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Identification of commonalities across different languages

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This article fulfills the need for quantifiable, physical, common characteristics across different languages, which is needed to support the theory that humans use domain-general neurocognitive machinery to acquire, process, and produce language. It is shown that four different languages—English, German, Slovak and Japanese—contain linguistic chunks characterized by at least one redundancy, degeneracy, pluripotentiality, or modularity (R, D, P, or M, respectively) trait, following precedent from other fields of signal investigation. It is first established that *language can be regarded as a set of signals* between individuals within a complex adaptive system framework and that all signals in all signaling systems exhibit R, D, P, and/or M traits. It is then shown that *linguistic chunks can be regarded as individual signals* and that the *chunks examined from the aforementioned languages express at least one R, D, P, and/or M trait*. The present contribution thereby indicates the potential provision of a new source of data for quantifying some of the pressures involved in language production and processing, and the work concludes by assessing the value of the present work for further investigation in related fields.

KEYWORDS

language acquisition, signals, degeneracy, modularity, robustness, resilience, commonality

1 Introduction

All human societies use language to communicate (see Gontier, 2022, for a more extensive treatment of what language is), and all humans use the same neurocognitive machinery to process and produce language (Del Maschio and Abutalebi, 2019; Macuch Silva et al., 2020; Malik-Moraleda et al., 2022). However, the characterization of common traits across different languages is lacking. This work presents a suggestion for classifying linguistic chunks, thereby allowing their quantitative analysis across different languages in the future. A tentative first assessment of this suggested system of classification is then made across four languages—English, German, Slovak, and Japanese.

The investigation begins by establishing whether it is possible to view language as a system of signals. This is done by assessing language as a phenomenon within a complex adaptive system (CAS) theory framework, and it is shown that it is possible to consider language as a system of signals between independent actors in a CAS. The investigation continues by identifying commonalities across all systems of signaling within CASs, establishing that it is feasible to regard linguistic "chunks" as signals, and it finishes by verifying the existence of four universal chunk traits across four different languages, all of which have been used on a routine basis by the author at one time or another.

2 Considering language a system of signals

Language has been viewed as a system of signals (Holler and Levinson, 2019; Macuch Silva et al., 2020), although this view is also contested (Reboul, 2015). To further substantiate this idea, the concept of language as a system of communication between autonomous agents (Lipowska and Lipowski, 2022) is examined within a CAS theory framework.

2.1 CASs

CAS theory seeks to understand how seemingly unconnected individual, autonomous, possibly heterogeneous components inside a chaotic assembly interact and exhibit a sustained, recognizable self-organization at the macro-level. Furthermore, the activity of these autonomous actors produces a predictable behavior of the system as an entity observable from outside the system—*the behavior emerges.* However, the behavior of individual actors in the system and the behavior of the system as a whole might be very different. Since the phrase "complex adaptive system" was first used in the late 1960s by Walter F. Buckley (1968) and the framework developed further in the 1990s by such as Gell-Mann (1994), Holland (1996), and Kauffman (1993), CAS theory has been applied to many areas to better facilitate an understanding of them, including immune systems (Grilo et al., 2002), the economy (Tesfatsion, 2003), the brain (Sporns et al., 2000; Singer, 2018), organized crime gangs (Magliocca et al., 2019), supply chain networks (Surana et al., 2005) and language (Larsen-Freeman, 1997; Cornish et al., 2009; Five Graces Group et al., 2009). A domain-general CAS model is presented in Figure 1.

Inside the system, (A) "Actors"—free to enter and leave a system, for example, through birth and death or migration between communities—are possibly heterogeneous, self-maximizing,

