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Semiotic systems with duality of patterning and the issue of cultural replicators

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Abstract Two major works in recent evolutionary biology have in different ways touched upon the issue of cultural replicators in language, namely Dawkins' *Selfish Gene* and Maynard Smith and Szathmáry's *Major Transitions in Evolution*. In the latter, the emergence of language is referred to as the last major transition in evolution (for the time being), a claim we argue to be derived from a crucial property of language, called *Duality of Patterning.* Prima facie, this property makes natural language look like a structural equivalent to DNA, and its peer in terms of expressive power. We will argue that, if one takes seriously Maynard Smith and Szathmáry's outlook and examines what has been proposed as linguistic replicators, amongst others phonemes and words, the analogy meme-gene becomes problematic. A key issue is the fact that genes and memes are assumed to carry and transmit information, while what has been described as the best candidate for replicatorhood in language, i.e. the phoneme, does by definition not carry meaning. We will argue that semiotic systems with Duality of Pattering (like natural languages) force us to reconsider either the analogy between replicators in the biological and the cultural domain, or what it is to be a replicator in linguistics.

Keywords Replicator · Meme · Duality of Patterning · Evolution · Linguistics

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1 Introduction

After a long fall from grace, the last 40 years have seen a great renewal of interest in evolutionary thinking in the humanities and the social sciences, and linguistics makes no exception to this rule. The major impetus for the renewal in linguistics seems to have been the publication of *The Selfish Gene* (Dawkins 1976/2006). In his seminal book, R. Dawkins argued that the level of natural selection is the gene—and the gene alone. He furthermore stated that the gene is only one particular instance of a more general phenomenon, namely *replicators*, that is, entities that can be copied. More specifically, he introduced the idea that there are cultural replicators, which he called "memes", and which are memory-based entities, also subject to processes of natural selection. While the discussion in Dawkins (1976/2006) is rather short, Universal Darwinism proved to be fertile, and a number of linguists have applied the idea of selection on memes to language change, most notably by creating the notion of *linguemes*[1] (Croft 2000—term attributed to Martin Haspelmath), an adaptation of the concept of meme to the linguistic field.

The analogy between linguistic evolution and biological evolution is far from being recent. Indeed, there is an old tradition of evolutionary thought in linguistics, going back to the nineteenth century (see Errington 2008 for an overview). In particular, the idea that languages and biological species form and develop by very similar processes dates from that period. It is important to notice that evolutionary thought in linguistics has not consisted in a unilateral process of superimposing (with more or less justification) ideas from biology into linguistics. While some linguists, like August Schleicher (1873) enthusiastically embraced Darwinism, the acknowledgement of similarity also concerns eminent biologists at this early date. For instance, Charles Darwin himself remarked in the 2nd chapter of *The Descent of Man* that "[t]he formation of different languages and of distinct species, and the proofs that both have been developed through a gradual process, are curiously the same", citing similar observations by Charles Lyell, but also by linguists like Max Müller and Schleicher (Darwin 1871, p. 59). Darwin makes the explicit connection to his own evolutionary theory when he adds that "[t]he survival or preservation of certain favoured words in the struggle for existence is natural selection" (ibid., p. 60f.). Therefore, the idea of cultural evolution—at least in linguistics—is probably at least as old as the idea of biological evolution, and its recent reflourishing is not a whim that is likely to pass any time soon.

On the contrary, the relation between language and cultural evolution has been strengthened in recent years also from the side of biologists, when J. Maynard Smith and E. Szathmáry included the emergence of human language as one of their so-called "Major Transitions" in evolution (Szathmáry and Maynard Smith 1995; Maynard Smith and Szathmáry 1995), i.e. points in evolution where there is an augmentation of complexity. This inclusion as the last major transition is striking, and at the same time, somewhat puzzling. While the discussion is couched in terms

[1] As pointed out by one anonymous reviewer, and as we will see below, it is far from clear to what entities that term should apply. Henceforth, we will use *lingueme* as synonym to "linguistic replicator", without wishing to imply a specific conceptual content.

of language as enabler of human society, the motivation for considering the emergence of natural language as a major transition is probably not that human language allows for a kind of social structure unheard of in animals (many eusocial insects live in complex societies), but concerns rather the structural similarity of the coding mechanisms—which is spelt out in a clearer way in their popular science book (Maynard Smith and Szathmáry 1999), where the authors state in the preface that "there have been 'major transitions' *in the way that information is stored and transmitted*, starting with the origin of the first replicating molecules and ending with the origin of [human natural] language" [our emphasis]. For them, both language and DNA provide systems of "unlimited heredity" (Maynard Smith and Szathmáry 1999, p. 169).

In this paper, we will dwell upon the theoretical development that some of the most prominent recent evolutionary approaches to language change have adopted in one form or another, focusing on the notion of *replicator* that was introduced above. In particular, we will try to point out some difficulties that result from applying the concept to natural language, and a possible conflict in outlook between a strict application of Dawkins' approach to linguistics (as proposed by, e.g., Ritt 2004), and the vision of natural language as endorsed by Maynard Smith & Szathmáry. We will also investigate what the possible answers to these questions may entail for the discussion in other domains of cultural and biological evolution.

As will be explained below, the critical property underlying the analogy between DNA and natural language made by Maynard Smith and Szathmáry (1999, p. 169) is the fact that in both systems, an a priori indefinite number of living beings or sentences can be coded for by a small number of units (nucleotides or phonemes). This property is known in linguistics as Duality of Patterning. In the first part of this paper, we will dwell upon this structural similarity of natural languages and DNA. In the second part, Duality of Patterning will be defined more precisely, and we will also look into claims of its universality. The third part discusses the complications that arise in applying memetics to natural language, given its nature as a semiotic system exhibiting Duality of Patterning. In our final section, we conclude that, as promising as the analogy between DNA (or genetics) and Duality of Patterning (or natural language) is, its pledges have not been met yet.

