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Combinatoriality and Compositionality in Communication, Skills, Tool Use, and Language

Nathalie Gontier[1] · Stefan Hartmann[2] · Michael Pleyer[3] · Evelina Daniela Rodrigues[4]

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Abstract

Combinatorial behavior involves combining different elements into larger aggregates with meaning. It is generally contrasted with compositionality, which involves the combining of meaningful elements into larger constituents whose meaning is derived from its component parts. Combinatoriality is commonly considered a capacity found in primates and other animals, whereas compositionality often is considered uniquely human. Questioning the validity of this claim, this multidisciplinary special issue of the *International Journal of Primatology* unites papers that each study aspects of combinatoriality and compositionality found in primate and bird communication systems, tool use, skills, and human language. The majority of authors conclude that compositionality is evolutionarily preceded by combinatoriality and that neither are uniquely human. This introduction briefly introduces readers to the major findings and issues raised by the contributors.

Keywords Combinatoriality · Compositionality · Primates · Birds · Hominids · Humans · Multimodal communication · Tool use · Skills · Language

Handling Editor: Joana (Jo) M. Setchell

✉ Nathalie Gontier
nlgontier@fc.ul.pt

Stefan Hartmann
hartmast@hhu.de

Michael Pleyer
pleyer@umk.pl

Evelina Daniela Rodrigues
erodrigues@ispa.pt

[1] Applied Evolutionary Epistemology Lab, Center for Philosophy of Science, Faculty of Science, University of Lisbon, Lisboa, Portugal

[2] Department of German Linguistics, Heinrich Heine University Düsseldorf, Düsseldorf, Germany

[3] Center for Language Evolution Studies, Nicolaus Copernicus University in Toruń, Toruń, Poland

[4] William James Centre for Research, ISPA - University Institute of Psychological, Social and Life Sciences; PCRG - Primate Cognition Research Group, Center for Philosophy of Science, Faculty of Science of the University of Lisbon, Lisboa, Portugal

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Introduction

Combinatoriality involves combining different elements into larger aggregates with meaning. Compositionality refers to combining meaningful elements into larger constituents whose meaning is derived from their component parts. Combinatoriality is generally recognized to be present in primates and other animals. Compositionality often is considered to be uniquely human. Questioning the validity of these assumptions, the authors in this issue examine how combinatoriality and compositionality can be defined and identified in three key players of the debate: (multimodal) communication systems of primates and birds; hominin tool use and skills; and human language. The majority of authors conclude that the evolution of combinatoriality precedes that on compositionality and that neither are uniquely human.

Communication Systems, Tool Use and Skills, and Language

Research on animal communication in general, and communication in apes, hominins, and birds in particular has primarily focused on how single, specific orofacial, manual, vocal, or other bodily gestures consistently convey meaning. This research was originally inspired by information and communication theory (Dawkins & Krebs, 1978; Maynard Smith, 2000; Shannon & Weaver, 1949; von Neumann, 1948), which placed emphasis on the meaning of signals and symbols and how they are transmitted, much more than on how meaning comes about and possibly changes depending upon contextual usage. These fallacies were remedied by semiotic (reviewed in Deacon, 1997; Wheeler, 2020), pragmatic (Austin, 1962; Grice, 1968; Wilson & Sperber, 2012), and overall 4-E approaches to cognition and behavior (Clark & Chalmers, 1998; Lock & Peters, 1999; Varela *et al*., 2017) that understand cognitive behavior as physically *embodied* and *enacted* by the organism, as well as *embedded* and *extended* into sociocultural and ecological settings.

