schneider-Zioga 2012, I argued that Tara's difficulties with accurate temporal sequencing of codas could be interpreted from a minimalist perspective as a problem of linearizing phonological material at the SM interface. Very often, linear ordering in phonology is taken for granted. In contrast, linearization in syntax has been a focal point of minimalist research at least from the time of Kayne's (1994) Antisymmetry theory. Minimalist works concerned with linearization as mapping to the SM interface have presupposed that the ordered grouping of phonemes within a word is simply a given. Raimy (2003) and Idsardi & Raimy (2010) are important exceptions to this view. If the sublexical parts of words themselves require linearization, it is possible to conceptualize Tara's problem with linearization of phonemes as a problem that involves the mapping to the SM interface, given an articulatory phonology approach to the data.

From the point of view of articulatory phonology, each speech gesture is associated with a clock, or planning oscillator. Gestures are temporally coordinated through coupling their oscillators to each other. Goldstein, Byrd & Saltzman (2006) propose that phonological systems exploit in-phase and anti-phase coupling modes of oscillators as the basis of syllable structure. They propose *the coupling hypothesis of syllable structure*, namely the hypothesis that CV structures arise out of the in-phase coupling of C and V (planning oscillators), whereas anti-phase coupling of V and C planning oscillators underlies VC structures. That is, onsets are synchronous with the vowel. This is an example of in-phase coupling of the consonant and vowel. Codas are sequential to the vowel. The sequence arises through anti-phase coupling. Consider now the linearization of a syllable with a coda such as C_1VC_2. C_1V is a unit (via synchronous coupling) whose linearization is presumably for free, arising from third factors. C_2 needs to be linearized with respect to V because it is not synchronous with it– therefore, it must be linearly ordered with respect to it. In short, CV syllables present no problem for linearization whereas CVC syllables require ordering. As noted in Schneider-Zioga 2012, Vergnaud (2007) proposes a formal interpretation of *the coupling hypothesis of syllable structure* model by extending minimalist views on syntax to syllable structure. He proposes that the elementary syllable CV be represented as the unordered, achronological pair below:

(3) **{X, Y}**, where X = C (respectively V), Y = V (respectively C).

He argues that this is equivalent to viewing the onset and vowel as coarticulated segments. He further proposes that a CVC syllable has the following achronological representation, where the syllable consists of {CV} and {C}:

(4) **{{CV}, {C}}**

Given this model, the problem for Tara is the linearization involved in the mapping of these achronological units to the SM interface. The problematic point for linearization involves the sequencing of the coda with respect to the CV unit. Tara's reading errors, which involve a conspiracy to avoid CVC units, illustrate difficulties with the linearization of subsyllabic units.

On a number of measures discussed in Habib (2000) and the references therein, people with dyslexia "demonstrate 'abnormal collaboration and/or communication between the hemispheres.'" As noted, von Plessen et al. (2002) carry out an MRI study that documented a less developed corpus callosum in dyslexic subjects. Specifically, the auditory regions were affected and shortened. They found a: "shorter CC shape in the dyslexic group, localised in the posterior midbody/isthmus region." The shortening was in the region containing interhemispheric fibers from primary and secondary auditory cortices." In sum, dyslexia involves an atypically short corpus callosum, especially affected in the auditory region, producing an extra-narrow bandwidth. This might make accurate linearization too difficult. Clearly the too short corpus callosum impacts communication between the hemispheres.

2.3. Bandwidth and brain size in Primates

With respect to the bandwidth of the corpus callosum, humans are distinct among primates. Rilling (2010) notes that whole brain MRI scans of various primates reveal that humans have the smallest corpus callosums relative to brain size or cortical surface area of all the primates. Rilling suggests that this decrease in size of the corpus callosum in large brained humans "reflect[s] the difficulty of maintaining interhemispheric transfer times in larger brains where interhemispheric connections are necessarily longer." Rilling points out that the smaller corpus callosum that arose in humans is possibly an economical solution to the problem of connecting the hemispheres of a large brain.

It is not particularly useful to assert that a large brain size is responsible for language in humans. However, to note that the consequence of the large brain size led to a corpus callosum that had a relatively small bandwidth is useful given the hypothesis that the narrow bandwidth of the human corpus callosum created the conditions for linearization of language. It also provides a useful way to think about the observations of Di Sciullo et al. (2010) that "[e]xperimental studies of language comprehension in animals are more promising than those of production, suggesting that a fundamental bottleneck in the evolution of language was the connection between linguistic computation and its externalization in linguistically meaningful structures**."** From the perspective of the narrow bandwidth conjecture, externalization arose due to the physical morphology of the human brain. That is, it was the physical presence of a relatively small corpus callosum that provided the connection between linguistic computation and linearization of the computations.

3. Communication and Thought

The linearization-due-to-narrow-bandwidth proposal provides a counter-perspective to the Pinker & Jackendoff (2005) assertion that the phonological component of Faculty of Language Broad (FLB) is unnecessary to so-called private uses of language; that is, why would private thought require a phonology? This lack of functional value for phonology, Pinker & Jackendoff argue, is an important reason to reject the view that the evolution of language was driven by its private use.

Pinker & Jackendoff (2005) see the SM interface as imposing phonology on language due to its linearization requirement. Pinker & Jackendoff argue that "the only way to make sense of the fact that humans are equipped with a way to map between meaning and vocally produced sound is that it allows one person to get a meaning into a second person's head by making a sound with his or her vocal tract." However, we have just seen that the narrow bandwidth of the corpus callosum provides an important private motivation for phonology: it allows one hemisphere to get a meaning to the other hemisphere.

Moreover, the narrow bandwidth solution is also important from the viewpoint of Fitch, Hauser, and Chomsky (2005). Their view seems to predict that the phenomenon of sentences silently uttered in our thoughts having a phonology indicates that externalized language was re-internalized at some point. In that case, the reinternalization would have to have been useful somehow from an evolutionary perspective. But how would it be useful? There is a straightforward explanation that appears to avoid all redundancies of systems with respect to either (a) a public, or (b) a private motivation for the evolution of language, if linearization were a direct result of a constraint imposed on Faculty of Language Narrow (FLN) *before* it was ever externalized.

The mutation that produced FLN was enormously useful because it resulted in the harnessing of not just one mind to another, but of two minds—in the same body—to two other minds. It did not matter that the second mind could not speak. From this point of view, human language functioned as a vehicle for thought *and* as a vehicle of communication before it was ever externalized. The externalization was a direct extension of the communicative function of language that existed due to the linearization imposed by the narrow bandwidth of the corpus callosum—a bonus.

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Patricia Schneider-Zioga
California State University, Fullerton
Departament of English, Comparative Literature, & Linguistics
800 N. State College Blvd.
Fullerton, CA 92834-9480
USA
pzioga@fullerton.edu