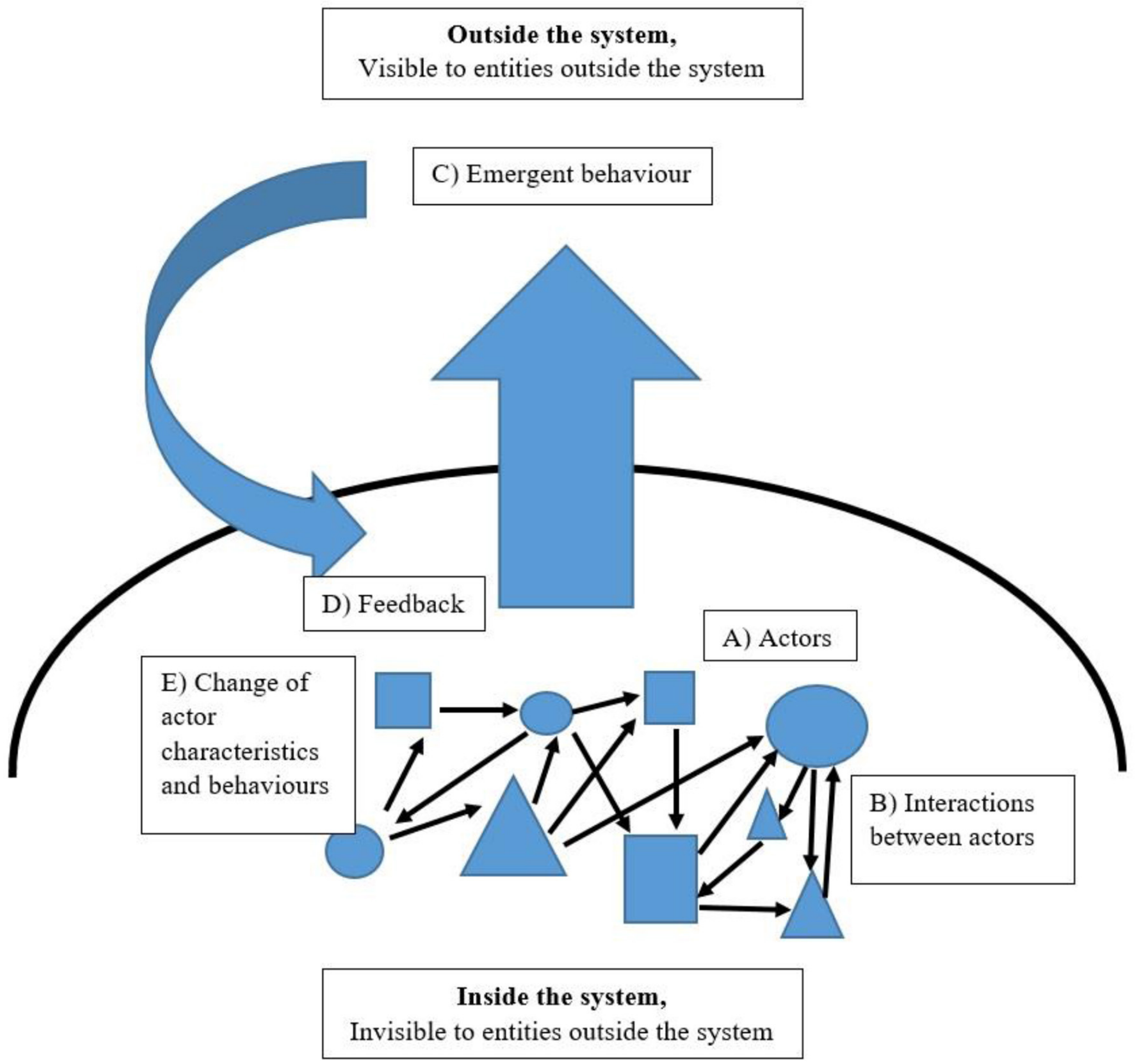

FIGURE 1
A domain-general complex adaptive system.

TABLE 1 Similarities of relevant formal approaches.

	Formal approach			
	Control theory	Economics	Biological cells	Games
How the state of the system is represented	Process variables	Activities	Phenotypic features	Board configuration
Cost of actions	Operating costs	Activity costs	Metabolic costs	Board evaluation
Value of goals	Objective function	Profit	Fitness	Payoff
How actions are guided toward the goals	Control policy	Plan	Reaction net	Strategy

Adapted from Holland (2006).

self-replicating, autonomous individuals that use energy; there is no central control over their behavior, and whether consciously or not, all these individuals are doing what is best for themselves, which may, under certain conditions of reciprocity, include helping each other. (B) "Interaction between actors" is any kind of transfer between actors, including information as signals, resources, and/or collaboration. (D) "Feedback" comes from the outside environment, and it feeds down to interactions between individual actors inside the system. Feedback can be positive, which increases the activity of actors and leads to growth, chaos, and instability, or negative, which stabilizes or reduces activity by actors and leads to a steadier state. Feedback might then lead to (E) "Change of actor characteristics and behaviors," which may or may not change the nature of the interactions of actors. Meanwhile, at the macro-level, (C) "Emergent behavior" is how the system appears to the outside world, and from the outside an observer sees a system with properties and/or behaviors that the individual actors do not possess on their own and that only emerge when the individual actors interact.

As the ideas regarding CAS theory have become more developed, commonalities across systems have been identified, thereby enabling all examples to be discussed in the same way. An early attempt is shown in Table 1. Tables 2 and 3 show different examples of CASs created to better fit the model in Figure 1.

2.2 CASs and self-organization of autonomous individuals without central control

Another defining characteristic of a CAS is chaos inside the system as many autonomous individuals go about their activities, resulting in order and predictability of the system overall. For this reason, a bee colony, for example, cannot be viewed in a CAS framework as individuals are under the complete control of a central agent, the queen.

2.3 CASs and energy use

Pertaining to a later section about whether language is a CAS, the idea of CASs using energy is a core idea at the heart of CAS theory. Some self-organizing systems do not use energy, for example, a crystal forming, and are energetically near equilibrium. However, a central definition of a CAS is that individual actors are using energy and that the system maintains a state away from equilibrium. For this reason, almost all CASs are connected somehow with living organisms, humans or otherwise, and the conceptualization of different biological systems in a CAS framework has a long and diverse history.

2.4 CASs and transfer of information between individual actors

Signal transfer between individual actors is by no means a new idea in CAS thinking, and it was a central idea in Holland's early work (2006). At the micro-level, interactions between actors are facilitated by some kind of exchange of information.

2.5 CASs are resilient against outside disturbances and robust against internal failure

CASs are *resilient* and are able to recover from disturbances from the environment outside the system and adapt in response to long-term changes; they are also *robust* in that they can overcome partial failures inside the system, for example, when a node fails to develop a function (Klau and Weiskircher, 2005; Sha and Panchal, 2013; Chen and Crilly, 2014; Peckre et al., 2019; Davis et al., 2021; Gillett, 2021). Resilience and robustness (R&R) are important traits in network science, and they are referred to again in the Discussion.

2.6 A definition of CASs

For the purpose of this work, the following is a definition of CASs:

- CASs exhibit innate self-organization of autonomous individuals without central control, allowing predictable order to emerge and be observable from outside;
- CASs use energy to maintain a state away from equilibrium;
- CASs are made up of individual actors that transfer information between each other, for example, as signals;
- CASs are robust to internal failure and resilient as they evolve with a changing environment.

TABLE 2 Comparison of actors and their interactions in different complex adaptive systems (CASs).

	Macro-level system					
	General CAS theory scheme	A market economy	An industry	A species	An ecosystem	A human social community
(C) Emergent behavior(s)	A system that uses energy to persist away from equilibrium, which overcomes short-term internal failures and evolves with long-term changes in its environment	Decentralized, non-random (optimized) allocation of goods, labor, and capital	A community of different companies making a profit by doing very similar things	The continuing existence of a species—whether plant, animal, fungus, or a single-celled organism—through time	Diverse species of plants, animals, fungi, and single-celled organisms living together in space and time in stable populations	A community of humans living together sustainably in space and time
(A) Actors and their interactions	Autonomous, self-maximizing, self-replicating individuals, making optimized resource allocations, including time and energy spent on behavior	Individuals/ companies; suppliers/customers exchanging agreements, entering negotiations, and making transactions	Companies competing for the same suppliers, raw materials, customers, and investors and being regulated by the same authorities	Individuals from current generations that have competed to maximize their reproductive output communicating with individuals of future generations	Reproductive groups of different species competing for limited resources in different trophic levels and niches	Groups of families cooperating under an implicit social contract
(B) Signals between actors	Information being transferred that is copied, reproduced each time and reproduced slightly imperfectly	The contents of contracts and agreements	Advertising, share price, product prices, quality awards	Genes*	Individuals	Individuals

*The Extended Evolutionary Synthesis (ESS) that has arisen in the 21st century acknowledges a role for epigenetic factors in evolution (Banta and Richards, 2018; Yi and Goodisman, 2021). However, epigenetic factors, that is, factors that operate alongside DNA, are not a single class of factors but a mix of different mechanisms with different origins that affect how some genes are expressed in some situations, and they can, in certain situations, modify the specific form of an individual's phenotype (Lind and Spagopoulou, 2018; Stajic and Jansen, 2021) but not DNA in a nucleus or—over the space of a few generations at least—not the relative frequency of different genes in a population. Finally, few epigenetic factors are heritable, and those that are do not have the same heritability as each other. Indeed, if two different epigenetic mechanisms are heritable, then the mode of heritability is not necessarily the same (Adrian-Kalchhauser et al., 2020; Ashe et al., 2021). Therefore, change in gene frequency is still acknowledged in the EES as the major driver of evolution, and epigenetic factors are not regarded as signals per se in this scheme, being more akin to message context.

