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Environmental adaptation in language

Spatial grammar, landscape knowledge and human survival

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Abstract

We argue that the human ability to linguistically describe spatial locations, relations and paths is likely to contribute importantly to human survival, and that consequently the relation between linguistic elements and structures used in spatial reference, and the environment in which humans navigate, ought to be of concern for evolutionary studies of language. We make the case for systematically studying the correspondences between the structures of human spatial language and the spatially structured practices of human groups within specific landscapes, and for considering this relation within a diachronic framework, as a process of cultural and linguistic adaptation to the physical environment. The last section presents the research design of the Nahuatl Space Project, which investigates the possibility of environmental adaptation of spatial language in four varieties of the Nahuan languages of Mexico.

Keywords

adaptation – frames of reference – landscape – language evolution – space

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1 Introduction

Recent studies that have examined the role the environment plays in structuring language have focused on hypothesized biological pressures exerted by specific environment types on articulatory phonetic production. These studies have used statistical correlations between some phonetic feature of a language (e.g., lexical tone) and some property of the local environment (e.g., ambient desiccation) to argue that patterns are caused by adaptive processes such as energy conservation (Everett, Blasí and Roberts, 2016; Everett, 2017; Dediu, Janssen and Moisik, 2017; Maddieson 2018). Even though these nomothetic studies of language evolution were criticized for positing only correlational evidence in support of their hypotheses, and evidence that was sometimes not sufficiently robust (see e.g. Roberts and Winters, 2012; Roberts, 2018), this new line of research has reenergized the discussion of the topic of environmental adaptation as a potential influence on language change. Such discussions had been previously untouchable in anthropology and linguistics. This is both because of the historical association of ideas of language evolution with racist linguistic ideologies that saw language differences as evidence of differentially evolved intellectual abilities, and because of the long ascendancy of theoretical currents in linguistics that consider language structure a part of a universal human cognitive infrastructure, and language differences to be superficial and essentially arbitrary. There are, in fact, good theoretical reasons that at least some elements of language might be sensitive to the environment. Specifically, the fact that language use is an embodied process means that language can be affected by physical forces that operate on the body, and affect physical processes such as speech production (Winter and Wedel, 2016). Nevertheless, while the possibility of environmental influence on phonology may be increasingly accepted by linguists, from some theoretical vantage points it appears impossible that environment may act on the grammatical structure of language. For example, Mendivil-Giró (2018), who understands language as Chomskyan I-language, argues that the immediate environment of language is not the natural environment in which humans act, but the neurological structures of the human brain, and that therefore language is not responsive to environmental pressures. In this view, language change follows paths largely determined by typological structures and historical coincidence but does not allow environmental selection to operate on morphosyntax. Mendivil-Giró's argument represents a generativist view of language which has so far been influential in the field of biolinguistics.

In contrast to this generativist view, functionalist views of language change argue that language structure, and particularly its diverse manifestations across

the world's languages, must emerge through adaptation to the communicative needs of their speakers and their use of language in discourse (Nichols, 1984; Givón, 1995, 2002; Evans and Levinson, 2009). One such view on adaptation in language is provided by Lupyan and Dale (2015), who cite Cassirer's statement regarding how linguistic systems of classification arise as a result of the social and cultural engagement of humans with the environment: "Every classification is directed and dictated by special needs, and it is clear that these needs vary according to the different conditions of man's social and cultural life [...] Languages vary with the functions they fulfil in the cultures in which they are spoken" (Cassirer, 1962: 136). In line with this functionalist view of language, and with recent work in spatial linguistics such as Bohnemeyer (2015); Palmer (2017); Wassman and Dasen (1998); and Lupyan and Dale (2016), we consider that some parts of language may in fact be responsive to conditioning of the physical environment of language use. However, where functionalist studies such as those mentioned see language change primarily as a process of gradual adaptation to human communicative needs, we argue that this process can also potentially represent adaptation in a Darwinian evolutionary sense. This would, for example, be the case when language change occurs in response to environmental pressures and results in promoting human survival and subsistence. The functions of language use exist in a context that is not only cultural, but bio-cultural, since the survival of human communities depend on successful interactions within a surrounding physical environment, and cultural and linguistic practices play important roles in ensuring success.

The processes of causation and structuration that cooperate in language evolution, operating at different temporal and social scales, from the individual to the trans-generational community, and from communicative to individual time, have been theorized in a functionalist perspective by scholars such as Enfield (2014) and Evans (2003). Enfield draws on Tinbergen's (1963) theorization of evolutionary causation, suggesting that adaptive causation must be understood as operating across several time scales. Tinbergen emphasized that the successful demonstration of an adaptive hypothesis not only requires the demonstration of an adaptive outcome in evolutionary time, but also the demonstration of a mechanism of change that operates in the timescale of the life of the organism under study, and its interactions with its immediate environment. For Tinbergen, the distinction between ultimate causes and proximate causes in adaptation motivated an ethological approach that demonstrates how a given trait improves success in a given environment instead of merely assuming that it does or inferring it statistically (Bateson and Laland, 2013). This insight transfers to the question of language adaptation, by moving us to study language change as a process rooted in everyday language use,

TABLE 1 Causation types and their different time scales

	Selective pressures and constraints	Time scale
Proximate	Communication	Interactional time (enchrony)
	Learnability	Biographical time (ontogeny)
Ultimate	Grammaticalization	Historical time (history)
	Cognition	Evolutionary time (phylogeny)

and language structure as the outcome of such usage. Enfield (2014) theorizes the relations between different temporal scales of language change and evolution, which allows for tying the linguistic tokens of everyday language use to the development of linguistic types in large-scale historical and evolutionary processes.

Following Tinbergen's argument, the challenge for an attempt to support a hypothesis of adaptation is that in addition to providing a plausible historical process it must demonstrate both the proximate mechanism of selection and the adaptive outcome. This poses a significant challenge for researchers who have to construct hypotheses and find data that can connect these different scales. Table 1 summarizes the relations between Tinbergen's different types of causation, Enfield's different temporal scales, and the selective pressures and constraints operating at each level.

Because language in use is sensitive to elements in the social and physical environment, and because, in the functionalist view, morphosyntactic structures arise as accumulated patterns of language use, adaptation of language structures is theoretically possible—especially in those domains of language that are sensitive to the physical environment.