2 The structural similarity of natural language and DNA

One of the striking analogies between DNA and natural language is that DNA can code for a seemingly infinite amount of life-forms, whereas natural language can generate an indefinitely large number of meaningful sentences (see Maynard Smith and Szathmáry 1995, p. 283). And there also seems to be an underlying analogy of coding: genetic code consists of a small number of basic ingredients (the nucleotides in the DNA-code) which, individually, do not code for anything and have no function. However, sequences of these basic elements form codons, which in turn form genes, and therefore, form the functional units of heredity. Genes, according to the definition in Brown (2012, p. 1) are "units of *biological information*" (Brown's emphasis). They code for proteins or regulate the production of other genes; and,

they are also the units of biological inheritance. In Dawkin's (1976/2006) terminology, genes are the biological replicators.

Consider for instance the Human FOXP2 gene, which had been touted for some time as *the* speech-gene. Its first 180 nucleotides are given below.[2]

```
cttgaaccttt gtcacccct cacgttgcac accaaagaca taccctagtg attaaatgct
gattttgtgt acgattgtcc acggacgcca aaacaatcac agagctgctt gatttgtttt
aattaccagc acaaaatgcc atcagtctgg gacgtgatcg ggcagaggtg tactcacagt
```

This sequence of nucleotides codes for the following sequence of amino acids[3]:

MMQESATETISNSSMNQNGMSTLSSQLDAGSRDGRSSGDTSSEVSTV
ELLHLQQQQALQA

The FOXP2 gene encodes a number of functions,[4] and mutations may lead to severe disabilities (for instance, a change at position 553 from R to H leads to a language disorder and oro-facial dyspraxia).[5] Yet, as far as we know, it does not seem to be the case that one particular nucleotide (of adenosine, for instance) *as such* has a clearly defined function in constructing a given body part, a protein, or something else. It is only in a given DNA-sequence that it has the effects it has.

Now, natural languages such as English, French or Burushaski (a language isolate spoken in the Gilgit-Baltistan area of Pakistan) have at some level of abstraction a strikingly similar structure. They exhibit meaningful entities (e.g. "words") such as "cat" (/kæt/), which themselves are made up of several individual parts, namely /k/, /æ/ and /t/. These basic elements in themselves do not have any meaning, that is, the meaning of "cat" is not derivable from the meaning of the sounds /k/, /æ/ and /t/ and their combination, like the meaning of "the cat is sleeping on the mat" is derivable from the meaning of the individual words in that sentence, and the grammatical rules of English. In natural languages as well, a point mutation (e.g., if the /t/ in final position were replaced by a /p/) may cause a striking difference in meaning. However, there is a general consensus that the difference in meaning between "cat" and "cap" cannot be due to a difference in meaning between the sound /t/ and the sound /p/. This property of natural language is known as *Double Articulation* or as *Duality of Patterning* (see Sect. 3): sentences can be split into basic meaningful entities (which we call *words* or *morphemes,* and which are basic signs) that are made up of meaningless entities (which we call *phonemes*). So, it looks like (and this analogy has not been lost on Maynard Smith and Szathmáry) that natural language reproduces the *expressive capability* of the genetic code in a culturally transmitted manner. Maynard Smith and Szathmáry (1999, p. 169) even

[2] Retrieved from http://www.ncbi.nlm.nih.gov/nuccore/NM_001172766, on 16/05/2016.

[3] Retrieved from http://www.uniprot.org/uniprot/O15409.fasta, on 04/04/2016.

[4] See, e.g., http://www.uniprot.org/uniprot/O15409 for an overview with respect to the function of the gene. See http://blast.ncbi.nlm.nih.gov/blastcgihelp.shtml for the meaning of the letters.

[5] See Lai et al. (2001).

state that the "discrete, digital nature of the units [i.e., phonemes and nucleotides] is probably necessary" for specifying a system of unlimited heredity.[6]

Maynard Smith and Szathmáry (1995) are far from the only ones making this analogy. Marcus, for instance, writes: "Our interpretation was to assimilate the first articulation with the level of codons and the second articulation with the level of nucleotide bases. This means that the former are the morphemes of the genetic language, while the latter are its phonemes" (Marcus 2004, p. 319; see also Marcus 2007, p. 385ff and references therein). Ji (2012, p. 166, Table 6.3) endorses the same analogy, but in a less specific and less linguistically informed way: for him, *letters* (i.e., phonemes) correspond to the nucleotides *or* amino acids, whereas *words* correspond to genes *or* polypeptides.

Among culturally transmitted items, natural languages seem to be unique in being doubly articulated. Consider for instance the instructions for making a particular kind of biface, or a recipe for preparing a particular type of food. These activities can be decomposed into smaller parts (striking off a flake, or cutting onions). However, there does not seem to be a level of analysis where there is the emergence of a phenomenon that is clearly not present at a lower level, and which isolates higher-level phenomena from the lower-level elements. For instance, sentences can be pronounced with a foreign accent—and therefore be strange to a native speaker—while being perfectly irreproachable from the point of view of meaning. We should therefore expect the meme-based evolution of natural language to be more similar to biological DNA transmission than other types of memetic evolution. However, while the structural similarities to the genetic code are striking, there are also some equally profound dissimilarities between these two message transmission systems.

As far as we are aware, the four nucleotides are universal among DNA-based living beings.[7] That is, the molecular base for coding a mushroom, a banana or a human being is the same. However, this does not hold for natural languages. The phonemes of English are not identical to the phonemes of French (this is why we have an accent speaking foreign languages), and even within a language such as English, there is competition and evolution with respect to the phonemes; compare, e.g., the received (British) phonemic structure of "dance" (which is /dɑns/) to the standard American English phonemic structure (/dæns/).[8] Such competition leads in

[6] This is a very strong claim, and it implies that this property should be universal in natural languages—a claim we will investigate below. The correspondence between phonemes and nucleotides has been rejected by some authors, such as Collado-Vides (1993), based on the fact that there are no (what one would call in linguistics) phonotactic constraints on nucleotides (any nucleotide can follow or precede any other), and based on the idea that differences between nucleotides can be sometimes non-coding (a phenomenon that would be called neutralization in linguistics).