2.7 Language *per se* is not a CAS

The phenomenon of language cannot be considered a CAS because if linguistic chunks were the individual actors in the system, they do not themselves metabolize energy to continue through time in a state away from equilibrium. Furthermore, linguistic chunks within a generation are not self-maximizing autonomous individuals as they need other linguistic chunks of a different type to be able to function in the system: if the system were all one type of linguistic chunk expressing the same piece of information, that system could not function.

2.8 Comparing different signaling systems and commonalities across different CASs

Signaling systems have been analyzed in different theoretical frameworks, and some kind of information transfer is seen in all CASs, including species (Maynard Smith and Harper, 2003; Rendall et al., 2009; Bradbury and Vehrencamp, 2011), central nervous systems (e.g., Fung and Vanden Berghe, 2020; Chen et al., 2021), commercial activity (e.g., Fredin and Lidén, 2020; Adamchuk et al., 2021; Arthur, 2021), developing embryos (e.g., Johnson and Toettcher, 2019; Kölle et al., 2020), genomes (Dawkins, 1976; Maynard Smith and Szathmáry, 1995; Maynard Smith and Harper, 2003, when discussing genetic replicators[1]), and immune systems (e.g., Tiberio et al., 2018; Dorrington and Fraser, 2019), and some examples of signals between actors in CASs are presented in Table 4.

2.9 Individuals within a system who use more complex signaling are more successful

In some CASs, it is easy to perceive actors competing against each other to self-maximize, for example, in a sports league or a species. However, in other systems, such as the immune system of an individual, although actors are autonomous, it is less easy to appreciate on what level they are competing and how they would self-maximize, and such a discussion is beyond the necessary realms of the current work. However, if the actors are not competing with each other, the system is not a CAS, and in a CAS, individuals who can create and use more complex signals are more successful (Choi et al., 2022), for example, the lesser prairie chicken (Gould and Augustine, 2020) and the wolf spider (Hebets et al., 2013). Indeed, much of the returns to complexity in animal mating

1 Epigenetic mechanisms of evolution do not have their own replicators, are not signals and cannot be considered replicators themselves.

TABLE 3 Comparison of feedback from outside the system and changes made in different complex adaptive systems (CASs).

	Macro-level system		
	General CAS scheme	A market economy	A species
(D) Feedback as information is received from the interface with the outside	Positive feedback increases actor activity; negative feedback stabilizes or reduces actor activity.	The system interfaces with other aspects of society, and in order for individual economic entities to avoid bankruptcy, they must continue to create a profit.	Genes, as modulated by epigenetic factors, interface with the wider environment after two haploid genomes meet in a fertilization event. As mediated by epigenetic factors modulating phenotypes, individuals acquiring enough resources to stay alive and maximize returns from mating efforts due to heritable advantages determine which genes meet in future fertilization events and in what proportions.
(E) Change of actor behaviors allowing the system to overcome internal failure in the short term	Actors adapt in the short term to overcome internal network failure in order to continue functioning.	Following a failure of allocation, changes in day-to-day activity, such as capital mix (fixed income vs. equity) and levels of employment and salaries, and prices offered are short-term survival options.	Failure to find food, shelter or mates elicits a change in those activities, e.g., by increasing the time spent foraging or seeking mates.
(E) Change of actor characteristics allowing the system to evolve in the long-term in response to environmental change	Actors are able to evolve in the long term and cause changes in the system's interface with the outside world.	Following a reduced competitive advantage, individual economic entities make changes in order to continue making a profit in the long term, for example, through adopting new technologies or changing the focus of operations.	Permanent change of heritable traits that offer a selective advantage.

systems are accrued through not making mistakes between closely related species in mating situations (Tibbetts et al., 2020), which would constitute a waste of valuable resources with the creation of infertile hybrid offspring.

2.10 More complex CASs have more complex signaling systems

More complex CASs have been shown to have more complex signaling systems (Freeberg et al., 2012; Peckre et al., 2019). More complex systems are those where individual actors come into contact more often, especially the same individuals (Freeberg et al., 2012); have larger groups of individuals interacting (Knörnschild et al., 2020); have greater chances of uncertainty (Rebout et al., 2021); have a greater number of social alliances, more social competition among groups, and/or a higher number of different social roles within a group (Sewall, 2015); or have more complex mating and offspring-care systems (Peckre et al., 2019).

2.11 Why other animals do not have a signaling system as complex as human language

Proto-human societies, living hunter-gatherer lifestyles in multi-family groups of different generations, must have already been highly complex when language started to evolve, with actors exhibiting different activities and having different motivations, and no other animal society can be said to have ever been as complex. A theory has been put forward and largely corroborated saying that signaling systems are as complex as they need to be, and as no other animal society is as complex as human societies were when language started to evolve, no other signaling system is as complex as human language (Beecher, 2021; Penn and Számadó, 2021; Wacewicz, 2021).

2.12 Alone, a single signal is likely to be ambiguous and equivocal

Signals between animals of the same species appear to be ambiguous (Santana, 2014), and ambiguous signals seem to be associated with multimodal signaling (Partan and Marler, 2005; Mühlenbernd, 2021). This also appears to be true in human languages (Piantadosi et al., 2012; Gibson et al., 2019).

2.13 A definition of signals in CASs

For the purpose of this work, language as an uncountable noun is to be considered *a system of signals between actors in the CAS of human communities*. Signals in CASs have been studied extensively (Dawkins, 1976; Maynard Smith and Szathmáry, 1995; Maynard Smith and Harper, 2003; Scott-Phillips, 2008; Holland, 2012; Barker et al., 2019), and it is possible to make the following definition of signals in CASs:

TABLE 4 Examples of information transferred as signals as seen in some example complex adaptive systems (CASs).