More recent investigations of communication systems level up on existing research on how signals and symbols convey meaning, by examining how single information units join into larger and more variable structures that convey context-dependent meaning in the process of making meaning. Meaningful call combinations have now been observed in numerous animal and primate species (reviewed in Engesser & Townsend, 2019; Suzuki & Zuberbühler, 2019). Multimodal communication in primates (Levinson & Holler, 2014; Liebal *et al*., 2014, Slocombe et al., 2011) is one such example whereby already meaningful constructions, each produced by different modalities, often become joined into larger aggregates with variable meanings dependent on their context of use. Multimodal communication in humans can take on the form of co-verbal gesturing, where spoken utterances are combined with movements of the arms and hands (Morgenstern, 2014). In apes, multimodal communication can include the co-occurrence of distinct facial expressions with manual gestures, such as variants of the reach gesture (Oña *et al.*, 2019), the integration of visual and acoustic features in behaviors, such as lip-smacking (Micheletta *et al.*, 2013), or the combination of social calls with different gestures (Genty *et al.*, 2014). Bird song also can show variability

in call combinations (Suzuki *et al*., 2019). For instance, bird songs often combine with coordinated visual displays whose performance can affect listener response (Girard-Buttoz et al., 2020; Williams, 2004). In all cases, the meaning of the units combined varies depending on how they are joined into larger aggregates, as well as how they are used in differential sociocultural settings.

The presence of combinatorial and compositional cognitive behavior also can be derived from tool manipulation and other skilled behavior. Tool use is observed in a wide variety of extant primate and other animal species (Bentley-Condit, 2010; Boesch *et al.*, 2009; Mann & Patterson, 2013; Seed & Byrne, 2010). The archeological record associated with extinct hominins in particular shows a significant increase in raw material preference and tool type production (Gibson & Ingold, 1993; Uomini & Meyer, 2013; Uomini, 2017; Stout *et al.*, 2000), as well as an associated increase with other skilled behavior, such as hunting, weaving, or housing. These practices require the combination of different behaviors into even more complex and compositional actions whose functions can vary not only because of how they are combined but how they are used.

The evolution of communication, as well as tool use and skill development, also provides valuable ways whereby scholars can understand and study language evolution. The transition from protolanguage to language is theorized to involve the hierarchical structuring of multiple, possibly already multimodal symbols, each with variable meaning, into larger narratives with new meanings derived from their parts as well as their context of use (Ferretti, 2022; Żywiczyński & Wacewicz, 2022). Such pragmatic approaches differ from older research on language and its evolution that mostly focused on how the hierarchical structuring of language comes about (e.g., Janssen, 2012), which in turn involves the study of word order and the more general rules of grammar (Berwick & Chomsky, 2016).

Introduction to the Papers

In this multidisciplinary issue, primatologists, psychologists, anthropologists, linguists, and philosophers of science investigate how their respective fields contribute to the study of combinatoriality and compositionality. Roughly divided into three parts, the first collection of papers reviews how the presence of combinatoriality and compositionality is examined in extant primate and bird communication systems. The second series of papers looks for evidence for combinatorial and compositional behavior in hominid evolution. The last cluster of papers examines how the various forms of compositionality are studied in human language.

Combinatoriality and Compositionality in Extant Primate and Bird Communication Systems

Research on combinatoriality and compositionality in communication systems is kicked off by Federica Amici et al. (2022) who write on *Compositionality in primate gestural communication and multicomponent signal displays*. The authors review

how the multimodal gestural communication systems of nonhuman primates demonstrate compositionality, which they define as "the ability to combine meaningful elements into new combinations with novel meanings" (Amici *et al.*, 2022). According to the authors, meaning is traditionally understood to define primary communication, but scholars disagree on the meaning of meaning. A review of the literature makes the authors conclude that compositionality research requires the inclusion of meta-communicative aspects of communication. Secondary to primary communication, these include the intentionality (goal-directedness), contextuality (social use), and temporality (e.g., sequentially of calls) of signals, all of which rely on hierarchical organization. The scientific inclusion of metacommunicative aspects of communication requires an analysis of ever larger data sets. The authors briefly review how statistical analyses can help with such data mining that also requires organized data exchange between primatologists.