[7] Not all forms of life are DNA-based: some viruses (such as HIV or Ebola) are based on RNA.

[8] Note that the non-identity of the basic unit also holds if the retained meaningless entities are phonological distinctive features, e.g. [± voice], rather than phonemes—which is an option because phonologists do not necessarily see phonemes as unanalysable primitives. Ritt (2004, p. 133) rejects phonological features as potential replicators because of their 'universality'. However, such an analysis is disputable: phonological features are universally accessible to any language, but they are not attested in all the languages. While some of them arguably are—e.g. [± consonantal]—, most of them are not—the feature [± constricted glottis] is absent from French, for instance.

the long term also to historical change in the phonemes: for instance, the phoneme inventory of Contemporary English is not the same as the one of Middle or Ancient English (as far as we are aware, no variety of Contemporary English has the phoneme /ç/–which corresponds to the pronunciation of the *ch* sequence in the German pronunciation of the philosopher *Fichte*, and which used to correspond to the pronunciation of the sequence "gh" in words like *knight*—compare its German cognate *Knecht*). More generally, the phoneme inventory of natural languages range from 11 (Rotokas; Papua-New Guinea, North Bougainville language) to over 100 (!Xóõ; Botswana, Khoisan language).[9] So, it seems to be clear that phonemes themselves are targets of evolutionary pressure—which is not obviously the case for nucleotides.

This has led to a divide in the field of linguistics that sees itself as applying memetics: what are the memes in natural language? Ritt (2004) has argued forcefully that phonemes provide the clearest examples of linguistic replicators, whereas people such as Croft (2000) argued against this view. However, it seems clear that the mere existence of a doubly articulated system of information transmission raises a number of interesting problems in the domain of memetics.

In the following section, we first review in more detail what is meant by Duality of Patterning, and we will investigate claims and counterclaims with respect to its universality in natural languages. Based on this, we will then investigate whether one can speak of two different levels of independent replicators, or whether there is reason to single out one particular level as the one housing replicators, whereas the other level would be in some way derivative, or secondary.

3 Defining double articulation or duality of patterning

Before turning to the nature of linguistic replicators, i.e. linguemes, it is necessary to briefly address the nature of Double Articulation or Duality of Patterning (henceforth DoP). While there is a consensus that this is indeed an important property, the initial claims of universality by Martinet (1949) and Hockett (1960/1982) have been criticized recently.[10]

As already indicated in the previous section, the basic idea is that language has two different levels of organisation: one where the basic units carry meaning, and one where the basic units do not carry meaning. Meaning-carrying units can be combined to form bigger meaning-carrying units. Consider the sentence below, together with its phonetic transcription:

The cat-s are sleep-ing.
ðə kæts ɑr slipɪŋ

This simple sentence contains six basic morphemes, which sometimes correspond to a word. Note, however, that "cats" and "sleeping" are made up of two

[9] Taken from Crystal (2010), and Hall (2000, p. 80).

[10] As pointed out by Ladd (2012), the definitions by Martinet and Hockett are not completely identical, but for our purposes, there is no point in elaborating on these differences.

different morphemes (or meaning-carrying elements). For instance, "cats" can be analyzed as consisting of a morpheme "cat", and the plural morpheme "-s". This level of analysis is called by Martinet the first articulation (henceforth A1). One can analyze the same sentence also as consisting of 14 phonemes (/ð/, /ə/, /k/, etc.). This level of analysis is called the second articulation (henceforth A2).

The basic intuition behind this distinction is that the elements of A1 carry meaning, whereas the elements of A2 do not; what is important for elements in A2 is that they be different. The hallmark of the existence of A2 is the existence of minimal pairs, that is, elements of A1 that are distinguished by only one sound. In English, for instance, such minimal pairs include /kæt/ 'cat', /mæt/ 'mat', /pæt/ 'pat', /bæt/ 'bat', /fæt/ 'fat', etc. And clearly, there is no particular semantic proximity between those words.

Both Martinet and Hockett conceived DoP as being a defining feature of human languages, which distinguishes natural languages from animal communication systems, and therefore has to be universal. Such an analysis would lead to posit DoP as one of the keys for the emergence of human language as a Major Transition in evolution. As we have seen above, this is the position of Maynard Smith and Szathmáry (1999, p. 169). However, this claim to universality has come under criticism recently, and we will review two angles of attack: first of all, DoP might fail to be a defining feature of natural language because not all natural languages feature it (or feature it systematically). Second, it might be that animal communication systems show (at least the beginnings of) DoP, and therefore, it is not a distinguishing feature, either.

We will look into these two arguments now.

3.1 Is A2 a universal in human languages?

By far the most serious challenge for the universality of DoP concerns the universality of the presence of A2 in all natural languages, and is based on Sandler et al. (2011), analyzing the emerging sign language of a small and segregated Bedouin community in Israel, Al-Sayyid Bedouin Sign Language (henceforth ABSL). According to Sandler et al., there is no evidence in favor of the existence of a phonological system in this language, and therefore, no A2. They present the following evidence in favor of this claim: (i) the complete absence of minimal pairs (see above; other sign languages do exhibit minimal pairs, for instance, in hand-shape); (ii) the absence of constraints on the form of the signs (e.g. contrary to what has been observed in other sign languages, the number of fingers involved in a sign can change throughout its realization); and (iii) the great deal of intra- and inter-speaker variation that has been observed (e.g. in the shape and orientation of the hands, or in the type—clawing, curving—and number of movements involved). On the other hand, they show that ABSL is a fully functional community language, which satisfies the same communicative needs as the community's oral Arabic vernacular, and has a "normal" A1. Building upon the ABSL case, W. Sandler and her colleagues claim that DoP should not be considered as a "necessary property of languages", but rather as "an empirical observation" (Sandler et al. 2011, p. 505).