CAS	Actors		Communication	
	Sender	Receiver	Signal	Message
A genome	A parental genome	An offspring's genome	A gene	Create protein *x* at time *y* because this protein is a good one and has stood the test of evolutionary time.
A species	An individual in a current generation	An individual in the next generation	A haploid genome	These instructions will create a future individual well suited to the current environment and ecology.
A community	An individual	Other members of the community	The expected behavior, e.g., lookout, communal care of young, pack hunting/foraging	I'm a member of the team and I'm doing my bit, so I should be able to stay in the group.
	An individual	Potential mates who can afford to be choosy	Displays of quality, e.g., calling, physical displays	I can offer your offspring the best genes they can get.
An industry	A company	Investors	Share price/financial statements, reports	Your capital is safe with us.
		Employees	Salary, other benefits	You are valued, and we want you to continue working for us.
		Customers	Advertising, quality offerings, loyalty programmes	Continue buying our products because they are high quality and good value.
		Partners	Invoices, orders, payment notification	We are a trustworthy partner, and you can rely on us.
		Competitors	Share price/financial statements, reports, patents	No hostile takeovers today; taking market share will be difficult.
A sports league	A team	Their own fans	Programmes, commentaries, media reports	Support us; we win; we're cool; we present the image you want to associate with.
		Fans of other teams	Programmes, commentaries, media reports	We're better than your team; support us instead.
		Media	Interviews	We're going/staying up; pay for large contracts with us.
		Investors	Share price, reports, financial statements	Invest in us.

- The primary purpose of a signal is to transfer information, that is, all signals contain information that is immediately processed as a recognized meaning;
- Alone, a single signal is likely to be ambiguous and equivocal while being the smallest constituent part that retains some meaning;
- Signals are intentional and honest;
- Signals are the same as those used by individuals in previous generations;
- Signals are reproduced each time they are used;
- Each copy of a signal contains some variation/inaccuracy.

2.14 Different signaling systems have common characteristics

It was earlier stated that within a system, individuals using more complex signaling are more successful and that across systems, more complex systems use more complex signaling systems. There are two main routes for increasing complexity that have been identified in theory and that are found to a lesser or greater extent in all signaling systems: increasing the number of signals for any given unit of information/meaning, called *degeneracy* (D), and; increasing the number of uses for a given signal, called *modularity* (Chen and Crilly, 2014; Hebets et al., 2016; Peckre et al., 2019; M). Moreover, within a signaling system, degeneracy and modularity will always arise (Newman, 2006; Chen and Crilly, 2014) as the added complexity provides benefits. Furthermore, in more complex systems, different types of degeneracy and modularity can be found, namely, *redundancy* (R) as a form of degeneracy with different signals used simultaneously and expressing the same meaning and *pluripotentiality* (P), or multifunctionality, as a form of modularity where a single signal has a number of different, related context-dependent meanings. Table 5 compares the R, D, P, and M in two systems.

For example, a degenerate system of communication between actors in a CAS that appears to be functionally redundant with respect to particular outcomes in a particular context but that may perform differently in a different context was discussed in work by Tononi et al. (1999), who worked on the functioning of the human brain. They also stated that "redundant systems in which many elements can affect the output in a similar way but do not have independent effects." The relationship and distinction between redundancy and degeneracy were also later

TABLE 5 Redundancy, degeneracy, pluripotentiality, and modularity in two different signaling systems.

	General signaling system description	Specific examples from a corporation communicating with investors	Specific examples from a human society using English as a set of signals
Redundancy	Same communication instance; repeated message; different, separate signal	Annual reports (same communication instance) contain different metrics (separate signal) made up of the same data (repeated message); e.g., there is necessarily a very close relationship between income statement and cash flow data.	Singular/plural, countable/uncountable verb grammatical agreement, e.g., The cat is/the cats are, Sunshine is warm/apples are sweet Third-person singular verbs in simple present, e.g., She runs/they run Corresponding facial expressions or hand gestures (prosody)
Degeneracy	Different communication instance; same message; different signal	Stock price shown in different places, e.g., on websites or on the TV, and a similar meaning is derived.	Approximate synonyms, e.g., *look*, *see*, *watch* More exact synonyms, e.g., *get off*, *disembark* Metaphors, e.g., His name's Dirk the Blade, . . . Idioms, e.g., He's as sharp as a knife.
Pluripotentiality	Different communication instance; different message; same signal	For example, a change in the stock price is compared with changes in other phenomena; e.g., political, climatic, and different meanings are derived; e.g., the stock price has gone down because party *x* has won the election, or the stock price has gone up because of the bad weather.	Words with multiple uses in different contexts (polysemy), e.g., *use*, *get*, *like* Verbs used as nouns and adjectives Nouns used as verbs and adjectives Past participles as passive, perfect, and adjective Present participle, as gerund, adjective, and continuous
Modularity	Different communication instance; different message; signal components selected from a fixed range and combined to create messages appropriate to the situation	Different situations decree which ratios are used to express information; e.g., return on capital employed vs. return on investment use some of the same inputs but, nevertheless, derive different numbers that have meaning in different situations	Prefixes and suffixes, e.g., *un–*, *dis–*, *–ed*, *–ing*, *–ly*, *–ated* Auxiliary verbs *be*, *do*, *have*, (*get*?) combined with present and past participles Verb and prepositions collocations, e.g., *think about*, *turn around*, including phrasal verbs, e.g., *get up/down/on/off /in/out/around* Frequently used multiword collocations

discussed by Friston and Price (2003)—again with respect to brain function—who said that "degeneracy refers to a structure-function relationship.... Redundancy refers to the function of a necessarily degenerate set of structures," and that, "degeneracy is necessary for redundancy." Chen and Crilly (2014), in discussing the matter, make the distinction that redundancy is spare capacity, whereas degeneracy is different structures performing the same function in certain situations.

Additional modularity in CASs has been shown to be another route to increasing complexity, for example, in engineering systems (Sinha and Suh, 2018) and the power, propulsion, and cooling systems of naval ships (Paparistodimou et al., 2020). In signaling systems, modular signals have been shown to increase signal complexity in some species of monkeys (Snowdon and Ziegler, 2021) and bacteria (Hengge, 2021).