One linguistic domain in which such adaptation would be likely to occur is the domain of spatial reference (Lupyan and Dale, 2016: 653). Successful communication about the location of objects, especially natural resources, is central to many human activities, including subsistence activities. Hence, the study of spatial language in a diachronic framework potentially offers the possibility of observing any adaptation of linguistic structures, including lexicon and grammar, to features in the physical environment where the language is spoken (Enfield, 2014; Palmer et al., 2017). This argument is laid out in § 2, which also reviews the literature on Frames of Reference (FoR), and the hypothesis that FoR usage may adapt to the environment.

Studying the use of spatial language in its communicative setting may also allow us to discover the adaptive value of specific forms of communication

about the environment—that is, the ways in which they promote the survival and well-being of the speakers that use them. Section 3 describes various ways in which spatial language forms part of human strategies for subsistence and survival in various types of environments and how it seems to have an adaptive value. We are particularly interested in the use of language to facilitate orientation and navigation as humans move within their local environments, particularly the use of spatial frames of reference, and the use of linguistically mediated mental maps of territories to facilitate movement in and interaction with the landscape and environment. We argue that if some ways of using spatial language are more helpful for their speakers than others, then the process that promotes these forms of language use and their associated morphosyntactic structures and discourages others, is a form of environmental selective pressure, and resulting changes may be considered to be adaptations in the evolutionary sense.

In order to make the question of adaptation of language structure accessible as an avenue for empirical inquiry, in § 4 we describe the research design and methodology to be applied in the *Nahuatl Space* study. This study aims to investigate whether adaptation of spatial grammar to an environment can occur, by studying the grammar of spatial reference in related languages spoken in different environments. While nomothetic studies of language adaptation have so far only demonstrated correlation, this research design aims to address also the issue of causality, by adding a diachronic dimension to the study, linking ultimate and proximate scales of causation. We suggest combining methods from descriptive and historical linguistics to demonstrate the process of adaptation, together with ethnographic observation of spatio-linguistic practices in the studied language communities to demonstrate the adaptive mechanism in terms of its relevance for human survival.

2 Landscape and grammar: the role of language in behavioral adaptation

For social species, it is of adaptive value to be able to share information about the location of objects and the spatial relations that hold between them. Vervet monkey alarm calls, for example, differ with respect to predator type, each requiring different forms of evasive action. The calls convey information not only about the presence of predators, but also about the direction from which they are likely to attack (Seyfarth, Cheney and Marler, 1980). Honeybees may share information with their hive-companions about the location of sources of nectar through dancing. They use the intensity of the dance to iconically

represent the quality of the source, and their bodily position as they dance to describe the direction of the source relative to the position of the sun, and the distance expressed as either "near" or "far" from the hive (Von Frisch, 1974). A truism that has been pointed out by early scholars of human cultural evolution is that humans do not simply adapt to the world as it is, but rather as they imagine it to be (see e.g. Childe, 1949; Sapir, 1912). Therefore, it is important to construct a theoretical approach that acknowledges the process of mediation posed by human experience, including the ways in which cognitive, social and cultural components may affect human ways of understanding the environment, and how they also motivate different types of interaction with the environment. Language, for example, enables the social sharing of geospatial and environmental experience, but also structures the ways in which such information can be shared: different languages have different words for landscape types and features, they encode spatial relations in different ways, and they provide different options for encoding information about movement and direction (Levinson and Wilkins, 2006). As humans, our understanding of the environment is not only shaped by our own experience, but also by the information we retrieve from fellow community members, and by the semiotic infrastructures in which it is encoded (toponyms, landmark systems, verbal route descriptions, maps, photos, GPS technology, etc.) many of which are at least partly linguistic. Language and semiotic processes therefore contribute to our conceptualization of the physical environment, and also shape the ways in which we can adapt our behavior in response to the environment (Thiering, 2014).

Language enables humans to convey highly detailed information about spatial relations, including not only fixed positions of objects (e.g., the cup is on the table or Phoenix is north of Tucson), but also complex paths of moving objects (e.g., we have to cross the stream and then go uphill past the cabin) using language. The different ways humans orient in space are both a matter of cultural conventions, and the kinds of elements in a landscape (e.g., landmarks) and in the larger environment (e.g., cardinal directions based on the sun or the stars) that humans can be expected by other humans to know and navigate by. Different conceptualizations and categorizations of the landscape, and thus, the different types of landmarks and coordinate systems at our disposal can play a role in how we formulate and remember route descriptions (Lovis and Whallon, 2016; Ünal and Papafragou, 2016: 565–568). In addition to the lexicon, the grammar of the language(s) we speak may support certain ways of orienting and describing spatial relations and discourage others. For example, speakers of a language that encodes up-river and down-river movement on verbs may more easily encode such movement linguistically (and in memory) than move-

ment along a north-south axis (see e.g., Boeg Thomsen and Volhardt, 2018 for evidence of directional grammar aiding spatial memory).

Spatial descriptions of locations of objects or the change of location of objects are linked to the environment in which the utterance was made. This can include information regarding the larger speech context, as well as shared information between interlocutors. In this paper, we are concerned with the environment or landscape since the location of natural resources and such ecological events in the landscape is crucial to human survival. Language is a tool we have at our disposal for describing and classifying the location of plant and animal resources (Hunn, 1990: 81, 91), as well as for the transmission of such knowledge between members of a social group (Levinson, 2006).

2.1 *Spatial frames of reference as sites of adaptation*

Certain types of spatial descriptions require the use of a coordinate system for their interpretation. Such coordinate systems, which serve as the basis of spatial Frames of Reference, involve the specification of a search-domain based on the ground object that specifies an angle that projects from the ground (Levinson, 2003:67). In these types of spatial descriptions, the ground object is not the location of the figure itself, but the location is expressed relative to the ground object by means of an additional grammatical or lexical element (e.g., *west* of the river/*downriver* from the house/*left* at the intersection/*uphill* from the road/*seawards* of the palm tree). In some cases the coordinate system can be abstracted from other elements: the direction of movement of the sun, the flow of a river, or the slope of a hill. Spatial relations are grammatically encoded in some languages, for example, through directional affixes on verbs, or with specific parts of speech such as adpositions, or relational nouns. FoRs are of particular relevance to our argument because some types of FoRs rely on reference to elements in the landscape, and because the use of some FoRs may be embedded as part of grammar (for example, directional (verbal) affixes that use a riverine system or cardinal directions they are of significant interest as a potential locus for adaptation of grammar to landscape). In the rest of this section, we review this literature and point to additional evidence to demonstrate spatial adaptation: namely, the diachronic perspective that ties mechanisms of change (human communication in and about a local environment) to the adaptive outcome (linguistic change that makes language structure fit the environment).

