

Title: New Perspectives on Duality of Patterning: Introduction to the Special Issue

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1 — Introduction

This special issue assembles a number of papers that present recent work on the nature and the emergence of duality of patterning. Duality of patterning (Hockett 1960) is the property of human language that enables combinatorial structure on two distinct levels: meaningless sounds can be combined into meaningful morphemes and words, which themselves could be combined further. We will refer to recombination at the first level as *combinatorial* structure, while recombination at the second level will be called *compositional* structure.

According to Hockett (1960), duality of patterning is a *design feature* of human language (meaning that all human languages have it) while it is also *unique* to human language. He argued that it evolves when a growing number of meanings need to be expressed, so that combinatorial structure helps to keep signals distinct. More recently similar arguments have been made on the basis of mathematical and computational models (e. g. Nowak *et al.*, 1999; Zuidema & de Boer, 2009). Although it seems to be uncontroversial that recombination of meaningful elements (i.e. compositional structure) is needed for an unlimited system, the relation between an unlimited set of signals and recombination of meaningless elements (i.e. combinatorial structure) is less clear.

1.1 *Is duality of patterning a design feature?*

On the one hand, simple combinatorial structure has been found in systems of primate vocalizations with a relatively limited set of signals (Arnold & Zuberbühler, 2006; Yip, 2006), indicating that duality may not be uniquely human and that it may occur in systems in which it is not needed to keep signals distinct. On the other hand, there is some evidence that duality of patterning is not required for a human language. Combinatorial structure does not appear to have crystallized in a recently emerging sign language: Al-Sayyid Bedouin Sign Language even though it is a fully expressive language (Sandler et al 2011).

In the ~75 years since its emergence, Al Sayyid Bedouin Sign Language (ABSL) has come to serve all the communicative functions usually associated with language and has been shown to have compositional structure at the levels of morphology (Meir et al 2009) and syntax (Sandler et al 2005; Padden et al 2010). However, the community has not yet converged on a conventionalized level of meaningless elements, although the beginnings of phonology can be discerned (Sandler et al 2011). The ABSL findings show that a language without a clearly phonological level of structure is possible. This contrasts with more established sign languages, whose lexical signs are made up of meaningless contrastive units belonging to the categories of handshape, location, and movement.¹ While there is a degree of linear organization in the combination of elements in a sign, certain key formational elements combine with one another simultaneously and, as a result, a likely holistic source is often quite transparent. Because sign languages have a strongly iconic base, so that language users needn't distinguish large sets of purely arbitrary holistic auditory signals, the ABSL researchers suggest that the development of a large vocabulary before holistic gestures are decomposed into a system of meaningless elements might be easier in

¹ See Sandler (2012) for an overview of sign language phonology.

signed than in spoken languages. However, as Blevins (this issue) shows using data from spoken languages, iconicity is not a necessary condition for isomorphism between the two levels of structure to occur frequently in a language, and explanation of the evolution and predominance of dual patterning remains a challenge.

We see then from the case of ABSL that the need to express a large set of signals does not necessarily lead to combinatorial structure, while conversely from the animal systems, it appears that combinatorial structure does not necessarily need a very large set of signals to emerge. As combinatorial structure is the main defining characteristic of duality of patterning, it appears that both the status of duality of patterning as a design feature of language and the evolutionary pathways leading to it need to be rethought.

1.2 *New perspectives on duality of patterning*

There is more than one way to think about compositional and combinatorial structure from a theoretical point of view, and research shows that languages are not as uniform in distinguishing between these two levels as one might expect. The focus of inquiry could either be placed on distinctions between the two (in the spirit of Hockett 1960) or on the relation between them (after Martinet 1980), and each vantage point leads to different expectations regarding the nature of the structure at each level. An objective survey of actual human languages reveals that duality of patterning is not exceptionless, and a range of phenomena blur the two in many languages of the world. Examples are so-called root-forming morphemes in words like *glimmer*, *glitter*, *gleam*, *glisten* (Bloomfield 1933), ideophones or expressives, morphemes in which sound and meaning are intertwined (Klamer 2002), and mimetics, systems in which non-word sound sequences and even individual phonological features are associated with meanings (Hanamo 1994). Why and how then does duality triumph as the predominant type of organization?