2.15 Increasing systems stability as modularity balances degeneracy

There is a huge lack of consensus across the network science literature as to what redundancy and resilience are, and most descriptions are not mutually exclusive. In this work, the signal characteristic of *degeneracy is said to endow a network of signals with the network characteristic of robustness*, and likewise, the signal characteristic of *modularity confers the network characteristic of resilience*. A networked system of signals that has a number of different linkages within it derived either from degeneracy *and/or* modularity can now be envisaged. This "and/or" situation is of great importance, and a single signal would have a mix of R, D, P, and M traits that is different to the mix exhibited by another signal. Therefore, for example, the more overlapping R and D traits of a signal, the more sound and meaning nodes and edges in a network would be shared by that signal with other signals, and the more likely the network would be able to overcome any internal problems: a phenomenon in network science called *network buffering* (Whitacre and Bender, 2010). Nevertheless, network buffering has complications because while system-wide connections—or *connectedness*—offer advantages, this same measure in excess—or *over-connectedness*—can increase the risk of cascades of potentially catastrophic systemic failure after an external disturbance, when one failure leads to more because all the failing components are interlinked. However, this risk is mitigated by *modularity* (Carpenter et al., 2012; Clune et al., 2013; Walker, 2020). Therefore, a system with some degenerate signals, some modular signals, and some signals with both traits would have a more reliable functionality in an unpredictable environment.

3 Linguistic "chunks" as the signals in human language

Table 5 presents a scheme depicting the characteristics of signals between actors in two different CASs. If human society is a CAS, and human language in all its forms—German, Persian, Hindi, Russian, and others—is a signaling system between actors in that CAS, the actual signals themselves must be identified.

3.1 Identifying the signals between actors in the CAS of human society

Returning to the definition of a signal that was given earlier, the first requirement is that a signal must have information that is immediately processed as a *recognized* meaning, which relates to the processing that has been carried out previously or something that has been learnt previously; the second requirement is that although a single signal is likely to be small, ambiguous, and equivocal, it must still contain some *meaning*. Nevertheless, when deciding how to discuss signals in languages, there is a huge problem with terminology and with what certain specific terms have become associated with through time. A term that relates both to processing and meaning is *chunk*. Here, it is proposed that linguistic chunks and signals in language are synonymous, as both must be *recognized immediately to allow reflex-like processing and both must contain a meaning.*

The term *chunk* is not new, and the idea of working memory having a limited capacity has a long history (Miller, 1956). It is also theorized that the capacity of working memory is limited by the number of chunks that can be stored, not the number of items or the amount of information (Gobet et al., 2016). It is postulated that chunking is a neurocognitive mechanism carried out when humans use language (Christiansen and Arnon, 2017; McCauley and Christiansen, 2017), and a "linguistic chunk," to paraphrase an early scholar in the field (Abney, 1995), describes an *encoded*, or *known*, sound pattern with a concomitant *meaning* that is *processed* simultaneously. Furthermore, it is postulated that this processing is instantaneous and carried out in a reflex-like manner because the processing function has been proceduralised (O'Grady, 2015; Ellis and Ogden, 2017; DeKeyser, 2018) after successive repetition of the same processing routine.

It must therefore be asked how multiword sound patterns that constitute a chunk are to be differentiated from those multiword sound patterns that do not. To answer this question, the ideas of variability in working memory and the process of proceduralisation must be considered. Across individuals, there is variation in the capacity of working memory and, therefore, it is presumed here, the size of chunks that can be processed in a single routine, including variation in individuals of the same age (Daneman and Carpenter, 1980) and older individuals usually being able to accommodate larger chunks (Cowan, 2016). This difference is also augmented with training (Titz and Karbach, 2014; Schwaighofer et al., 2015) and related to language use and learning (Huettig and Janse, 2016; Kidd et al., 2018). However, proceduralisation occurs through neuroplasticity, which is a neurological growth process and during which neurones repeatedly used in a certain process reinforce their connectivity to enable rapid reactions (Lillard and Erisir, 2011; Gallistel and Matzel, 2013). This idea is enshrined in the wellworn axiom "neurones that fire together, wire together" (Hebb, 1949). Taken together, these ideas would predict that what constitutes a chunk would be different for people of different ages and in topics for which different people have had different amounts of prior exposure. Therefore, older people with more knowledge and experience in a certain topic would be able to process larger and more specific multiword sound patterns than younger people with less experience in the same topic. Moreover, of course, what constitutes a chunk to a monolingual speaker of, for example, German, would be different to what constitutes a

TABLE 6 Comparisons of constructions exhibiting the trait of redundancy in English, German, Slovak, and Japanese.