In their paper titled, "Operationalizing Intentionality in Primate Communication: Social and Ecological Considerations," Rodrigues & Fröhlich (2021) further link research on combinatoriality and compositionality to examinations of intentional primate multimodal communication. Pragmatic approaches explain that communication can only be effective when it leads to mutual understanding which in turn requires mentalization of intentionality in both partners. The authors review and compare the literature on zero-, first-, and second-order intentionality in prelinguistic human children with the goal of operationalizing intentionality in monkeys and apes. In these species, intentionality can only be derived from behavioral markers, such as gaze patterns and attention-getting behavior. Such behavioral markers, however, are not generalizable across certain signal types (gestures, vocalizations, and facial expressions), contexts, settings, and species. The authors argue instead that the inclusion of ecological settings and social use is a means to understand these intentional acts as multimodal, combinatorial, and compositional behaviors.

Waller *et al.* (2022) contribute a paper titled, "The Face is Central to Primate Multimodal Signals." The authors lament the lack of inclusion on facial data in primate communication research, which they attribute on the one hand to the methodological difficulty facial analysis introduces and conversely to the fact that facial expression often is categorized as emotional rather than communicative in kind. The authors however show the important role played by the face in multimodal communication, where it not only functions as an attention grabber but also as a medium for other components of communicative behavior, such as, for example, eye gazing or vocalizations. Faces in and of themselves, including neutral faces, are a gateway to a better understanding of multisensorial combinatorial and compositional communicative behavior.

Spiess *et al.* (2022) turn our attention to birds and write on "Syntax-like Structures in Maternal Contact Calls of Chestnut-Crowned Babblers (*Pomatostomus ruficeps*)" Chestnut-crowned babblers (*Pomatostomus ruficeps*) are a bird species found inland of southeastern Australia. They communicate socially through a series of calls, around 18 in total. Acoustic analysis and playback experiments of maternal contact calls show that these serially produced, high-pitched, piping calls can flexibly combine elements from two other calls: middle-distance contact calls used to recruit group members, and adult begging calls used during allo-feeding. The

resulting calls, exclusively produced by breeding females, indicate syntax-like structuring. Differential hierarchical structuring of the maternal contact call components furthermore leads to differential social replies indicating the distinct compositions serving different functions.

Combinatorial and Compositional Skills in Primates and Hominids

The following two papers in the issue turn to combinatorial and compositional skills. The first of these papers is written by Gontier (2023), and it turns attention to "Combinatoriality and Compositionality in Everyday Primate Skills." The author shows that everyday primate skills associated with subsistence and hygienic practices already indicate the presence of combinatorial and compositional behavior. By combining existing comparative primatological data with research on behavioral logics as well as *chaîne opératoire* thinking and insights from hierarchy theory, the scholar examines skills, such as pointing, grooming, and eating for how they require combinatoriality or compositionality. The author provides a scheme wherein spatial combinatorial skilled behavior is understood as aggregational, and temporal combinatorial skilled behavior as linearly hierarchical, while compositional skilled behavior is either nested or interactionally hierarchical. The approach furthermore enables to distinguish accidental from teleonomic, intentional, and creative behavior.

The second paper, written by Putt *et al.* (2022), turns to anthropological and archaeological evidence for the evolution of combinatorial and compositional behavior in hominid tool use, and is titled "The Evolution of Combinatoriality and Compositionality in Hominid Tool Use: A Comparative Perspective." Reviewing functional neuroimaging studies, the authors explain how tool and language use activate the same neural areas in the human brain. This suggests that both capacities rely on domain-general and thus shared cognitive functions rather than distinctly evolved modules. The authors identify these domain-general and shared cognitive functions as the capacities for combinatoriality and compositionality. They subsequently compare primatological and anthropological research on tool use in monkeys, apes, extinct hominins, and modern humans and propose a gradual evolution from combinatorial to compositional cognition. According to their scheme, hominin combinatorial tool use starts with the Lomekwian tool industry dated to be around 3.3 million years old, and simple compositional tool use is estimated to begin some 1.75 million years ago, with the production of Acheulean tools by *Homo erectus* and similar species. They reckon both to be conservative dates for the onset of protolanguage and syntactic language.