Various classifications of different FoR types exist, but many of them share certain characteristics (Levinson, 2003). Here we opt for a fine grained set of distinctions between FoR types that includes direct, object centered (also known as intrinsic), geomorphic, landmark-based categories and absolute

(these three are also known as the geocentric category), as well as relative (O'Meara and Pérez Báez, 2011). Direct and object centered FoRs involve spatial relations expressed through the features or facets of the ground object (e.g., the mat's topside, as opposed to its underside), whereas a relative FoR involves the expression of a relation through a particular viewpoint that is different from the figure and the ground (e.g. the cat is to the left of the mat, where left is the perceiver's or viewer's left). Absolute FoRs involve a coordinate system that is anchored to some type of fixed bearing found in the wider environment, in which both the figure and ground is contained. Of interest here are the geomorphic and landmark-based categories since they rely on local environmental features to establish spatial reference and may therefore be expected to be sensitive to environmental variables. The geomorphic FoR projects axes from some landscape feature or gradient (e.g., the cat is downhill from the mat), whereas landmark-based FoRs project a vector pointing in the direction of a landmark from the spatial anchor/ground (e.g., the cat is on the mountain side of the mat). The specific difference between these two types of FoRs is that the geomorphic one is an angular anchored system and the landmark-based FoR is a head anchored system. The former depends on the orientation of the anchor for their interpretation, whereas the latter depends on the location of the anchor (Bohnemeyer and O'Meara, 2012: 220).

While most languages have various FoR options to instantiate in the description of the same spatial configuration, the frequency of use of different FoR strategies varies among the world's languages (Levinson and Wilkins, 2006: 541–542). Speakers of some languages have preferences for allocentric and others for egocentric FoRs. And in some languages, certain FoRs may not be used at all, not forming part of the language's spatial grammar. The cause of such preferences impinges on the question of potential adaptations: Do they stem from aspects of the environment, from cultural preferences, or is it perhaps aspects of a language's inherited grammatical structure that makes particular FoR strategies more likely to be used by speakers than others?

The MesoSpace project has shown that FoR strategies may spread by diffusion in the interaction between groups of language users and the environment (Bohnemeyer et al., 2015). By looking at FoR strategies in seven indigenous languages of Mexico, one indigenous language of Nicaragua and three varieties of Spanish, the authors noted that languages within the Mesoamerican linguistic area seem to prefer allocentric FoRs and avoid relative ones, whereas speakers of Spanish tended to prefer relative FoRs. Further supporting the hypothesis of FoR transfer through contact, speakers of Mesoamerican languages with a high proficiency in Spanish applied the Spanish preference for relative FoRs when speaking Mesoamerican languages. This study suggests a strong role of

socio-cultural and linguistic practices in conditioning preferences for a particular FoR, but does not exclude the possibility that landscape features play a role in shaping FoR preferences.

If we focus on languages that prefer geocentric FoRs in discourse (absolute, geomorphic or landmark based), it is worth investigating whether shared landscape features play a role in the coordinate systems used in such strategies. With a similar question in mind, Palmer (2015) has proposed that in languages that have a preference for absolute FoRs, the choice of the FoR is motivated by salient features of the landscape. This proposal has been named the Topographic Correspondence Hypothesis (TCH) and predicts that: (A) a single language spoken in diverse environments will also exhibit a similarly diverse range of spatial reference systems; and (B) unrelated languages spoken in similar environment types will show similarities in spatial reference. One way of testing prediction A is to study a single language spoken in different environments and determine whether, over time, they tend to adopt similar or different FoR preferences. A way to test prediction B is by studying different languages spoken in a single type of environment. Palmer (2015) calls this method the Environment Variable Method (EVM). The research project outlined in section 4 tests prediction A of the TCH by looking at a group of related languages and their gradual divergence in different environments.

The EVM has been employed in a study of two distinct languages spoken in an atoll island environment where evidence for Topographic Correspondence was observed, in that both use the lagoon/ocean as a possible axis for an absolute or geocentric FoR (Palmer et al., 2017). Nevertheless, similarly to Bohnemeyer et al., (2015), Palmer et al. also note that cultural practices play a significant role in mediating the influence of landscape on spatial cognition, differences based on the occupation of speakers, as well as their degree of bilingualism. Though atoll-dwelling Marshallese speakers displayed very high frequency of geocentric FoR use, and correspondingly low frequency of egocentric FoRs, Marshallese speakers in suburban US displayed the opposite tendency (Palmer et al., 2017: 480). Hence, they propose a socio-topographic model of spatial cognition, in which neither environmental, linguistic, nor cultural factors can be considered alone or primary, in shaping human spatial cognition and FoR preferences. They propose that FoR preferences emerge as a function of the affordances of the environment, of the linguistic structure, and of the cultural practices within which both the environment and the language take on meaning.