Apart from this extreme case of total absence of A2, there are also claims to the fact that, even in otherwise "well-behaved" oral languages, DoP fails to apply to some elements of those languages. Blevins (2012) for instance claims likewise that A2 should be considered as a strong statistical tendency, not as an obligatory feature of language. She cites morphemes that consist of a single phoneme or phonological feature as problematic (she mentions Kabardian as an example of a language that displays several morphemes of this shape in its verbal morphology, but consider also English plural "-s"). Another example she thinks that makes the assumption of DoP as a universal problematic is the existence of "phonesthemes". These are a sequences of sounds that have no morphosyntactic function but which participate in the meaning of lexemes, e.g. /gl/, which is frequently associated with light or vision in English: 'glare', 'glitter', 'glisten', etc. The point here is that /gl/ may be associated with light, but there is no meaning associated to the remainder of the word (i.e., /ær/ or /iter/). Thirdly, she adduces "feature-sized morphemes in systems of sound symbolism or ideophones" (Blevins 2012, p. 285). Ideophones, and lexical items of similar nature, are "marked words depictive of sensory imagery found in many of the world's languages" (Dingemanse 2012, p. 654) which are frequently considered to display phonetic and phonological properties that are not shared by the other items in the lexicon of a given language. Dingemanse (2012) quotes, among others, Kruspe (2004), who says that ideophones of Semelai (an Austroasiatic language from Malaysia) are "distinguished by their aberrant phonology" (Krupse 2004, p. 102), or Epps (2005), who explains that those of Hup (a Nadahup language from Brazil) have a "distinctive phonology, involving special rules of length, tone, and stress" (Epps 2005, p. 869). As a consequence, the marginal sounds that the ideophones are composed of cannot be combined to form new meaning-carrying units, a characteristic that raises the question whether they can be doubly-articulated units. According to Blevins, all these arguments conspire against the idea that a meaningful unit can (always) be decomposable in smaller meaningless units in natural languages.

As interesting as these cases and analyses can be, their impact on (our understanding of) DoP has to be relativized. On the one hand, "*the kernels of a phonological system are already emerging in ABSL*" (Sandler et al. 2011, p. 507), despite the brief history of the language (the emergence of deafness in the community dates back less than a century). On the other hand, some of Blevins' arguments are questionable. The existence of morphemes that consist of a single phoneme is hardly problematic for DoP, since one can object that these meaningful units are made of one meaningless element: the existence of a morpheme "-s" in English does not imply that the phoneme /z/ to which it corresponds will always be associated with plurality—e.g. this is not the case for 'zero'. Also, the specific phonetic and phonological nature of holistic morphemes remains marginal. In his survey of the cross-linguistic properties of ideophones, Dingemanse writes:

> Most ideophones in a given language feature the regular phonemes of that language […], and even if peculiar sounds occur, they tend not to be random points in phonetic space but bear a relation to the phonemic system of the language, for instance by filling gaps in the phoneme inventory […]. What

> makes ideophones marked relative to ordinary words is not so much that they employ different sounds, but that they employ mostly the same sounds in a different range of possible configurations. (Dingemanse 2012, p. 656)

However, it bears repeating that fully functional natural languages without DoP are not only a theoretical possibility, but do actually exist—even though such systems may not be very stable in time, and may have a tendency to change into a more standard semiotic system with DoP.

3.2 Is A1 specific to humans?

We are not aware of any work where the universality of A1 in human languages is denied, or of a natural language consisting solely of non-articulated holo-phrases. In fact, it is not the universality of the first articulation that needs to be questioned, but rather its relevance for the communication systems of non-human primates (and, maybe, to other species—e.g. birds), and thus its history as a part of the 'major transition' of human language. In particular, it has been claimed that several monkeys display combinations of morpheme-like entities that may be considered as morphological or syntactic constructions (Arnold and Zuberbühler 2006; Ouattara et al. 2009a, b).

Among other examples (see below), the most famous one relates to the utilization of a look-a-like suffix in Campbell's monkeys alarm calls (Ouattara et al. 2009a, b, Keenan et al. 2013). Campbell's monkeys use a call glossed 'hok' to alert other monkeys to the presence of eagles, and a call 'krak' to alert to the presence of leopards.[11] Strikingly, the combination of 'hok' with the suffix '-oo' refers to any disturbance in the canopy, and the combination of 'krak' with the same element '-oo' refers to any disturbance coming from the ground (and/or the canopy). This led to an analysis of '-oo' as a combinatorial morpheme that conveys a generic meaning (Ouattara et al. 2009a, b; Schlenker et al. 2013). Following this research, researchers in Rennes discovered several elements of a similar nature in other monkey species, such as an 'Uh' element in mangabeys (Bouchet et al. 2010, 2012b), an 'I' unit in De Brazza's monkey (Bouchet et al. 2012a) or an 'A-call' in the vocal production of female Diana monkeys (Candiotti et al. 2011—note that this last element, contrary to the others, can be produced in isolation). The importance of these examples is not that the communication system would show a fully-fledged DoP; it is rather that it cannot be analyzed as being completely holistic.

So, let us take stock after these points. Even though DoP may not be a necessary feature of natural languages, and even though it may be entirely absent from some of them (as illustrated by ABSL), the fact remains that the immense majority of natural languages exhibit full DoP almost everywhere. The absence of DoP is a strange fringe-event, as far as natural languages are concerned. On the other hand, as far as we are aware, there is no animal communication system that would exhibit full DoP, and even though in rare cases, there are elements that can be described as

[11] We are simplifying a bit here. See the mentioned references for details.

showing the beginning of A1—which is exciting enough—the presence of some articulation seems to be a fringe-event.

Now, in what sense is all of this important? The main issue is here that if one assumes two different levels of analysis in a semiotic system (which is entirely standard for modern linguistics), this also involves potentially two different types of replicators, namely, replicators at A1 (morphemes), and replicators at A2 (phonemes). This, however, does not seem *prima facie* obvious, since, as we have seen above, phonemes seem to correspond to the nucleotides in DNA, which are not normally seen as replicators, but rather as *parts* of replicators (which are the genes), and whose essential role is to achieve the digitization of the replicator.[12] This seems to be a problem specific to natural language, since it seems to be the only culturally transmitted sign-system exhibiting DoP.