Recent advances in the experimental study of cultural evolution have made it possible to study questions related to the evolution of cognitive phenomena such as duality of patterning directly. These advances consist on the one hand of the use of agent-based computer modeling techniques (Kirby, 2002; Wang & Minett, 2005), and on the other hand on re-creating cultural evolution in the laboratory (Kirby *et al.*, 2008; Scott-Phillips & Kirby, 2010). In agent-based computer models, a population of individual language users (agents) is re-created in the computer and its behavior is followed over time. In this way, it is possible to precisely control the linguistic and cognitive properties of the agents, and the effect of such individual behaviors on the language can be investigated.

Inspired by the success of such agent-based modeling efforts, researchers have recently begun to re-create cultural evolution in a laboratory setting using human participants (Galantucci, 2005). Despite certain complications and complexities inherent in such experiments, faithfulness to human minds is increased, since the learning behavior is given – it is ordinary human learning. Crucially, these experiments allow for the possibility of controlling the cultural setting exactly. There are two variants. In ‘social coordination experiments’ (Garrod *et al.*, 2010), it is possible to model the spread of conventions in a population. In ‘diffusion chains’ (Smith *et al.*, 2008) language is transferred from one experimental generation to the next.

By presenting recent theoretical, modeling and experimental work on duality of patterning in this special issue, we hope to show that duality of patterning is still a rich topic of research, and to show how theoretical analyses of naturally occurring linguistic phenomena can be successfully complemented by laboratory experimentation of different kinds to elucidate aspects of the evolution of cognition and culture.

2 — The contributions

The special issue consists of six contributions, two of a more theoretical nature, based on naturally occurring language data, and four using models or experiments to test hypotheses about the emergence of duality of patterning through cultural transmission and social coordination.

2.1 Theoretical contributions

Ladd's overview article opens the special issue by exploring the theoretical underpinnings of the notion of duality of patterning. There he contrasts Hockett's design feature view with Martinet's concept of double articulation and considers implications for investigation of the phenomenon. For Hockett, the breaking down of meaningful linguistic signals into meaningless combinations of sounds must have arisen in order to make it possible to generate larger vocabularies than could have been possible with holistic calls. The most important characteristic of duality for Hockett is the patterning – distinct kinds of structure at each level. Neither the particular form each level takes nor the relation between the two levels is central to the role of duality in human communication. For Martinet, both levels of structure are necessarily linear in form, and the primary, meaningless level of phonemes comprises the secondary, meaningful level of words, which in turn comprises sentences. Through clarification of theoretical differences between these two ostensibly similar approaches, Ladd identifies different implications for the study of language evolution, as well as for the comparison of duality in signed and spoken language.

In any treatment of duality, the main point is that the phonological/segmental level is distinguished from the morphological level. In her article in this issue, Blevins unpacks the notion of duality of patterning by asking whether it is a given -- and thus a mandatory -- design feature of human language or whether it is a statistical tendency. She provides data showing that there are spoken languages containing words in which each segment is a meaningful morpheme. On the basis of such data, Blevins argues that it is hypothetically possible to construct quite a large vocabulary with the right combination of segment inventory size, templatic morphology, and syllable types, even without duality of patterning. Blevins goes so far as to suggest that "the absence of languages with all and only mono-segmental morphemes could be viewed as accidental".

2.2 Experimental contributions

The next four contributions use experimental techniques to test hypotheses about the emergence of duality of patterning from cultural processes.

Roberts and Galantucci's contribution investigates the effect of lexicon size on combinatorial structure through a social coordination experiment. They propose two

possible (and non-exclusive) routes to duality of patterning. The first route comprises an increase of set size leading to combinatorial structure in order to keep signals apart (as Hockett 1960 proposed). The second route consists of conventionalization of iconic signs, and their subsequent re-interpretation as consisting of recombinable elements. In their experiment, participants develop a set of non-persistent visual signals to express a set of objects. They measure the size of the set of signals that are learned correctly, as well as the level of iconicity of the signals and the degree to which they have combinatorial structure. Their statistical analysis indicates that both of their scenarios are supported by behavior of the participants in the experiments.

Wedel's contribution investigates the hypothesis that diachronic change towards duality of patterning is the result of synchronous biases on learning and production of speech, rather than the effect of an increasingly large set of signals. He makes a number of observations of human behavior: that speakers tend to exaggerate meaningful contrasts in speech, that precise realization of phonemes is influenced by how other speakers realize those phonemes and that speech errors tend to be in the direction of making words sound more similar. Wedel proposes that this leads to two opposing processes: one trying to preserve lexical contrast and one trying to make sub-lexical elements (e.g. phonemes) sound as similar as possible. His agent-based computational model demonstrates that combinatorial structure using a small set of sub-lexical elements can in fact emerge under these conditions. He goes on to demonstrate that the same model can account for chain shifts, that is, if one sub-lexical element is moved, the other elements will re-arrange themselves over time to rebalance the system. Wedel's contribution presents a bottom-up model of how combinatorial structure can emerge: small individual biases conspire to produce very clear structure on the population level.