Previous studies (e.g., Bohnemeyer et al., 2015; Palmer et al., 2017) do not explicitly adopt a diachronic historical perspective, and therefore do not demonstrate adaptation as the cause of FoR preference in the sense of Tin-

bergen (1963), as described in §1. Nevertheless, diachronic conclusions can be extrapolated from their results: the lagoon/ocean contrast is fully grammaticalized in the Marshallese language belonging to the Austronesian language family, whereas in the Indo-Aryan language, Dhivehi, spoken in the Maldives, the grammaticalization of this same contrast is incipient, used only by some speakers. This is of interest because the tradition of living in an atoll environment goes back many thousands of years in the Austronesian family, whereas the speakers of Indo-Aryan were originally located far inland in Northern India. The date at which speakers of Dhivehi split from Sinhalese and migrated to the Maldives from Sri Lanka is estimated between the first and fifth century AD (Gnanadesikan, 2016: 17); whereas the speakers of proto-Oceanic, linguistic forebears of the speakers of Marshallese, were probably already living in island environments 4000 years ago. This suggests that perhaps grammaticalization of FoR strategies in adaptation to a landscape may be quite a slow process that does not lend itself readily to being documented by studies of recent migrations, but calls for a deeper time perspective.[1]

The data from Dhivehi imply a deep historical change in the process leading from the originally land-dwelling proto-Indo-Aryans to the atoll-dwelling Dhivehi—but for adaptation to be demonstrated, rather than assumed, the change would have to be reconstructed using either historical documentation and/or the comparative method. But the hypothesis of adaptation of grammar to landscape cannot be supported unless we can also demonstrate that the landscape may have been a causal factor in the established history of the language. Therefore, the next step towards demonstrating the adaptation of spatial grammar to landscape should be a study that directly links historical change in spatial language in one or more languages to proximate causes in the form of landscape variables and associated communicative practices.

When language adapts its strategies of spatial reference to a landscape, it is part of a process in which the speakers adapt their subsistence form to the landscape as well. This of course does not mean that speakers must adapt their language's grammar to the landscape in order to ensure survival. Several communicative strategies may be equally adaptive in many environments. For example, when some speakers of Dhivehi use cardinal directions as part of an

1 A reviewer has correctly pointed out that there are an important considerations to be made about the definition of grammaticalization, and the question of when a language can be said to have grammaticalized the use of a FoR, and how different typological profiles may lend themselves to different paths of grammaticalization in the domain of spatial language. For lack of space however, we do not go into this discussion here, but take an open or agnostic position to the definition of grammaticalization in relation to spatial grammar.

absolute FoR, while others use a geocentric lagoon/ocean contrast, this difference does not mean that one of these forms is "more adapted" than the other, as long as they both fulfill the communicative functions they are serving. But once a specific FoR strategy becomes "fixed" among the speakers and the strategy is fully grammaticalized, we may say that the language itself has adapted to the environment.

3 How spatio-linguistic practices contribute to human survival

As mentioned, it is possible, and perhaps even likely, that elements of language could adapt to the environment without this being a process of adaptation in the evolutionary sense of enhancing the potential for survival and reproduction. Therefore, in this section we argue that spatial language and cognition, including toponymy and the use of geocentric FoRs, may be expected to have a positive, if perhaps indirect, impact on human survival and fitness. It is likely to be very difficult, or perhaps impossible, to demonstrate empirically the ultimate evolutionary value of spatial language in humans, but at least the assumption that it exists merits justification by argument. Therefore, this section further motivates the study of spatial grammar as a topic of interest for studies of language evolution. It proposes some ways in which aspects of spatial grammar are significantly implicated in human strategies for subsistence and survival in different landscapes. Spatial language is, we argue, a significant element enabling human communities to adapt to diverse environments, even in the face of seemingly inhospitable conditions.

Culturally accumulated knowledge and traditional systems of behavior may be crucial for the survival of human populations, especially those living in adverse circumstances. According to Levinson (2006), on Rossel Island in the Louisiade Archipelago of Papua New Guinea, a system of emergency preparedness actions in case of cyclones exists as part of the local environmental knowledge, as does knowledge of which potential foods are poisonous or how to prepare potentially poisonous foods in ways that render them edible. Such systems rely on the communicative function of language to transmit knowledge between generations in the absence of direct experience of the risk, and such systems drastically improve the survival of the entire community. Language and culture, in this way, allow human populations, not just human individuals, to adapt to an environment across generations, similar to the way biological adaptations allow species to adapt to an environment. Levinson does not specifically mention spatio-linguistic practices as a kind of cultural adaptation to the environment on Rossel Island, but there are several ways in which such

practices have an obvious mediating effect between human communities and the environment(s) they inhabit. Such effects are found both in the lexical and grammatical structure of the language, and in the cognitive structures underlying spatial orientation such as the choice of FoR strategies.

3.1 *Toponyms, landscape types, and mental maps*

The lexicon includes elements such as toponyms and words for landscape types and features that form part of our mental maps, and which have as their base the local environment we inhabit (Lovis and Whallon, 2016: 5, Lovis and Donahue 2011). Mental maps, which involve both visuospatial information and linguistic labels for places, regions or landscape types, such as toponyms, facilitate travel and navigation between locations in a territory. With the help of linguistically transmitted descriptions of territory we may incorporate places into our mental maps with which we do not personally have prior experience, enabling us to travel even through unknown territory that someone else has visited (Thiering, 2014, and see e.g. Widlok, 1997 for the role of "topographic gossip" among the Hai||om of Namibia). In this section, we look at the way toponyms, landscape types and mental maps are relevant to spatial reference.

Place names serve an important function in organizing our knowledge of locations, and practices of place naming are embedded within wider cultural practices, including those related to subsistence. Studies of toponymy in indigenous languages have shown that places are often named after the most salient natural resource to be found there. Such strategies have been documented for Ahtna (Kari, 2008, 2011), Rarámuri (LaRochelle and Berkes, 2003: 366) and Sámi (Cogos, Roué and Roturier, 2017), among others. Such a strategy would appear to be adaptive, particularly for nomadic peoples inhabiting regions with resources dispersed over large territories, in that it links named places directly to the biological and physical resources located at those places, or to potential dangers that can be found there, facilitating access and memory.

A classic discussion related to environmental salience and lexicalization patterns centers on whether languages are more likely to make more (and finer) semantic distinctions for environmental features that are particularly salient or significant for members of a speech community. Having finer distinctions could be expected to be adaptive for populations inhabiting such environments.[2] The importance of ice-knowledge encoded in language has been

2 There is a long-standing debate about whether Inuit people have unusually many words for snow (Martin, 1986), with some arguing that there is no such correlation between environment and lexical distinctions. Recently this debate seems to have been settled, with the documentation of fine-grained lexical distinctions between different kinds of weather con-

described for Northern Slavey Dené (Athabascan) of Canada's Northwest Territory (Basso, 1972), and for Inuit languages (Krupnik and Müller-Wille, 2010). The lexical distinctions between different kinds of ice are related to cultural conventions about which kinds of travel are appropriate at different points in the year. Similarly, Aporta (2002) has described how ice vocabulary, residential mobility and toponyms are tied together for the Baffinland Inuit, who have toponyms for ice features that are significant both as landmarks for navigating and for organizing subsistence activities (see also Henshaw, 2006). In a region with such particular living conditions as the Arctic, knowledge of places with their associated resources and risks, and knowledge of types of landscape and weather conditions are of particular relevance for survival. It appears likely that this knowledge, passed down between Inuit hunters over generations, plays some role in the adaptation to the environment they inhabit.