Redundancy	
Definition	In the same communication instance, the same information is transferred multiple times using a different signal, e.g., grammatical agreement, (doing the same thing in different ways at the same time)
English	**Agreement**, e.g., plurals/countability, e.g., the verb *to be*, the cat is/ the cats are; sunshine is warm/ apples are sweet; Third-person singular *have*, e.g., I have, she has; Collective nouns, e.g., a herd of sheep; a flock of birds; a shoal of fish
German	**Agreement**, e.g., noun gender (male, m.; female, f.; neuter, n.), number (singular, s.; plural, p.), adjective and case (e.g., dative, accusative, etc.), e.g., *Talk about the blue man/the blue men/the blue woman/the blue women/the blue child/the blue children.* Sprechen Sie über (*after 'über' accusative case in this situation*) den blauen Mann (m., s.)/die blauen Männer (m., p.)/die blaue Frau (f., s.)/die blauen Frauen (f., p.)/das blaue Kind (n., s.)/die blauen Kinder (n., p.) *Talk to the man/the men/the woman/the women/the child/the children.* Ich rede mit *(after 'mit' dative case)* dem Mann/den Männern/der Frau/den Frauen/dem Kind/den Kindern. *I gave the book to the man/the men/the woman/the women/ the child/ the children.* Ich gab dem Mann (*indirect object*) das Buch/den Männern/der Frau/den Frauen /dem Kind/den Kindern. **Noun and relative pronoun agreement,** e.g., *I found the gold, which I lost last week.* Ich habe das Gold gefunden, welches ich letzte Woche verloren habe. *I found the monkey, which I lost last week.* Ich habe den Affen gefunden, welchen ich letzte Woche verloren habe. *I found the monkeys, which I lost last week.* Ich habe die Affen gefunden, welche ich letzte Woche verloren habe. **Verb ending reaffirms nominative person.** e.g., Du hörst nicht zu! (second person, *You aren't listening!*) **Verb ending reaffirms nominative person and level of formality** Sie hören nicht zu! (Second-person singular formal, *You aren't listening!*) *This could be multiple people formal or informal or formal singular, so it also depends on context.* **Some collective nouns**, e.g., *a herd of sheep*, eine Schafherde; *a shoal of fish*, ein Fischschwarm
Slovak	**Multiple negation marking**, e.g., **ne**chcem **nič**. (*Literal meaning [lit.]: I don't want nothing.*) **Agreement,** e.g., noun gender, number, adjective, and case agreement, e.g. *(see German for translations)*, Hovorte o (*after the preposition 'o' locative case*) modrom mužovi (m., s.)/modrých mužoch (m., p.)/modrej žene (f., s.)/modrých ženách (f., m.)/modrom dietati (n., s.)/modrých detoch (n., p.). Hovorím s (*after the preposition 's' instrumental case, in this situation the ending of the preposition also changes*) mužom/ mužmi/ ženou/ ženami/ dietatom/ detmi. (*indirect object*) Dal som knihu mužovi/ mužom/ žene/ ženám/ dietatu/ detom. **Noun and relative pronoun agreement,** e.g. (*see German for translations*), Našiel som zlato, ktoré/ opicu, ktorú/ opice, ktoré som stratil minulý týžden. **Verb ending reaffirms nominative person**, e.g., Ty nepočúvaš! **Verb ending reaffirms level of formality** Vy nepočúvate! *(See German for more information.)* **Different number forms for gender, animate/inanimate, and plurals**, e.g., dvaja muzi (m., animate), dva stoly (m., inanimate) dve zeny (f.), dve piva (n.), dvoje hranolky (n.), two. **Some collective nouns**, e.g., *a herd of sheep, črieda oviec; a pride of lions,* svorka levov
Japanese	**Animacy agreement** with *aru* (ある)/ inanimate and *iru* (いる)/animate with nouns and the verb *to be*/*have*, e.g., *stone* (inanimate) and *child* (animate). *The child is in the park.* 子供は公にいます。(formal) *Kodomo wa koen ni imasu.* 子供は公にいる。(informal) *Kodomo wa koen ni iru.* The stone is in the park. 石は公にあります。(formal) *Ishi wa koen ni arimasu.* 石は公にある。(informal) *Ishi wa koen ni aru.* **Different number counters** for different types of things being counted, e.g., 枚, まい, *mai*, (counter for flat things) (e.g. 二枚の, *ni-mai no kami*, two pieces of paper); 本, ほん, *hon* (counter for long, thin things); 匹, ひき, *biki* (counter for small animals that can be picked up), and; とう *tou* (counter for big animals). **Immediate rephrasing** of the speaker's and the speaking partner's last utterances in conversation are automatic and much more common than with European languages in native use.

TABLE 7 Comparisons of constructions exhibiting the trait of degeneracy in English, German, Slovak, and Japanese.

Degeneracy	
Definition	In different communication instances, the same information is transferred using different signals, e.g., synonyms, metaphors, and idioms. (a repertoire of different ways of doing the same thing from which a particular instance of use can be chosen).
English	**Approximate synonyms**, e.g., *look*, *see*, *watch*, which are used in different situations. **More exact synonyms**, e.g., *get off*, *disembark*, which can be used interchangeably without changing the meaning. **Metaphors and idioms**, e.g., His name's Dirk the Blade, he's as sharp as a knife.
German	**Approximate synonyms**, e.g., annehmen, akzeptieren, gelten lassen, (*all of which mean 'accept' but which are used in different situations*). **More exact synonyms**, e.g., die Spitze, der Gipfel (*both mean 'the summit' and can be used interchangeably without changing the meaning*). **Metaphors and idioms**, e.g., Um den heißen Brei herumreden. *(lit: to talk around the hot porridge, figurative meaning [fig.] to beat around the bush)*; Lügen haben kurze Beine. *(lit. Lies have short legs; fig. Lies don't travel far because they get discovered)*.
Slovak	**Approximate synonyms**, e.g., stretnutie, zasadanie, schôdza (*all of which mean 'meeting' but which are used in different situations*). **More exact synonyms**, e.g., mnoho, vela (*both mean 'a lot' and can be used interchangeably without changing the meaning*); postel, lôžko, (*both mean 'bed'*); pivo, pivko, pivečko (*all meaning 'beer', are euphemistic diminutives used without literal diminutive meaning*). **Metaphors and idioms**, e.g., tunelovanie (*lit. tunneling/ digging a tunnel, fig. to remove money from a company via fraudulent transfer*); nosit drevo do lesa (*lit. take wood into the forest, fig. do something pointless*); *euphemisms for bribes or gifts* obálka (*lit. envelope, fig. something containing money*) *or* flaša (*lit. bottle, fig. something containing distilled alcohol*).
Japanese	**Approximate synonyms**, e.g., different ways of saying 'I' depending on the formality of the situation, the gender of the speaker and the age of the speaker, e.g.,わたし/私watashi; わたくし/私 watakushi; あたしatashi; あたくしatakushi; うちuchi; わし washi; ぼく/ boku; おれ/俺 ore; じぶん/自分 jibun; われ/我 ware; Inferior, 劣る otoru, い warui, 劣性の ressei no, 下等の kat ō no. **More exact synonyms**, e.g., *to hurry*, 急ぐ, いそぐ, isogu, あわてる, awateru I hurried home from school. 学校から急いで家にった。*Gakko kara isoide ieni kaetta*. 学校から慌てて家にった。*Gakko kara awatete ieni kaetta. to run*, 走る（はしる）*hashiru*, ける（かける）*kakeru* I ran home from school. 学校から走って家にった。がっこうから はしって いえに かえった。*Gakko kara hashitte ieni kaetta*. 学校からけて家にった。がっこうから かけて いえに かえった。*Gakko kara kakete ieni kaetta*. Metaphors and idioms, e.g., が硬い, atama ga katai, *lit. stiff head, fig. to be stubborn* はしごを上げる, hashigo o ageru, *lit. to step up the ladder, fig. to rise through a hierarchy. A word can have the same sound but literal or figurative meaning with a different Chinese character when written*, e.g., うまれる/umareru *(to be born)* 生まれる, *Birth as a new beginning; the appearance of someone or something in the world.* 大阪で生まれた歌, Ōsaka de umareta uta, *a song born/made/written in Osaka* 大阪で生まれた, Ōsaka de umareta, *was born in Osaka* まれる,*Birth as the biological phenomenon of emerging from the mother's body.* まれた, umareta jikan, *the time someone was born*

TABLE 8 Comparisons of constructions exhibiting the trait of pluripotentiality in English, German, Slovak, and Japanese.