So, treating a signaling system with DoP leads to the following questions. Are there two levels of (potential) replicators? And is there any reason to assume that one level of these (potential) replicators is any way prior or more important than the other?

4 What is a Linguistic Replicator, and Why Should We Care?

While much research in linguistics has adopted in one way or another the basic assumptions by Dawkins (1976/2006), and therefore, the idea that there are linguistic replicators, the question remains of how much importance one should accord to the correspondence between memes and genes. After all, these are in principle two different entities, even though they may have many properties in common. The issue is also whether integrating the ideas of Maynard Smith and Szathmáry (1995) into a basically Dawkinsian account could provide another perspective.

The simplest kind of answer one could give would probably be that in natural language, there are two different levels of replicators, one for A1, and another for A2. However, such a perspective involves dodging the question of what is a linguistic replicator (or a meme). As Ritt (2004, p. 117ff.) points out, this has been the prevalent tendency in the literature, and the discussion on the issue has not been characterized by excessive precision.[13] On such a basis, carrying out an investigation about the replicator-status of the two articulations seems to be doomed from the outset. Ritt also points out that—if one wants to address this

[12] Maynard Smith and Szathmáry (1999, p. 8ff.) insist on information transmission in genes as well as in language. For them, "continuing evolution" (that is, the emergence of life, and what one generally associates with biological evolution) is possible only in a system of unlimited heredity—which is provided by both DNA and natural language. In this sense, they set apart "modules" (what they take to be not single nucleotides, but base-pairs). In any case, there is a functional distinction to be made for these two types of entities.

[13] For instance, Blackmore (1999, p. 66) concludes a long discussion on the issue as follows: "I shall use the term 'meme' indiscriminately to refer to memetic information in any of its many forms; including ideas, the brain structures that instantiate those ideas, the behaviours these brain structures produce, and their versions in books, recipes, maps and written music. As long as that information can be copied by a process we may broadly call 'imitation', then it counts as a meme".

thorny issue—clear criteria should be used to define a linguistic replicator, and that an evolutionary approach needs to identify solid criteria for linguistic replicator-hood (see Ritt 2004, p. 120f.).

We will follow here Ritt (2004 p. 123f.) in our discussion, which is ultimately based on Dawkins. Ritt discusses for linguistic replicators the four following criteria. First, *longevity*, the fact that a replicator must be able to exist for some time. The second criterion is *copying-fidelity*, that is, offspring must have some recognizable similarity to its originator. Thirdly, for an entity to be a replicator, it must have a minimum degree of *fecundity*, and fourth, a replicator must have an *active* role in bringing about its replication.

Ritt's basic idea is that any item of linguistic competence *might* be a replicator, and while he does not deny replicator status to other linguistic entities, phonemes are for him the entities that satisfy exemplarily the properties he distinguished (see Ritt 2004, p. 133).[14] This is because they have high copy-fidelity (many phonemes of English have remained stable for more than 1000 years), they are fecund (they are transmitted generally without problems to new speakers), and long-lived (once one acquires the phonemes of one's mother tongue, it is difficult to get rid of them, even if one tries hard). Therefore, based on these criteria, there is no doubt in Ritt's mind that phonemes qualify as replicators, and—if these were the only criteria—we would certainly agree with it. Notice, however, that at no point, Ritt mentions *information* or *meaning* as a criterion for replicator-hood, a property that tends to figure very prominently in the discussions of Maynard Smith and Szathmáry (1995) or Dennett (2017). Indeed, Ritt (2004, p. 138) goes so far as saying that "the issue [of meaning] is still so poorly understood that committing oneself with regard to the potential replicator status of linguistically transported meaning would clearly be premature" and he notes elsewhere that "form-meaning pairings as assumed in lexicography and traditional structuralist morphology may have no status as units in a replicator based approach to language" (Ritt 2004, p. 153).

While Ritt's contention may look methodologically prudent, it evacuates what makes language language—and what makes it so exciting to at least some evolutionary biologists and also laymen: its a priori unlimited capacity to transmit meaning (whatever that may be). An issue related to this is the fact that what figures as prototypical memes is quite divergent in the discussions by Ritt and, e.g., by Dennett (2017). For Dennett, words are the prototypical memes.[15] We are therefore faced with the paradox that the linguist who has vindicated most vocally and carefully a meme-based and Dawkinsian approach to linguistics also ends up having memes that look very unlike the memes other (non-linguist) memeticists attend to.

One might contend that this is a pure issue of terminology. It seems to us on the contrary that the idea of information transmission is what is implicitly at the base of the whole idea of memetics, and that it would be premature to dispense totally with

[14] Ritt (2004, p. 133) insists on the idea that "phonemes" must designate linguistic *competence* entities, that is, ultimately, neural networks in the brain for categorising a given class of sounds, and for producing them. That is, the replicator /t/ is not some (class of) physical and external sound(s), but a mental program capable of detecting and producing this class of sounds.

[15] Remember also Darwin's quote on words at the beginning of the paper.

it. We will pursue this discussion in Sect. 4.3. But before we do so, we will point out two other points that argue for a separation of these two levels: First, we will show that there is evidence for fitness conflicts between elements of A1 and A2; second, we will argue that there is at least the possibility that at some stage protolanguages had A1, but not A2.

4.1 Fitness conflicts between A1 and A2

If there is no interaction or conflict between (potential) replicators in A1 and A2, these two levels can be seen as completely independent, and there is no real stake in trying to determine whether there is one or several different levels of replicators in a language, and which level should be accorded the privileged replicator status. However, there is an observation (see, e.g., Fenk-Oczlon and Fenk 2008), that the level of complexity at an underlying level has an impact on the immediately superior level of complexity. While Fenk-Oczlon & Fenk do not consider this particular case, there is every reason to assume that the number of phonemes in a language conditions the length needed to code signs in that language (Wichmann et al. 2011), which implies that phonemes and signs do not have entirely separate fitness interests.