Similar to the way that the Arctic might seem like an indistinguishable landscape to the inexperienced, desert environments can also appear inhospitable and "empty" of landscape features. This can also be reflected when looking at official maps of these areas, where there are oftentimes few officially named places listed. This is the case in a large part of the territory of the Seri, a traditionally hunter-gatherer-fisher semi-nomadic people who currently lead a more sedentary lifestyle in northwestern Mexico, where official government maps do not show many named places. However, after conducting an initial community mapping project, a plethora of named places was documented, especially names for traditional temporary campsites. One Seri collaborator named at least 174 places (O'Meara and Henzi, in press). Groupings of related place names were also documented, drawing similarities to what Kari (2008, 2011) has called "generative geographic capacity". In the Seri case, this results in groups of related toponyms like the following: *Coniic* (campsite on Tiburon Island), *Coniic Iime* (place at sea where sea turtles were hunted), *Coniic Iyat* (*Coniic* point), *Coniic Xtaasi* (*Coniic* estuary), and *Coniic Yataam* (*Coniic* pass). These types of generative naming patterns have been claimed to facilitate learning and the use of toponym systems (Kari, 2008), where the speaker learns one unique toponym and then can generate its associated features by adding landscape terms to modify the place name. Such naming patterns are thought to be cognitively advantageous, especially in cases where individual speakers are required to be familiar with the location of a large number of named places for navigational purposes, as well as to keep track of the location of natural

ditions and types of ice and snow cover, and the demonstration of the significance of this vocabulary for travel for the Inuit (Eskimo-Aleut) (Krupnik and Müller-Wille, 2010).

resources, including sources of freshwater and food sources, both crucial to survival in the desert.

Environmental features play important roles in navigation. For example, the Seri people use triangulation based on the location of two mountain peaks, plus the location of the navigator while at sea. These peaks are visible from long distances and could prove to be crucial during daytime navigation (the stars served an important purpose during nighttime travel). If the wrong mountain peaks are used for navigation, one could spend unnecessary time fishing at the wrong place or even get lost at sea. However, an even more treacherous component of travel at sea are the winds that blow in the Seri territory. Seris recognize at least 10 different named winds that blow in their territory, some of which can be dangerous when at sea (O'Meara, 2014). Knowledge of these winds is crucial for successful sea navigation and for knowing where to best set up a temporary campsite at different times of the year. If the winds are ignored, seafarers can be shipwrecked, making knowledge of the different winds and when they blow crucial to survival in the Seri territory.

In conclusion, spatial vocabulary encodes and organizes knowledge of locations, landscape types, resources, risks, and survival strategies—and as such, is likely to play a significant role in facilitating survival for human communities that are dependent on such knowledge for survival.

3.2 *Geocentric FoR constructions*

Frames of reference can play important roles in navigating new spaces and sharing routes through unknown territories by anchoring spatial expressions in elements of the landscape that can be assumed constant. Such elements in the landscape and the larger environment can include celestial objects or prominent geographic features that can be used to "frame" a landscape, such as rivers, or mountain ranges.

In languages that show a preference for geocentric FoRs (including both absolute and landmark based FoRs) different types of expressions may require a geocentric FoR for their interpretation, including place names, names for geographic features and landscape terms, and names for environmental gradients in the expressions that are used for communicating FoR.[3] The coordinate systems of such FoRs are anchored to the environment and are learned through cultural and linguistic practices that involve interaction with the landscape and

3 Note that linguistic expressions do not refer to a FoR, but rather in a particular discourse context their correct interpretation can require a FoR. This is made clearer with terms like 'left' and 'right' in English which can be interpreted with either a relative FoR (to the left) or an intrinsic FoR (to the car's left).

regular climatic phenomena. Not only does knowledge of the anchor of such a FoR have to do with the specific environment that the speakers inhabit, but also the language specific categorization of the environment. Shapero (2017) has argued that for speakers of Ancash Quechua differential degrees of experience of the environment are the best predictors for the choice of geocentric FoRs, illustrating that the patterns of interaction with the landscape may play a role in FoR preference.

Wind directions are also salient environmental features in some languages. For instance, in the case of Seri, older speakers were documented using terms derived from the names of the winds that require an absolute FoR for their interpretation, whereas younger speakers prefer other strategies (O'Meara, 2011). Isthmus Zapotec (Otomanguean) speakers in the town of La Ventosa, Oaxaca, Mexico also use wind terms in expressions that require a geocentric FoR for their interpretation (Moore, 2018). Speakers of Isthmus Zapotec in some nearby towns do not have this preference nor do they use a coordinate system based on wind directions even though their communities do also experience strong winds. Winds appear to be more encrusted in local cultural practices in La Ventosa than in other towns, and Moore (2018: 138) proposes this cultural salience as the reason for the preference for this coordinate system there.

Speakers of Tenejapa Tseltal (Maya) have been described as preferring absolute FoRs (Levinson, 2003; Brown, 2006), as well as descriptions involving landmark-based FoRs (Polian and Bohnemeyer, 2011). More specifically, speakers of varieties of this language use an up/down coordinate system that is based on the environmental gradient or slope found in the local mountainous terrain. However, their use of this system appears to vary depending upon the salience in each village or town of the local topography. For instance, in the villages of Majosik' and Ch'ajkoma (both in the municipality of Tenejapa) the slope is salient and speakers use up/down in their spatial descriptions involving an absolute FoR. This contrasts with the low salience of the mountain slope in Lum and the lack of preference for using the up/down axis in spatial descriptions of objects located in "tabletop" or proximal space (Polian and Bohnemeyer, 2011: 888).