Pluripotentiality	
Definition	In different communicative episodes, different information is transferred using the same signal, e.g., polysemy (same word, multiple related meanings), homonymy (same word, multiple unrelated meanings). (the same thing has different uses and is modified by what it is used with and when)
English	**Polysemy**, e.g., wing, meaning body part, part of a building, sports team position **Homonymy**, e.g., question words as questions and relative pronouns; different uses of the contractions *I'm*, *I've*, *I'd*, *she's*; different meanings of *they're*/*there*/*their*; simple content words such as *bark* as a noun and a verb with unconnected meanings **Multiple uses of prepositions in combination with verbs and adjectives**, e.g., *get up*/*along*/*around*; *look out*/*for*/*like*; *be helpful for*; *be excited about*; is an often talked about point **Past participles** as passive, perfect and adjective, e.g., I've already stolen it. It's been stolen. It's a stolen car. **Present participles**, as continuous, gerund, and adjective, e.g., He's running. He's in the running. They're running shoes.
German	**Polysemy**, e.g., *Flügel-wing*, meaning body part, propeller blade, part of a building, sports team position; *Läufer-runner*, meaning a young pig, the bishop in chess, a root shoot, a revolving part of a machine, a moving part of a crane, the center half and outside half in soccer, a foot messenger **Homonymy**, e.g., der, die, dass *as many different kinds of pronoun; question words as questions and relative pronouns; content words such as* bank *meaning bench or shallow* **Multiple uses of prepositions in combination with verbs and adjectives**, e.g., abhängen von, *to depend on*; gespannt auf, *be excitedly about something in the future* bestehen auf *to insist on*, bestehen aus *to consist of* auf/aus/in/wek/weg/zu/gehen, *rise up/go out/go into/go wrong/go away/to go to* **Past participles**, e.g., *I've already stolen it. It was stolen. It's a stolen car.* Ich habe es schon gestohlen. Es wurde gestohlen. Es ist ein gestohlenes Auto. **Past participles**, e.g., *He's running. He's in the running. They're running shoes.* Er rennt. Er ist im Rennen. Die sind Rennenschuhe.
Slovak	**Polysemy**, e.g., myš *can refer to an animal or computer mouse*; rebro, *rib*; rebrá lietadla, *aircraft ribs*. **Homonymy**, e.g., som *is first-person singular of the verb;* byt *the verb* to be *or a past-tense marker for the first-person singular*; vír–výr, *a vortex/to whirl–eagle owl*; bit/ byt, *to beat or strike/to be.* **Verb prefixes** *that are not prepositions, e.g.,* pre *can mean 'through/across' as in* precitat, preplavat, prebodnut—*read through a book, swim across a body of water, stab a person, but with other verbs it means 'over/ too much,' e.g.,* precenit, prejest—*overvalue, overeat, and with other verbs it means 're-/ again' , e.g.,* prepisat, prezliect—*for rewrite, change clothes (lit. re-dress)*, premysliet *for change mind (lit. rethink)*. **Past participles**, e.g., *I've already stolen it. It was stolen. It's a stolen car.* Už som to ukradol. Bolo to ukradnuté. Je to ukradnuté auto. **Present participles**, e.g., *He's running. He's in the running. They're running shoes.* Beží. Je v behu. Sú to bežecké topánky.
Japanese	**Polysemy/homonymy**, e.g., 回ります, mawarimasu, *to revolve*; 周り, mawari, *goes around (adj.)*; ります, mawarimasu, *travel around a surrounding or nearby region its way*; 早い, hayai, *early*, 速い, hayai, *fast*;上る, noboru, *go up (steps, a hill)*, 登る, noboru, *climb, scale*, る, noboru, *ascend, rise (up to the sky)* 死亡, shibou, *a death*, 脂肪, shibou, *grease*, 志望, shibou, *ambition*; , hashi, *bridge*, 端,hashi, *end, edge*, 箸, hashi, *chopsticks* **The same counter used for the different types of things being counted**, e.g., ほん/hon *being used for stick-shaped or thin and long things*, e.g., containers, buildings, spaces, rolls of tape, wind and string instruments, the number of phone calls ion a volley of calls, performances, *etc*.

TABLE 9 Comparisons of constructions exhibiting the trait of modularity in English, German, Slovak, and Japanese.

Modularity	
Definition	In different communicative episodes, different information is transferred using signal components selected from a fixed range and combined to create messages appropriate to the situation (different messages are built from a fixed range of components)
English	**Collocations with prepositions,** including phrasal verbs, e.g., *get up/down/on/off /out/in*; verbs, e.g., *look at/up/around*, and adjectives, e.g., *bored by*, *interested in* **Collocations with adjectives and nouns**, e.g., sweating horse, perspiring man, glistening lady. **Collocations with nouns and verbs**, e.g., ask for the bill, pay the bill.
German	**Collocations with prepositions**, *including phrasal verbs*, e.g., nahmen mit/für/zu/auf *take with/for/to/off*; verbs, e.g., an jemanden oder atwas denken *think about someone or something*, nach jemandem oder etwas suchen *look for someone or something*, and *adjectives*, e.g., auf jemanden oder etwas *eifersüchtig* sein *be jealous of someone or something*, mit jemandem oder etwas zufreiden sein *be satisfied with someone or something*. **Collocations with adjectives and nouns**, e.g., eine **große Sorge, *a big worry, these might be compounds if used regularly,* e.g.,** das Schmerzensgeld, compensation for pain and suffering. **Collocations with nouns and verbs**, e.g., ein Foto machen '*make' a photo, not 'take' a photo as in English*, ein **Fahrrad fahren *travel a bicycle, not ride as a different word, but* ein Pferd reiten, *ride a horse.***
Slovak	**Collocations with prepositions**, verbs, e.g., mysliet na niekoho alebo niečo *think about someone or something*, and adjectives, e.g., byt s niekým alebo niečím spokojný *be satisfied with someone or something*. **Collocations with adjectives and nouns**, e.g., do najmenších detailov *to the smallest details* plané sluby *empty promises*, pokojný ako Angličan *calm as an Englishman*, Klobúk dole *hats off (to someone for something)*. **Collocations with nouns and verbs**, e.g., liezt na nervy *climb not 'get' on one's nerves*, pamätat si časy *remember the times.*
Japanese	**Honorifics with** *desu*, です, and *masu*, ます, used in formal/ceremonial situations. **Question words + particles**, e.g., だれか, dare ka, *someone*; だれも, dare mo, *everyone/no one*; だれでも dare demo, *anyone*; どこか, doko ka, *somewhere*; どこも, doko mo, *everywhere*; どこでも,doko demo, *anywhere* **Collocations with nouns and verbs**, e.g., 一にをごす, issho ni jikan o sugosu, *spend time together*; 人生をしむ, jinsei o tanoshimu, *enjoy life* With around 180 different particle uses, **the same particle can have different uses in different contexts**, e.g., amongst other uses, に (*ni*) indicates a location, time or frequency; the indirect object of a verb; the surface of an object where some action takes place; the one acting or the one acted upon; a joining of two or more nouns to indicate a list of items; etc. **Verb suffixes**, e.g., *(all in casual form)*, 食べる, taberu, *eat*; 食べない, tabenai, *don't eat* 食べよう, tabeyō, *let's eat*; 食べないでおこう, tabenaide okou, *let's not eat* 食べろ, tabero, *eat it!*; 食べるな, taberu na, *don't eat it!* 食べた, tabeta, *ate*; 食べなかった, tabenakatta, *didn't eat* 食べて いる, tabete iru, *eating now* 食べれば, tabereba, *will eat if*; 食べなければ, tabenakereba, *won't eat if* 食べられる, taberareru, *is being eaten by*; 食べられない, taberarenai, *isn't being eaten by*