In order to see that, let us consider a greatly simplified setup. We will assume a language with 2000 signs, that is, distinct elements of A1. We will assume, for the sake of the argument, that all phonemes (that is, distinct elements of A2) can be combined without any restrictions. Given k distinct phonemes, and a signifier-length of r, there are k^r different permutations of the phonemes. For strings of a length up to r, we get therefore a total length of different signifier combinations of $\sum_1^r k^r$. Since all memes are memory-based, all things being equal, the shorter the better. We will assume that there are no differences in elements of A2, but there clearly are signs with shorter signifiers than others (for instance, in English, the indefinite article *a* clearly has a lighter signifier than *umbrella*). So, the fitness interest of a sign implies a short signifier. However, the number of phonemes constrains the length of a signifier (or at least, the mean length of signifiers). This is illustrated in Fig. 1.

Figure 1 is based on the following assumptions: first, that every sign has to be coded by a unique signifier; and second, that every phoneme can co-occur freely with any other phoneme. These assumptions considerably facilitate the maths, and the basic points will carry over also to languages with more realistic phonological systems. However, one should be conscious that both assumptions are violated in naturally occurring linguistic systems. In English, there is no constraint on unique signifiers for signs. Indeed, the phenomenon is known in linguistics as *homonymy*, and is fairly widespread in natural languages. For instance, in English, /tu/ corresponds to at least two different signs, namely *too* and *two*. Homonymy reduces the maximal length of coding. Second, English does not allow phonemes to co-occur freely—a phenomenon known as *phonotactics*. Strings like "*ptgk*" are not possible signifiers in English, although all individual ingredients are phonemes of

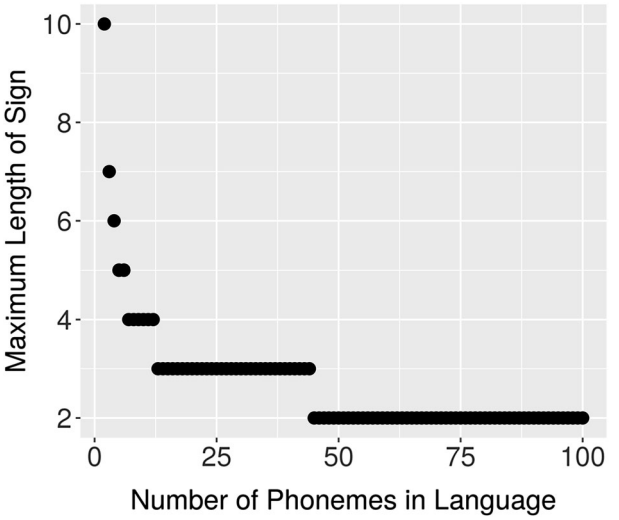

Fig. 1 Maximum string length needed to code 2000 signs in relation to the number of phonemes in the language

English. Constraints on phonotactics lengthen the minimally necessary string length.[16]

Let us come back to the diagram, and what it shows us about the possible competition between elements of A1 and A2. First of all, as the number of phonemes in a language grows, the maximum length (as measured in number of phonemes) needed in order to code a signifier decreases. In our example, in order to be able to code 2000 signs with unique signifiers, with two phonemes, we need a length of 10 phonemes, whereas in a language with 3 phonemes, that length is at 7 phonemes, and decreases further when there are more phonemes available. Yet, the decrease reaches a plateau at 2, beginning at 44 phonemes.[17] So, everything else being equal, signs have a fitness interest in having more phonemes such that they can be shorter (on average), but the advantage signs have from having more phonemes will quickly go down as the number of phonemes increases. Inside a plateau, the fitness interests of elements of A1 do not exercise any constraint on elements of A2.

On the other hand, the fitness interests of individual phonemes imply that there should exist as little other phonemes as possible, since their share in the speech-stream would then mechanically go up. Therefore, the interaction between elements

[16] It is probably safe to assume that the impact of phonotactics outweighs by far the impact of homonymy. Each case of homonymy reduces the number of unique signifiers by 1; each case of a phonotactic constraint reduces the number of unique possible signifiers by some factor *n*. For instance, English is generally assumed to have 44 phonemes, but the maximal sign length is clearly higher than 2 (for instance, *banana* has a signifier length of 6 phonemes).

[17] In order to code each sign with a unique one-length string, the number of phonemes would have to be equal to the number of signs, which would happen here with 2000 phonemes. But then, by definition, the language would no longer have DoP.

of A1 and elements of A2 can entail conflicting fitness interests between these two levels, and they are thus not completely independent one from the other.

4.2 The order in historical developments leading to DoP

While there is no solid data on how natural languages have arisen, there are a number of educated guesses that provide us with the basic steps ancestors of current natural languages must have gone through. At the beginning stands a completely holistic protolanguage (which may already have achieved a considerable degree of communicative sophistication). This means that a speech act consists of some vocalization or gesticulation where there are no discrete elements whatsoever, be they carriers of meaning or not. In any case, this step assumes that, already at the outset, the signals are conventional, and can be used for multiple illocutionary acts.[18] At the (provisional) end stand today's natural languages (be they oral or signed), which—with the exception of emerging sign languages like ABSL—are structurally very much alike when Duality of Patterning is concerned. Whereas the endpoints are reasonably clear, the intermediate steps on the path are much less clear.

We see in principle three different options: (a) A1 first, A2 second[19]; (b) A2 first, A1 second; or (c) one system evolves A1, another A2, and these two systems are eventually integrated. All three variants have their defenders: option (a) in Hockett (1960/1982, p. 12) and Sandler et al. (2011)—the latter based on ABSL; (b) is favored by Jackendoff (1999, p. 273ff.), and (c) seems to be the version defended by Fitch (2010). There are enlightening simulation-based accounts of the emergence of either articulation on its own (see Zuidema and de Boer 2009 for A2; and Kirby 2002 for A1); however, as far as we know, there is no detailed account describing the conditions under which the interaction of these two processes could have emerged.

Let us consider the first path. As we have seen with respect to ABSL, there exist even today languages that have elements of A1, but where there is not yet an articulation of A2. While ABSL is certainly much more complex than the first steps toward natural languages as we know today, its mere existence shows that highly elaborate communicative systems without A2 are possible, and that therefore, the A1 first, A2 second is a strong contender for an intermediate between the holistic protolanguage and fully doubly articulated contemporary natural languages. Now, this does not provide us with any degree of certainty, since all currently living speakers of such languages are behaviorally fully modern human beings, which was not necessarily the case for speakers of transitional forms of human languages in the distant past.