Verhoef's contribution also investigates the emergence of combinatorial structure in a relatively small set of signals. Her paper is based on two experiments. The first investigating the emergence of combinatorial structure using a diffusion chain in which participants are asked to learn and reproduce meaningless signals. The signals they reproduce are then used as input for the next generation. Although the set of signals is small, and although the lack of meaning precludes iconic signals, combinatorial structure nevertheless emerges over the experimental generations. Her second experiment investigates whether the structure that becomes apparent can be used by human listeners to categorize signals on the basis of whether they belong to the system or not, and she finds that this is indeed the case. Her findings indicate that combinatorial structure requires neither large sets of signals nor iconicity to emerge, and that listeners can actively use the emerged structure to classify signals. Interestingly, she finds that structure is created through the relatively abrupt processes of repeating, mirroring and recombining elements from learned signals. This is different from the more gradual processes proposed by Wedel, although the gradual and abrupt processes are not mutually exclusive.

Del Giudice's contribution covers a middle ground between the experiments of Roberts & Galantucci and of Verhoef. It uses graphical signals that are quite similar to those of Roberts & Galantucci, but it investigates a diffusion chain, just like Verhoef's experiment. It presents two experiments: one in which signals are not associated with meanings, and one in which signals are associated with meanings. Del Giudice observes less clear use of iconic structure than was found in Roberts and Galantucci's

experiment, but the study does show an increase in the use of combinatorial structure. Like Verhoef, Del Guidice does not attribute emergence of combinatorial structure to simple maximization of distinctiveness, favoring instead a two-step interpretation of the emergence of structure. He observes that subunits are introduced spontaneously, and that minimal pairs are then embellished in order to make them more distinctive. This path to duality is compatible with the model proposed by Wedel.

3 — Discussion

From these papers, it appears that duality of patterning is not as straightforward a design feature of language as it might seem at first sight, and that it is not even clear whether it is a necessary or unique property of human language. There also appears to be no simple answer to the question in which way and for what reasons duality of patterning has emerged. On the other hand, the papers show the value of combining cross-linguistic observation, computer modeling and experiments in tackling this fundamental issue. We believe this special issue helps to refine the notion of duality of patterning, testing concepts and processes that account for its existence in language, and in so doing, to shed light on its evolutionary origins – squarely addressing questions that were hitherto thought to be of the kind that can never be answered (Lewontin, 1998).

The relevant data for answering these questions may come from languages and aspects of language that are sometimes considered marginal, exceptional or even pathological. These can be emerging (sign) languages, such as ABSL, but they can also be aspects of an otherwise normal language, such as onomatopoeia, root-forming morphemes, mono-phonemic morphemes (as mentioned by Blevins) and ideophones. As becomes clear from Wedel's observations, it can also be useful to pay attention to cognitive linguistic processes that are sometimes considered to be marginal rather than central to linguistic processing, such as speaker adaptation and word-specific allophonic variation. As the contributions in this special issue show, these seemingly marginal phenomena shed light on questions that are central to linguistics, such as those of the nature and the origins of phonemes, morphemes, and duality of patterning.

3.1 Cultural evolution of duality of patterning

An apparent point of consensus from the papers in this special issue is that we should not see duality of patterning as a feature hard-wired into an innate language faculty, but rather as arising from multiple pressures operating on language as it emerges and changes in socially interacting populations. When we talk about the evolution of this design feature of language, then, we are referring more to cultural rather than biological evolution. In this sense, the papers in this special issue contribute to a view of language as a complex adaptive system in its own right – one which responds to pressures placed upon it in the process of being used communicatively and transmitted within populations and across generations. It appears that duality of patterning is a rather general state towards which sufficiently complex systems of signals evolve for different reasons: distinctiveness, learnability and a tendency to keep meaningful distinctions, while at the same time trying to make one's utterances sound similar to those of others in the population. Thus, multiple cognitive processes seem to lead to duality of patterning and therefore, there are probably multiple evolutionary pathways that lead to duality of patterning as well.