There are other salient environmental features beyond those mentioned in this section that are used in geocentric FoRs. For instance, there are riverine systems like those found in Karuk (Macaulay, 2004), Ahtna (Berez, 2011; Kari, 1985), and Kwakw'kw'ala (Rosenblum, 2015), in which the axes upriver/downriver, towards the river/away from the river are embedded in verbal morphology. Famously, several languages of Australia use an axis based on cardinal directions as their predominant FoR strategy, and speakers of these languages

have been shown to be acutely attentive to the cardinal directions, suggesting a relation between the way humans attend to space and the sociocultural and linguistic habits of the speech community (Levinson, 1997; Haviland, 1998; Majid et al., 2004).

What is worth noting is that even though there might exist a particular environmental or landscape feature in the territory, village or town where a language is spoken, it is not clear what would make such a feature an ideal candidate for forming part of a spatial coordinate system. One hypothesis is that such features should not only be psychologically salient for members of the community (e.g., following work done by Moore 2018 using free-listing to determine saliency), but also have cultural significance. Through the transmission of knowledge of such environmental features via cultural and linguistic practices, coordinate systems are acquired and encoded in linguistic and non-linguistic practices. What is common for all geocentric FoRs (including absolute FoRs involving cardinal directions) is that they rely on human experience of an environment and its various features, and that they facilitate navigation, orientation and the communication of movement and position, activities that are significant for many aspects of human subsistence.

For the reasons given above, spatial grammar is an area where linguistic systems may adapt to the environment in two senses: language structure, in this case the grammar of spatial reference, changes over time to fit features of the environment as speakers consistently use specific types of spatial language in communication. But this process of change is also adaptive in the true evolutionary sense—by using specific linguistic constructions for spatial reference human populations adapt their behavioral patterns to facilitate survival in the specific environments they inhabit. Previous research has established that FoR strategies vary between related language varieties and that this variation correlates significantly with differences in the local environment (Palmer et al., 2017; Moore, 2018). But these studies have not fully tied the observation of enchronic variation with a reconstruction of the history of the variation, and hence have not demonstrated that adaptation has in fact taken place. Therefore, we propose that it is possible to create a research design that will make it possible to test the hypothesis of environmental adaptation, by focusing on the development of spatial grammar in related languages whose speakers have moved into different environments. Such a research design effectively employs Palmer's Environmental Variable Method (see § 2.2), but adds a historical perspective, which is necessary to support the adaptive hypothesis. In the following section, we present a research design focused on investigating this question, which we are applying in an ongoing project.

4 Geospatial adaptation in language: a research design proposal

The *Nahuatl Space* research project at the University of Copenhagen is an interdisciplinary endeavor that aims to test the Topographic Correspondence Hypothesis (see § 3) by taking into consideration the four dimensions of causality (see § 1). The research design is similar to the study of Palmer and colleagues comparing the FoR usage of Marshallese speakers in suburban and atoll environments (Palmer et al., 2017) in that it uses the EVM model, but it adds a deeper diachronic perspective, and seeks to use ethnographic methods to document the mechanism of adaptation rather than simply demonstrating the difference as a correlation between environment and differential usage. The aim is to study a group of closely related languages spoken in different locations and environments in order to reconstruct the development of linguistic orientation strategies so as to ascertain the potential role of adaptation. The project collects data in four different locations in Mexico where different dialectal varieties of Nahuatl are spoken in different environment types. The overarching research question of the project is: Is the adaptive hypothesis for FoR variation supported by a comparative historical analysis of the language varieties, the ethnohistories of the speech communities, and their migratory paths?

In order to link evidence across proximate and ultimate timeframes we combine the use of enchronic evidence from ethnography and descriptive linguistics with reconstruction of historical developments, tying together observable functions of spatial language in communication and subsistence with historical linguistic and environmental changes. The first step in the research design is to identify whether there is a correspondence between the particular local environment and linguistic orientation strategies in the Nahuan varieties under study. This implies describing the environmental characteristics of each speech community and the preferred orientation strategies of speakers. Then, we use historical linguistics methods to reconstruct the development of each language variety from a reconstructed ancestral state to ascertain whether adaptation has potentially played a role in the changes leading to the specific forms in each of the language varieties.

Having carried out these steps, the adaptive hypothesis will be supported if the findings show:

a. ADAPTED FORMS: Covariation between salient features of landscape and FoR strategies in the four locations studied.
b. ADAPTIVE FUNCTION: Correlation between toponymic knowledge and subsistence strategies (if higher reliance on environmental subsistence is

associated with knowledge of more toponyms, or if known toponyms are semantically linked to presence of subsistence related resources).

c. ADAPTIVE MECHANISM: Covariation between spatiolinguistic practices and/or landscape knowledge and FoR strategies (for example, if more intense experience of landscape correlates with higher frequency of geocentric FoR).

The main confounding variables for which we need to control are:

LANGUAGE HISTORY: The structure of the language may itself motivate certain FoR preferences or certain paths of development. Languages may have adopted certain FoR strategies because of diffusion from other languages with which they have been in contact, including Spanish and other indigenous languages. We control for the effect of language structure and history through the reconstruction of the ancestral state and paths of development, including contact history.

COMMUNICATIVE CULTURE: Cultural norms may act as a confounding factor in the study, as the discursive norms for how one speaks about space may vary systematically between the communities. Communicative norms are the main factor that would reproduce the potential fit between language and local environment within a speech community over time, but also have the potential to override the fit. For example, in the Nahuatl speaking community of Hueyapan, Morelos a discursive norm is to avoid giving specific locations about people's whereabouts to others, which means that people often answer such questions with simply "uphill" or "downhill". But there is also a genre of small-talk in which people compete in displaying their knowledge of places around the community and of the people who live there, and here toponyms are the main identifiers of places. Such norms may color the record of spatial expressions if not accounted for in the analysis. To assess the potential role of communicative culture in promoting or suppressing the adaptive process we will collect ethnographic data in each community, including information about different discourse genres following the approach of ethnography of speaking (Bauman and Sherzer, 1975). To control for potential discursive factors we will identify the main discursive genres in which spatial information is relayed in the communities, and try to determine any constraints operating in those genres that may affect the way in which spatial relations are encoded. We will analyze communicative norms as represented in interview data, and through participant observation. While it is not feasible to produce a full ethnographic account of spatial discourse in each community given the timeframe, these factors should at least be considered during data collection and analysis, and any relevant findings should be accounted for.