What kind of process might have bootstrapped the development of A1? One idea is that reduplication provides a very simple and partially iconic way of creating a

[18] Evidence from language acquisition with pragmatic impairment suggest that different kinds of illocutionary acts are basically independent (see already Skinner 1957), and that using one and the same symbol for describing and asking for an object has to be learnt.

[19] By "X first, Y second", we do not mean that the semiotic system would have a complete articulation of one sort or the other in place, before starting the other; we merely wish to imply that there was at least the beginning of one articulation in place before the other starts.

segmentable message (see Marcus 2006). Another (possibly complementary) idea is that, if the signaling system contains a distinction between basically propositional signals (e.g., "ugly") and vocatives ("John"), these can be at some point juxtaposed. In this way, we would have a (rudimentary) language exhibiting the first articulation, that is, where signals can be composed of more basic building blocks having their independent meanings, meanings which are reflected in the meaning of the global signal. This would correspond to what Jackendoff calls the "concatenation of symbols"-stage. The benefit of A2 would then be to stabilize the elements of A1, and to eliminate variation.

While this scenario is sketchy, the possibility of a passage from holistic and unarticulated signals by A1-first-A2 second seems to be feasible. However, we are not aware of any attested natural language featuring an A2-first-A1-second pattern, nor of a situation where two different semiotic systems, both with some degree of one single articulation, but completely lacking the other, would have integrated. But then again, this might just be due to a lack of currently available data, or a historical accident.

The question is: can we reconstruct a A2-first-A1 second scenario, and would it be more or less plausible to lead to full DoP than the opposite order? Answering these questions in the affirmative does not appear obvious to us, for the following reason. The general idea of the function of A2 is that it stabilizes the signal and eliminates variation—which tends to be good for maintaining the replicators in whatever state they are in when A2 kicks in. However, if the systems stabilizes with A2 in place, and no A1—that is, all signs correspond more or less to sentences—, this would lower the pressure towards a subsequent move to full DoP, or for any further move whatsoever. Therefore, we would expect that an A2-first development at least slows down considerably the development of A1—even if it may not be sufficient to outright block the development of DoP.

The musical protolanguage hypothesis of Fitch (2010), which suggests that there was at some point a language with A2, but which had no propositional meaning attached to it, faces the problem of integration with some other very rudimentary communication system (possibly having a beginning of A1, but in any case, carrying propositional meaning). How and why this would have happened remains to be clarified, but if the non-musical, propositional system simply had imported A2, this would then in some sense be a variation of A1 first, A2 second.

Should these speculations be correct—and they might very well be proven to be incomplete or false by ulterior studies of the matter—, it suggests that, historically, A1 was the primary replicator level, and A2 a secondary level of replicators, whose essential feature was to stabilize the level of A1, and thus, serving its fitness interests by introducing what Dennett (2017, p. 109) calls the *digitization* of the signal. We take the existence of ABSL to be the major piece of evidence supporting this conclusion, even in case subsequent simulation studies should show that either direction of development is theoretically possible.

4.3 (Cultural) Replicators carry information

As we have seen above, the idea of a replicator is generally cast in terms of fecundity, copy-stability, and longevity. These are however purely formal features of replicators (and possibly, the only features that the simplest kinds of replicators have in an autocatalytic system).

The great excitement with genes and memes, however, does not seem to be caused by what one can see merely as *replication for replication's sake*. These replicators have a more substantial feature: they store and transmit *information*; they *code for* something. While this feature is most often left purely implicit in the case of memes, it is sometimes stated[20]; and biologists' talk about the "genetic code" is certainly not accidental, a fact that Maynard Smith and Szathmáry (1999, p. 9ff.) insist on.[21]

Now, by definition, it looks like the elements of A1 have this property, whereas the elements of A2 lack it. Therefore, one may argue, phonemes are no replicators (and by extension, no memes). This idea is, however, not as obvious as it may look at first sight, and it points to another thorny issue, namely the question of distinguishing information from proper linguistic coding. It is possible that such a distinction only makes sense in a system like a natural language, where we can distinguish what is coded in the message from the general information content of the environment in which the signal is produced.

Phonemes as such, by definition, do not carry meaning. However, this does not mean that one cannot extract information from them, because of a lack of entropy in their distribution. As an example, consider a simple substitution cipher, encoding a text of sufficient length in English, and let us pretend for the sake of the argument that the letters can be taken to be the equivalents of phonemes. Substitution ciphers are not safe, because one can simply analyze the frequency distribution of the letters in the encrypted text, compare this to the effective frequency distribution of unencrypted text in English, and deduce from there which symbol stands for which letter. Similarly, because some phonemes are much more frequent than others in a given language, the appearance of a relatively rare phoneme (such as /ʃ/ in English, which is the first sound in the word "*shoe*") is more informative than a frequent phoneme (such as /n/ in English), because it allows to deduce that one is confronted with an element of the small class of signs containing /ʃ/, and not with an element of the big class of signs containing /n/. Thus, in some way, one can say that phonemes convey information, even though it is also correct to say that they are meaningless, from a conventional linguistic perspective.[22]

[20] See, e.g., Sterelny (2012, p. xiv) who does not endorse a memetic perspective, but who helpfully provides a definition in his rejection: "I make no commitments to memes: to discrete, replicated *units of cultural information* that have fitness interests of their own" [our emphasis]. See also Maynard Smith and Szathmáry (1999), as already cited above. Dennett (2017) also insists on the importance of information.

[21] They do so based on their conception of life, which is at the same time metabolic and genetic, equating the genetic part (following Gánti) with informational control. As they write, such a conception ultimately goes back to Aristotle. See the first chapter of Maynard Smith and Szathmáry (1999, p. 1–13), which has the telling title "*Life and Information*".