Compositionality in Human Language

The final three papers are written by linguists concerned with matters of compositionality. Gil (2023) provides a hierarchical scaling of different kinds of compositionality relevant to animal (primate and bird) communication and human language, in a paper titled "Bare and Constructional Compositionality." Bare compositionality occurs when

"the meaning of a complex expression is determined solely by the meanings of its constituents" (Gil, 2023), and it is distinguished from constructional compositionality "in which the meaning of a complex expression is determined by the meanings of its constituents and also by various aspects of its structure" (Gil, 2023). The former, bare form of compositionality, is understood as an evolutionary precursor to the latter form of compositionality, which has a bipartite nature because it is determined both by its structure and the meaning of its constituents. The distinction is exemplified with data drawn from lesser-known human languages as well as primate, bird, and bee communication systems. The author concludes that all systems demonstrate the, possibly independent, evolution of both types of compositionality, and he indicates the cultural or sociopolitical level of complexity as a determining factor in the correlation and transition between the two types of compositionality.

Pleyer *et al.* (2022) follow with a paper on "Compositionality and Multimodality in Linguistics: A View from Usage-based Linguistics." In linguistics, compositionality generally refers to "the notion that the meaning of a complex linguistic unit is a function of the meanings of its constituent parts" (Pleyer *et al.*, 2022). The authors question the central role of this conception of compositionality in human language and instead analyze spoken and signed language from a usage-based, pragmatic point of view that integrates construction grammar. They examine to what degree factors, such as iconicity and conventionality, contribute to meaning without being compositional. Idiomatic structures also exhibit additive meaning that extends beyond the sum of the meanings of individual parts, and these are much more pervasive in language than often is acknowledged. They extrapolate their approach to animal communication, where the authors identify multimodal communication as a comparable source for additive meaning. The authors emphasize that all forms of added meaning construction rely upon learning and sociocultural transmission.

The issue closes with the paper by Ellison and Reinöhl (2022) on "Compositionality, Metaphor, and the Evolution of Language." Following a more general approach that assigns metaphor a pivotal role in language evolution, the authors examine how functor–argument metaphors, unique to human language, must have evolved from a protolinguistic stage onward. Functor–argument metaphors result "from the semantic clash between the default meaning of terms" "forcing a nonliteral interpretation" (Ellison & Reinöhl, 2022). The example the authors give is the verb to hide, which might have evolved in a concrete food context and subsequently might have combined with a less spatially concrete word, such as anger. Words thus become decontextualized and reused in different contexts, which underlies the beginning of metaphor formation. Metaphor, according to the authors, transcends compositionality understood as the sum of existing meanings, and it can be understood as an evolutionary driver for grammaticalization by underlying word order formation and fixation, as well as the development of demonstratives.

Conclusions

Research on compositionality was by and large defined in a context of philosophical and linguistic research on human language and thought processing. However, this issue shows that beyond human language, compositionality also can be found in ape,

hominin, and bird communication systems as well as in other forms of complex and skilled cognitive behavior, such as tool manipulation. Humans are thus not the only species capable of portraying compositional behavior.

The contributors to this issue agree that compositional behavior likely evolved from combinatorial behavior, possibly multiple times over in different lineages. To reach this general conclusion, authors have primarily focused on observable communicative behavior, behavioral skills that form part of daily life or that are deducible from archeological artifacts, or current sentence constructions of living languages. The capacities to display combinatorial and compositional behavior, however, also have a strong cognitive component to it, and much research remains to be done on the neurological underpinnings of both.

Cognitively speaking, several authors in this issue point to the close relationship between combinatoriality and compositionality on the one hand, and the rise of teleonomic or goal-oriented, intentional, and creative behavior on the other. Here too, species boundaries become fuzzy, and neither of these behaviors prove to be uniquely human. Rather, many animals can display this full spectrum of behaviors.

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Declarations

Conflict of Interest The authors declare to be free from conflicts of interest.

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