SPEAKER EXPERIENCE AND DEMOGRAPHIC INFORMATION: Different speakers have different degrees of exposure to the landscape and environment, and to situations that require spatial orientation language. They also have different degrees of multilingualism, which will also in turn correlate with age and literacy. We will collect biographical and sociolinguistic data of all participants to allow us to control for these variables in the statistical analysis.

4.1 *Choice of languages*

Not all languages can be expected to exhibit recognizable adaptive effects of spatial grammar to the environment, since this requires grammatical elements that are potentially sensitive to environmental features. Therefore, the central component of the research design envisioned here is the language group to be studied. The chosen group of languages should be one that exhibits a preference for absolute and/or geocentric FoRs, in order to see how the choice of landmarks as anchors for geocentric FoRs may have been affected by migration into new landscapes with different environmental features. Ideally, in the chosen languages the geocentric orientation strategy should be grammaticalized in some way, for example through locative or directional inflection of verbs. In languages where FoRs are encoded lexically, it will be harder to recognize and demonstrate adaptation, and to reconstruct the adaptive history. Ideally, the sample should comprise a group of languages for which it is possible to reconstruct the history of migrations and of linguistic change from the shared ancestor language.

In the *Nahuatl Space* project we have chosen to study varieties of Nahuatl, (which can be considered a group of quite distinct dialects, or closely related Nahuan languages), which make up a branch of the Uto-Aztecan language family spoken in Mesoamerica. Nahuan varieties are spoken in geographically distinct locations in Mexico and El Salvador, ranging from the arid region of Durango, to the tropical coastal lowlands of Veracruz and Tabasco, the arid highlands of Guerrero along the Balsas river, and in the tropical forests of the Huasteca region. Mesoamerican languages in general have been shown to have a preference for allocentric FoRs and against egocentric FoRs (Bohnemeyer et al., 2015), but Nahuatl has not been included among the languages studied in previous comparative work on spatial grammar in Mesoamerica. One variety of Nahuatl has been described as prominently using a geocentric FoR strategy (Hernández Vázquez, 2014), while another has been described as using only the object centered or intrinsic strategy (Salgado Rodríguez, 2014).

The language history of Nahuatl is well-studied and phonological, lexical and grammatical innovations of the different subgroups are well established (Dakin, 1982; Canger and Dakin, 1985 Lastra de Suárez, 1986; Canger, 1988;

Pharao Hansen, 2014). The probable time-depth since the split of proto-Nahuatl was at least 1500 years ago (Kaufman, 2001), giving a time depth similar to Dhivehi, though some scholars argue for an even deeper time frame (Dakin and Wichmann, 2000). This would suggest that the time depth of Nahuan is sufficiently deep at least to observe the kind of incipient adaptation that seems to be documented in Dhivehi. Nevertheless, based on previous research reconstructing the historical development and relations between the different groups of Nahuan languages, it will be possible to reconstruct the development of spatial grammar, once data has been collected from varieties belonging to the different Nahuan subbranches (the principal ones being Eastern and Western Nahuatl). We have chosen to explore four varieties of Nahuatl, two from the Eastern and two from the Western subbranch. The speech communities we have chosen are located in environments with different climate types, and with different salient topographical features: mountains, plains, forest, lakes, rivers, ocean, and different types of slopes and inclines. Given that many varieties of Nahuatl are endangered, we have chosen speech communities where the language is vital, with children still acquiring the language.

Nahuatl displays the ideal traits of a language group that could provide support for the adaptive hypothesis of spatial grammar given the following characteristics.

- It has distinct varieties with enough grammatical differences between them that adaptation of individual varieties to local landscapes is possible.
- Varieties are spoken in maximally distinct environments, with differences in landscape features, climate or other topographic elements.
- Likely have a preferred strategy of geocentric FoR, ideally with information about an environmental gradient or landmark grammaticalized in one way or another.
- There is a transparent historical relationship between varieties so that ancestral state and the path of development of each variety can be reconstructed. Known history of the languages should include sufficient time depth in the localities where the varieties are spoken to plausibly allow for adaptation to have occurred, and preferably a known migration to a place with a different environment.

4.2 *Research methodology*

EXPERIMENTAL DOCUMENTATION OF FOR STRATEGIES: With a team including researchers with expertise in Nahuatl language, ethnography, historical linguistics and experimental psycholinguistics we aim to conduct field research in four chosen language communities. In each community, we will collect data using both linguistic and ethnographic methods. We use the established meth-

ods of experimental psycholinguistics to document the basics of spatial grammar of each variety, including targeting the Basic Locative Construction, FoR use and preferences, and strategies for describing movement. For the documentation of the Basic Locative Construction of each speech community, we will employ the Topographic Relations Picture Series (TRPS/BowPed, Bowerman and Pederson, 1992) developed by the Max Planck Institute for Psycholinguistics. For the documentation of FoR preferences we will employ director matcher tests including both the "Man-Tree" game developed by the investigators at the MPI (Levinson et al., 1992), and the "Ball & Chair" game developed by the MesoSpace project (Bohnemeyer, 2008). We will also use a specially designed picture series of landscape features designed using the etic-grid principles to elicit local typologies of landscape types. For motion event descriptions we will use picture-based elicitation such as Frog Stories and the hunting story of Vuillermet and Desnoyers (2013), and we will use different series of video-stimulus designed to elicit the use of associated motion constructions. Using these methods will ensure that results are directly comparable with previous research in the field (e.g., Levinson and Wilkins, 2006; O'Meara and Pérez Báez, 2011; Palmer et al., 2017; Moore, 2018).