[22] The phonestemes discussed above possibly illustrate the same fact.

There is another sense in which one can take phonemes to carry information, if one places oneself in Ritt's competence-perspective on phonemes, that is, if one sees a phoneme as a neural network able to recognize and to produce linguistic sounds of a given class. According to this idea, a phoneme involves on the recognition-side categorization, and given a sound, it will output "true" if the sound corresponds to the phoneme, and "false", if the sound does not belong to the distinguished class of sounds. Now, according to formal theories of meaning (see, e.g., Heim and Kratzer 1998), this behavior is technically identical to the semantics of other types of linguistic predicates. Consider the meaning of a noun like "table", which, given an object that is a table, will produce "true", and given an object that is not a table, will produce "false".[23] Surely nobody would want to deny that "table" carries information, but then, in which way do phonemes differ from nouns in the kind of information they transmit, or how they are informative?

One idea is that the predicate involved in phoneme categorization does not seem to survive into sentence or sign meaning. This issue is qualified generally as the *compositionality* of natural language: the meaning of a complex linguistic expression (like a sentence) is a function of the meaning of its parts. Phonemes are strictly sequential, whereas meaning is not. Replicators carry information that form part of a speaker's commitment that is reflected in a speech act; but information provided by phonemes does not.

A second distinction one can draw between the two levels is what the information is about. The information encoded at the level of A1—which then combines into more complicated structures—can arguably be information about anything. The great advantage of using natural language is that it can be used to transmit ideas about subatomic particles, long-dead heroes, or basically unobservable mind-states of a speaker. There may be more convenient ways of expressing some of these states (e.g., by mathematics), because they are less ambiguous, or more concise; and natural language does not guarantee that everything one can say will be sound. With natural language, in principle, one can say anything about everything. Now, what about elements of A2? The idea is that information conveyed by elements of A2 presupposes the existence of elements of A1, and that information carried by A2 is necessarily about A1 in the direct sense, and can carry information about anything else only via A1.

Therefore, while one cannot say that by definition, elements of A2 do not carry information at all, there remains a logical anteriority of the level of A1, if we assume that it is a defining property of replicators to carry information. This notional anteriority of meaning to non-meaning is also obvious in the standard procedure of establishing whether a sound or gesture is a phoneme—the methodology of minimal pairs. This effectively presupposes that there is meaning encoded somewhere. It does not presuppose that meaning has to be necessarily articulated, that is, that one can establish meaningful subparts, but meaning has to be there nevertheless.

[23] In the type-theory of formal semantics, one would attribute the type ⟨e,t⟩ to both of them, even though the sort of entities classified (sounds vs. objects) would not be the same.

In this section, we have explored the replicator-status of entities of A1 and A2 in the context of the structural similarity of DNA and natural language. In particular, we have explored whether phonemes should be considered to be replicators, when they correspond structurally to the nucleotides of DNA, rather than to genes (as a meme should). A position according to which there would be two different and independent kinds of replicators in semiotic systems exhibiting DoP is not without its problems because a) there are (at least potential) fitness conflicts between the (presumptive) replicators of the two levels, and therefore, they are not really independent from each other; b) there are arguments to the effect that A1 is anterior to A2, and therefore, elements of A2 have the essential property of stabilizing elements of A1. Most importantly, the idea that a (cultural) replicator necessarily carries information—even considering the caveats seen above—strongly favors seeing the basic elements of A1 as replicators, and excluding from that status the elements of A2. It seems to us that the structural similarity of DNA and natural language (with DoP) is a profound one, and that it is not only a consequence of superimposing onto a domain of humanities supposedly clearer concepts from science.

That being said, it is equally true that phonemes are culturally transmitted, memory-based, and arguably more stable than run-of-the-mill signs. Research based on the cultural evolution-paradigm has yielded important insights into the development of combinatorial phonology. Yet, as such, a phoneme does not carry any information; its purpose is merely to be different from other phonemes.

Accepting phonemes as memes comes with a price: the general and neat analogy between genes and memes is obscured. Depending on how serious one is with Universal Darwinism, one might need to bite the bullet and attribute replicator-status to the nucleotides—which is probably not a particularly attractive option. On the other hand, if one wants to run with Maynard Smith & Szathmáry—who place language as the last major transition in evolution—and therefore deny replicator-status to phonemes, this has also non-obvious consequences: it requires to distinguish two different kinds of culturally transmitted memory-based entities, of which only one, the basic elements of A1, would be memes. It is also possible to consider that developing such an analogy—between two very different domains—necessarily leads to unresolved issues.

5 Conclusion

In this paper, we have taken as point of departure Dawkins' meme-based approach to cultural evolution, and Maynard Smith & Szathmáry's idea of language as a Major Transition of Evolution, corresponding to an entirely new way of storing and transmitting information. Against that background, we have tried to point out difficulties that arise when semiotic systems exhibiting DoP are treated in a memetic perspective. Our main conclusion is that the great similarity in structure of natural language and DNA, and their shared characteristics as systems of unlimited heredity, paradoxically complicate the application of memetic notions to linguistics —at least if one is willing to grant wisdom to the established distinction between

two radically different kinds of basic entities in natural languages, namely phonemes and morphemes (signs).

While we have argued that natural language provides structural complications that other areas of culturally transmitted artefacts-behaviors-concepts are not afflicted with, we do think that, if one considers an investigation into the nature of memes worthy of pursuit, linguistics is in a unique position in the humanities with respect to memetics. It is the one discipline (probably with musicology) that has the analytical tools and the collected data to meaningfully address the issue of the properties of replicators, and it is the only discipline (other than genetics) we are aware of that is working on a coding system with Duality of Patterning.

To us, the analogy between genes and memes, and the structure of DNA and of natural language seems interesting, and worth preserving—even though we are aware of its limits. So, what should we do in this case with phonemes, if we end up denying them the status of memes? One may propose to call them *modules* (following the terminology of Maynard Smith and Szathmáry (1999, p. 8), or *digits* (adapting the terminology of Dennett 2017)—since what they do is to decompose the signal and the memes into discrete, digital entities.

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