When considering duality of patterning (and therefore the nature of phonemic and morphemic structure of language) from this perspective, a number of questions become apparent. What cognitive mechanisms lead to duality of patterning, and how language-specific are these mechanisms? What are the minimal requirements for duality of patterning to emerge? As for observation of existing linguistic systems: it has already been mentioned that a number of phenomena that have a somewhat marginal status appear to be highly relevant for understanding duality of patterning, but are there perhaps other phenomena or linguistic behaviors that we could look at? What is the cross-linguistic variation in all these phenomena and behaviors? Are there other examples, besides ABSL, of languages in which duality of patterning is only partly present? We view the concepts, experiments and models presented in this volume as refinements of the issues involved in duality of patterning, and hope that they provide frameworks for future investigation of this fundamental organizing property of human languages.

References

- Arnold, K., & Zuberbühler, K. (2006). The alarm-calling system of adult male putty-nosed monkeys, *Cercopithecus nictitans martini*. *Animal Behaviour*, 72(3), 643-653.
- Bloomfield, Leonard. 1933. *Language*. New York: Henry Holt
- Galantucci, B. (2005). An experimental study of the emergence of human communication. *Cognitive Science*, 29, 737-767.
- Garrod, S., Fay, N., Rogers, S., Walker, B., & Swoboda, N. (2010). Can iterated learning explain the emergence of graphical symbols? *Interaction Studies*, 11(1), 33-50.
- Hamano, Shoko. 1994. Palatalization in Japanese sound symbolism. In *Sound symbolism*, eds. Leanne Hinton, Johanna Nichols, and John J. Ohala, 148-157. Cambridge: Cambridge University Press
- Hockett, C. (1960). The origin of speech. *Scientific American*, 203, 88-111.
- Kirby, S. (2002). Natural language from artificial life. *Artificial Life*, 8(2), 185-215.
- Kirby, S., Cornish, H., & Smith, K. (2008). Cumulative cultural evolution in the laboratory: An experimental approach to the origins of structure in human language. *Proceedings of the National Academy of Sciences*, 105(31), 10681-10686.
- Klamer, Marian. 2002. Semantically motivated lexical patterns: A study of Dutch and Kambera expressives. *Language* 78: 258-286.
- Lewontin, R. C. (1998). The evolution of cognition: Questions we will never answer. In D. Scarborough & S. Sternberg (Eds.), *An invitation to cognitive science* (Vol. 4: Methods, models, and conceptual issues, pp. 107-132). Cambridge, MA: MIT Press.
- Martinet, André (1980). *Éléments de linguistique générale*. Paris: Armand Colin.
- Meir, Irit, Aronoff, Mark, Sandler, Wendy & Padden, Carol (2010). Sign languages and compounding. In S. Scalise and I. Vogel (Eds.), *Compounding*. John Benjamins 301-322.
- Nowak, M. A., Krakauer, D., & Dress, A. (1999). An error limit for the evolution of language. *Proceedings of the Royal Society of London*, 266, 2131-2136.
- Padden, Carol, Meir, Irit, Sandler, Wendy, and Aronoff, Mark (2010) Against all expectations: Encoding subjects and objects in a new language. In *Hypothesis*

- A/Hypothesis B: Linguistic Explorations in Honor of David M. Perlmutter*, D. Gerds, J. Moore & M. Polinsky, (Eds.), Cambridge, MA: MIT Press. 573-595.
- Sandler, Wendy. 2012. The phonological organization of sign languages. *Language and Linguistics Compass* 6/3:162-182.
- Sandler, W., Aronoff, M., Meir, I., & Padden, C. The gradual emergence of phonological form in a new language. *Natural Language and Linguistic Theory* ; **29**: 503.
- Scott-Phillips, T. C., & Kirby, S. (2010). Language evolution in the laboratory. *Trends in cognitive sciences*, 14, 411-417.
- Smith, K., Kalish, M. L., Griffiths, T. L., & Lewandowsky, S. (2008). Introduction. Cultural transmission and the evolution of human behaviour. *Philosophical Transactions of the Royal Society of London*, 363(1509), 3469–3476.
- Wang, W. S.-Y., & Minett, J. W. (2005). The invasion of language: Emergence, change and death. *Trends in Ecology & Evolution*, 20(5), 263–269.
- Yip, M. J. (2006). The search for phonology in other species. *Trends in cognitive sciences*, 10(10), 442-446.
- Zuidema, W., & de Boer, B. (2009). The evolution of combinatorial phonology. *Journal of Phonetics*, 37(2), 125–144.