ETHNOGRAPHIC DOCUMENTATION OF ADAPTIVE MECHANISM: We expect to find a degree of variability in the use of different orientation strategies among speakers, and our goal is to be able to explore the relationship of this variability with different types of experience of the landscape and territory. The adaptive hypothesis may be supported if the use of geocentric FoR strategies is more frequent among speakers with more intimate knowledge of the landscape, or less frequent with speakers whose interactions with the landscape are more limited, or who are more exposed to types of experience requiring relative FoR strategies (e.g., reading/writing, driving). Since most speakers of Nahuatl also speak Spanish with different degrees of bilingualism, and since there is evidence that FoR strategies transfer between languages in bilingual speakers (Bohnemeyer et al., 2015), we also have to control for the potential role of bilingualism in producing variation between speakers. For this reason, we will collect sociolinguistic information on each research participant, including highest level of formal education, frequency of use of Nahuatl and Spanish (and any other languages), and migration outside of the Nahuatl-speaking area, and we will strive to test a group of speakers that are representative of the sociolinguistic makeup of speakers in the location on variables including gender, age, education, and bilingualism. In each location, we will also test a control group of Spanish speakers using the same battery of tests, which will enable us to discover any covariation of spatial grammar in Spanish, and to recognize influence between the two languages.

To document the relations between different spatial grammars and spatial practices, we plan on employing ethnographic and psycholinguistic methods. These will include conducting interviews about spatial experience, including activities realized in particular types of places, free-listing of known landscape categories, elicitation of travel narratives and route descriptions, mapping activities to represent known territories or jurisdictions, which will establish the differences and patterns of topographic knowledge among participants. This will help us discover any correlations between language use and the use of different orientation strategies to ways of navigating the landscape. It will also help us determine the landscape classification systems used by the speakers, which will allow us to focus our analyses on the most relevant landscape features as potential variables in the experimental studies. Interviews and travel narratives, and participant observation in travel and work contexts will also provide additional data about the use of FoR strategies outside of the experimental context. Route descriptions and mapping activities will allow us to discover correlations between toponymic practices and spatial knowledge, such as for example relations between place names and memory of locations of subsistence related resources.

Qualitative data derived from ethnographic methods is of course not directly comparable across sites, but the primary use of ethnographic and psycholinguistic data is to see whether the adaptive mechanism, in the form of communicative strategies that would support geocentric adaptation, is present in each community. What we will be looking for is whether there is consistency between the communicative strategies observed in the experimental setting, and the patterns of language use in subsistence activities.

CODING AND ANALYSIS: The different data types will require specific types of coding and analysis depending upon the nature of the data. For instance, data resulting from experimental methods of documenting spatial reference will follow the coding and analysis procedures provided by the stimulus creators, usually determined in a field manual or described in previous analyses. Any new stimuli will follow similar methods of coding and analysis to better understand the preferred linguistic strategies. Sociodemographic information, including both sociolinguistic variables (age, gender, schooling, literacy, bilingualism), and types of and degrees of environmental experience (e.g. farming, herding, foraging, fishing, driving etc.), will be coded for each participant in a master spreadsheet and analyzed to better determine if any of the variables correlate with the individual's FoR preferences, as well as with the results across the different tasks. Qualitative data will be analyzed differently depending upon the nature of the data. For instance, free listing data will be analyzed following standard methods (e.g., Sutrop, 2001). Route descriptions

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and mapping tasks will be used to help better understand individual knowledge of the landscape.

HISTORICAL RECONSTRUCTION OF ADAPTIVE OUTCOME: After data collection and analysis has been completed, the second stage is to reconstruct the development of the individual varieties. The reconstruction should establish the location of the original homeland of the ancestral speech community, and the routes that the speech communities under study have followed to their current locations, and also reconstruct the original state of the spatial grammar in the proto-language. It should also establish the adjustments and changes each variety has undergone in the period following the split from the ancestral speech community, and assess the possibility that these changes have been motivated by adaptation or by other factors (e.g., language internal "drift", paths of grammaticalization, diffusion from other languages through contact, etc.).

The reconstruction should follow the standard procedures of comparative historical linguistics (Crowley and Bowern, 2010; Campbell, 2013), assuming that traits shared by all descendent speech communities can be reconstructed also for the proto-form and seeking to determine whether non-shared traits are innovations or retentions from the earlier state. For example, if all of the four varieties employ a geomorphic FoR using an up/down axis and the sun's path as the main orientation strategy, then we would reconstruct this state of affairs also for the ancestral language. Nevertheless, in this case, we would have to conclude that the hypothesis has not been supported, because there has been no change from the ancestral state, and the ancestral state itself can be explained as having been acquired through diffusion from other Mesoamerican languages that also frequently display this set of preferences.

It is of course a limitation of this method that we can only reconstruct linguistic forms, but not the communicative functions to which they were put to use in the ancestral speech community. For example, having constructed words for 'uphill' and 'downhill' we cannot know with certainty whether this axis was used as a FoR strategy by ancestral speakers. Or having observed that the studied languages all preferentially employ a geocentric FoR strategy, we may be justified in assuming that the ancestral community had the same preference, but we cannot know which landscape features were used as anchors by ancestral speakers. The process of reconstruction of an ancestral state and paths of development is therefore really a control of whether a positive finding of ADAPTIVE FORM does indeed support the adaptive hypothesis, or whether it is an artefact of some other process of causation. It controls whether an alternative historical explanation of an observed fit between language and landscape is available.

Having carried out these steps, the hypothesis that speakers may adapt the spatial grammar of their languages to elements in the landscape through use, may either find support in the collected data or fail to do so. In the case of positive findings of evidence for adaptive form, function and mechanism, and in case the emergence of these findings in each variety under study is compatible with an adaptive scenario (that is, if it cannot be better explained by other processes of change), then there is positive empirical support for the overall hypothesis. If in turn, none of the findings for adaptive form, function or mechanism are made, or if they are made but the reconstruction of the path of development is shown not to be historically compatible with an adaptive scenario, then the hypothesis can be rejected for this language group.

5 Conclusions

Taking a biocultural and functionalist perspective on language and language change, we have argued that some aspects of the lexical and morphosyntactic structure of language are potentially sensitive to influence from the physical environment in which a language is spoken. We have argued particularly that the area of spatial grammar is a possible area where environment and landscape may influence the linguistic structures of a language and how this relates to the different ways speech communities organize their subsistence and communication activities to fit into a local environment. Spatial language is a means for sharing locative information of objects, facilitating navigation and location of resources and risks, and as such, is likely to enhance the evolutionary fitness of the members of speech communities by facilitating survival. Finally, we have proposed that by using descriptive and historical linguistic methods to study whether related languages whose speakers have migrated into different environments change their spatial grammar to fit elements of the landscape or environment, we can empirically test the hypothesis that language structure is able to adapt to the landscape.

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