chunk of, for example, Japanese. Furthermore, it is suggested here that what constitutes a signal in any given language might also contain collocations, constructions, words, morphemes, phonemes, and any other unit in that same language.

4 Methods

4.1 Examining different languages for linguistic chunks with r, d, p, and m traits

Having identified chunks as being individual signals in the signaling system of the CAS of human communities, an initial assessment of different languages for the presence of sound-meaning pairs that have R, D, P, and M traits was made. Examples are presented from four languages for R in Table 6, D in Table 7, P in Table 8, and M in Table 9.

5 Results

As can be clearly seen, all four languages express R, D, P, and M traits in their common chunks.

6 Discussion

It has been shown that four human languages—English, German, Slovak, and Japanese—contain chunks with at least one R, D, P, or M trait. This is the first time commonalities across different languages have been demonstrated, which is something other approaches have never done. It has also been demonstrated that R, D, P, and M traits are closely related to R&R traits in language when it is viewed as a signaling system in the CAS of the human community.

Again, as stated in the Introduction, this is only a tentative first assessment, and these four languages were chosen because they were well known to the author, not because of the degrees to which any R, D, P or M traits are expressed. Phylogenetic analysis of languages would place English and German as being closely related, Slovak as a close relative of the two, and Japanese as being only distantly related to those three (Greenhill et al., 2010).

Five main avenues of further research are opened up by the current work, namely, the existence of R, D, P, and M traits in the chunks of other languages; the quantification of R, D, P, and M in chunks; the role of chunks in foreign language teaching; the structure in CASs and system stability; and the evolution of different languages. These are discussed in more detail in the following subsections.

6.1 Quantifying r, d, p, and m in chunks

There are a number of reasons why it might be desirable to quantify R, D, P, and/or M in a chunk. For example, we might wish to compare R, D, P, and M traits in chunks from different languages or different chunks in the same language to investigate language processability or learnability. There are two sources of precedential work that can be drawn on to provide direction: corpus linguistics and network science in the natural sciences and engineering. Measures from corpus linguistics can be further divided into *syntactic association measures* (e.g., Gries and Ellis, 2015; Gablasova et al., 2017; Ellis and Wulff, 2019) and *semantic association measures* (e.g., Glynn and Robinson, 2014; Gries, 2015; Katz, 2019), while measures from network sciences can be further divided into *robustness estimation* (e.g., Peng et al., 2018; Dong et al., 2019), *resilience estimation* (e.g., Klau and Weiskircher, 2005; Turnquist and Vugrin, 2013), *network connectivity* (assortivity coefficient; e.g., Newman, 2003; Peel et al., 2018), and the potential for *cascades of failure leading to collapse* (e.g., Gutfraind, 2012; Liu et al., 2014).

6.2 The role of chunks in foreign language teaching

Prior work has shown R, D, P, and M traits improve learnability and usability, and examples of experimental evidence supporting (1) statistical and relational learning of language and/or (2) processing and production in use can be found for *redundancy* (e.g., Wang and Mintz, 2018; Bahrick et al., 2019; Brehm et al., 2020; Lany and Shoaib, 2020; Tal and Arnon, 2022), *degeneracy* (e.g., Vulchanova et al., 2015, 2019; Gentner and Asmuth, 2017; Thibodeau et al., 2019; Starr et al., 2021), *pluripotentiality* (e.g., Brocher et al., 2018; Srinivasan et al., 2019; Floyd and Goldberg, 2021), and *modularity* (e.g., Boers and Lindstromberg, 2012; Conklin and Schmitt, 2012; Christiansen and Arnon, 2017). However, since an individual construction can have multiple overlapping R, D, P, and/or M characteristics, meaning those traits amenable to learning and use are also overlapping, it might be difficult to separate out individually the effects of any particular trait of a certain chunk.

6.3 Structure in CASs and system stability

R, D, P and M and R&R add extra levels of structural complexity to language when viewed as a signaling system in a CAS. Parallels between structure in language and proteins have been drawn before (Lackova, 2018), and the signaling systems of other CASs also have extra levels of structural complexity; for example, DNA has supercoiling, and some animal mating systems take place in special groupings called leks. The function and origin of these extra levels of complexity are of great interest for system stability when the environment is unchanging and for evolvability/survival when the environment is changing.

6.4 The evolution of different languages

The genesis of different languages is a topic of contention amongst linguists and is much debated. Now having quantitative factors upon which the effects of the forces of selection can be measured might allow further resolution of some of the confounding ideas when considering why a single species, that is, *Homo sapiens*, uses so many different unintelligible variations of language.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

The author developed the concepts and wrote the manuscripts and is thankful for the assistance of those people mentioned in the acknowledgments for assistance with and verification of the languages other than English that are used here.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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